economics

The Competitiveness Impacts of Climate Change Mitigation Policies

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PEW CENTER ON Global CLIMATE CHANGE

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Prepared for the Pew Center on Global Climate Change

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Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

In the debate over mandatory policy to reduce the United States' greenhouse gas emissions, a major issue has been the potential impact on the competitiveness of American industry. Many are concerned that if the United States moves forward with mandatory climate policy while other countries do not, U.S. jobs and production will move to emerging economic powers like China and India. This economic relocation would be accompanied by emissions "leakage," with greenhouse gas reductions in the United States offset by increases elsewhere.

For the most part, the climate competitiveness debate has proceeded in the absence of hard data. With this report, the Pew Center on Global Climate Change hopes to contribute to a firmer analytical understanding of the potential for competitiveness impacts and of policies to address them. Through a detailed econometric analysis, authors Joseph E. Aldy and William A. Pizer provide a unique and robust quantitative assessment of the potential competitiveness impacts of mandatory climate policy on U.S. industry. Their findings strongly suggest that such impacts would be both modest and manageable.

First, the analysis indicates that, at a carbon dioxide price of $15 per ton, the competitiveness concern does not extend to the economy as a whole, but rather centers on a fairly narrow segment of U.S. industry—energy-intensive industries whose goods are traded internationally. Second, it projects that at that price, energy-intensive sectors will experience only modest declines in production. Third, most of the projected economic impact on energy-intensive industries reflects a move toward less emissions-intensive products—as would be expected from an effective climate change policy—not an increase in imports or a movement of jobs or production overseas. While the analysis does not rule out larger effects on a narrower set of industries or firms, it weighs against any notion of broad impacts even for typical energy-intensive firms.

It is clear from this analysis that fear of competitive harm should not stand as an obstacle to strong climate change policy. Further, policymakers have available to them a range of policy tools to mitigate the modest economic impacts that may be foreseen. Under a cap-and-trade system, for instance, emission allocations can be used to cushion the impact on energy-intensive sectors. As the authors argue, any policy response should be narrowly targeted to vulnerable sectors. In the long run, the best safeguard against competitiveness impacts is a comprehensive and effective international climate framework. In the meantime, smart policy can mitigate the potential economic risks.

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Executive Summary

In the debate over mandatory, market-based greenhouse gas mitigation policies, a principal concern is the potential impact on output and employment of the more energy-intensive United States (U.S.) manufacturing industries. By pricing carbon dioxide (CO_2) emissions associated with fossil energy, domestic production costs rise, eventually raising prices to customers and causing a decline in domestic sales. This production decline may reflect, in part, a shift of economic activity, jobs, and emissions overseas to key trading partners, if they do not face comparable regulation.

This paper seeks to quantify the potential "competitiveness" effect on U.S. manufacturing industries of a domestic cap-and-trade system to regulate greenhouse gases. Our statistical analysis suggests that at a modest CO_2 price of $15 per ton there is not likely to be a significant competitiveness impact on U.S. manufacturing as a whole. A subset of energy-intensive industries, however, may face competitive pressures from abroad as their energy costs rise with the imposition of a carbon price. These modest impacts could be addressed through policies targeted to those sectors or sub-sectors most vulnerable to these pressures, and we outline a range of policy options.

Any potential impact on U.S. manufacturing would occur within the context of a more energy-efficient industrial sector that is experiencing modest growth. The decline in petroleum consumption in industrial activities since the 1970s and the investment in new production techniques (such as the emergence of electric arc furnace steel production) have caused the industrial share of U.S. CO_2 emissions to fall from 39 percent to 28 percent. While many energy-intensive industries produce more output today than they did 25 years ago—including steel, aluminum, paper, cement, and glass—this sector has been outpaced by faster growth elsewhere in the economy. The manufacturing sector has witnessed declines in employment, and this trend is expected to continue into the next decade regardless of climate change policy. The market for U.S. manufactured goods has become more international as more foreign firms compete with domestic producers.

The potential impact of international competition on U.S. producers facing domestic environmental regulation has been the focus of a substantial amount of research. Empirical analyses of environmental regulation and manufacturing activity have identified factors that can limit a particular industry's exposure to adverse competitiveness impacts. Capital-intensive firms tend to locate in capital-abundant countries, such as the United States, and avoid relocating to capital-poor countries, such as most developing countries (though obvious exceptions are countries with rapidly growing domestic demand or abundant natural resources, both of which make capital more accessible). Firms that manufacture goods with high transportation costs locate near their consumers. Some firms co-locate with similar firms that allow them to exchange intermediate inputs in their production processes (so-called agglomeration economies) that discourage distant relocation. To the extent that environmental policy affects production and employment, it appears to be more a reflection of firm location within the United States when state policies create variation in regulatory costs across the country. Some recent research based on large simulation economic models suggests modest impacts on most manufacturing industries under the European Union Emission Trading Scheme (EU-ETS) and under a possible future U.S. emission mitigation policy.

The analysis presented here seeks to quantify empirically the effect of carbon pricing on U.S. manufacturing industries and to further identify trade effects—that is, how much of any decline in production represents a shift overseas. (For practical reasons, the analysis excludes refining and mining activities.) We do this by examining 20 years of data on more than 400 U.S. manufacturing industries' shipments, trade, and employment, and their relationship to energy prices—principally electricity. We use the results of our statistical analysis to simulate the effect of a domestic cap-and-trade policy assuming that our major trade partners do not impose a price on carbon. For purposes of this simulation, we focus on a price of $15 per ton in 2012. Importantly, this value is consistent with the variation in electricity prices in our historical analysis, representing one standard deviation in the data. To provide policy context for this estimate, the U.S. Energy Information Administration (EIA 2008) core case analysis of the Lieberman-Warner cap-and-trade bill (S.2191) estimated a 2012 allowance price of $16.88 per ton CO_2. While there may be interest in effects associated with even higher price increases, it is inappropriate to extrapolate our results, as history provides no guide.

We find that higher energy prices, of the sort associated with pricing CO_2 at $15 per ton, would lead to an average production decline of 1.3 percent across U.S. manufacturing, but also a 0.6 percent decline in consumption (defined as production plus net imports). This suggests only a 0.7 percent shift in production overseas. There is no statistically discernible effect on employment for the manufacturing sector as a whole.

We also focus more narrowly on those manufacturing industries that are potentially most vulnerable because they are energy-intensive. We do this by estimating a model that allows the competitiveness effect to vary with energy intensity. We estimate that industries with energy costs exceeding 10 percent of shipment value, (e.g., metal foundries, cement, and lime) would expect output declines of about 4 percent and consumption declines of 3 percent, associated with a $15 per ton CO_2 price, suggesting a 1 percent shift overseas. The decline in consumption presumably reflects efforts to economize on the use of energy-intensive manufactured commodities in end-use products and substitution to less-energy-intensive input. This 1 percent shift—out of a 3–4 percent decline in production—illustrates that most of the domestic climate policy impacts on industry do not reflect adverse competitiveness effects at the price levels we can study. Rather, they reflect shifts in consumption patterns. While we estimate a smaller decline in domestic employment than in production from this CO_2 price, the data do not allow us to estimate how much of this represents a shift overseas (as there are no measures of "consumed or imported jobs" comparable to measures of consumed and imported goods).

We can apply our results to key energy-intensive manufacturing industries based on their particular energy intensity. We calculate production declines of 2.7 percent in iron and steel, 2 percent in aluminum, 1.6 percent in cement, 3.4 percent in bulk glass, and 3.3 percent in paper, associated with a $15 per ton CO_2 price. The comparable estimates of production shifts overseas range between 0.7 percent and 0.9 percent in these industries, roughly on par with the overall manufacturing sector (more narrowly defined energy-intensive industries would expect competitiveness effects ranging from 0.3 percent to 1.8 percent). Importantly, these estimates for particular industries are based on the average for all industries with similar energy intensity; our results do not rule out the possibility that among similarly energy-intensive industries, some may be harder hit than others.

We conclude with a brief discussion of potential policy measures aimed at addressing these competitiveness impacts. As our overall results suggest a relatively small effect for manufacturing as a whole at a price of $15 per ton CO_2, broad approaches to address competitiveness are likely to be inefficient. Rather, the analysis suggests value in targeting only a narrow set among even the most energy-intensive industries. The finding that most of the effect on domestic production arises from a shift in consumption away from carbon-intensive goods—rather than a shift in production to unregulated foreign imports—also has important policy implications. This shift away from carbon-intensive goods represents cost-effective emission reductions that will be foregone—raising the overall cost of the policy—if the price of energy intensive goods does not rise under a cap-and-trade policy. This suggests that any competitiveness remedy be scaled to the competitiveness portion of any production loss. Several vehicles for such a tailored approach are possible; all involve potential trade-offs among effectiveness in eliminating competitiveness impacts, consistency with World Trade Organization (WTO) rules, environmental outcomes, effects on other domestic industries, and impacts on the prospects for, and design of, an international agreement.

I. Introduction

A cap-and-trade program sets a clear limit on greenhouse gas emissions and minimizes the costs of achieving this target by giving a financial incentive to control emissions and the flexibility to determine how and when emissions will be reduced. Given these benefits, cap-and-trade has emerged as the favored approach to tackle climate change by governments around the world, including the European Union (EU), Australia, Japan, New Zealand, Norway, and the United States (U.S.). The northeastern U.S. states participating in the Regional Greenhouse Gas Initiative have launched an electricity sector carbon dioxide cap-and-trade program and California has proposed to pursue a cap-and-trade program as well. The California emission trading market could expand through the Western Climate Initiative—an effort involving seven U.S. states and four Canadian provinces—and trading could play a role in the Midwestern Greenhouse Gas Reduction Accord among nine U.S. states and one Canadian province. The 110th U.S. Congress witnessed more than a dozen bills proposing cap-and-trade programs and numerous hearings on the design of such a policy approach to climate change.

Implementing a cap-and-trade program will slow and reverse the growth of U.S. greenhouse gas emissions. By allowing emission trading, such a regime will effectively impose a price on emitting a ton of carbon dioxide (CO_2) (and other greenhouse gases). While this emission price creates the incentive to invest in more energy-efficient technologies and to switch to lower-carbon fuels, some have also raised the concern that the cap-and-trade program could adversely affect the competitiveness of American firms. In response to an emissions price, some energy-intensive firms may lose domestic market share as foreign competitors not subject to equivalent regulation increase their presence in the U.S. market. Manufacturing activity also may relocate to countries that do not have domestic climate regulations.

Such competitiveness effects reflect more than simply the economic costs of regulation. This relocation of energy-intensive manufacturing activity could also undermine the environmental objective of the climate policy. Countries failing to implement their own domestic climate policy program and absorbing American manufacturing activity could see their emissions grow faster than would have been expected otherwise. This so-called "emission leakage" offsets some of the benefits of constraining emissions domestically as emissions grow elsewhere. Since the impacts of climate change reflect the accumulation of global emissions, this leakage directly harms the United States (and all other nations), and effectively weakens the U.S. emissions target by the amount foreign countries' emissions increase. So, any competitiveness effects could cause job loss and capital flight, and reduce environmental benefits.

This report focuses on estimating the magnitude of the competitiveness impacts under a future domestic U.S. cap-and-trade program.[1] We define such competitiveness effects as the "adverse business impacts related to a domestic climate policy and the absence of regulation on international competitors." It is the harm domestic firms bear because they face a higher price on factors of production than their foreign competitors, specifically owing to differences in the climate regulatory regimes faced by firms participating in a given market. Some of these domestic firms have limited pricing power for manufactured commodity-like goods that compete in a global market, and this inhibits their ability to pass through the costs of a domestic climate policy.

Let us be clear about what is *not* a competitiveness effect of climate policy. The costs of complying with a cap-and-trade regime are not synonymous with competitiveness impacts. Even if all major economies in the world implement cap-and-trade policies that deliver a common price on emitting a ton of carbon dioxide, some energy-intensive and carbon-intensive firms in the United States could still bear substantial costs.[2] The costs of investing in new technologies to reduce a firm's carbon footprint or declines in consumption of energy-intensive goods are distinct from a firm losing market share or profits because a domestic cap-and-trade program increases costs relative to those of global competitors who face no similar regulation.

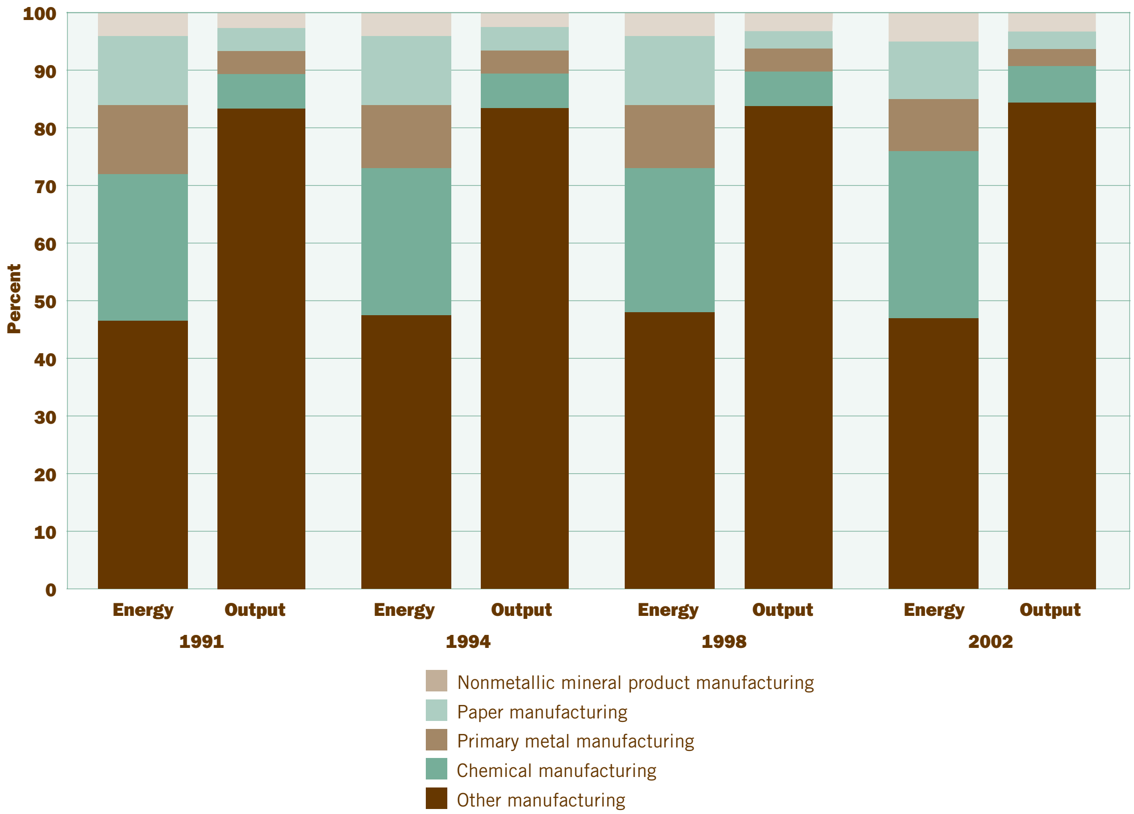
The next section of this report presents an overview of the state of U.S. energy-intensive manufacturing to provide context for our estimates of the competitiveness effects of a domestic climate change policy. The third section continues with a review of the literature that describes the competitiveness effects of environmental regulations and climate change policy. The fourth section presents our primary measures of competitiveness and our approach to estimating competitiveness impacts. The fifth section discusses these estimated impacts of climate change policy on these measures of competitiveness. The final section concludes with an assessment of various policy options for addressing competitiveness concerns. In addition, several technical appendices present details on the data, methods, and results underlying our analysis.

II. Overview of the State of the U.S. Manufacturing Sector

The manufacturing sector varies considerably in terms of the energy required (and hence the associated CO_2 emissions) to produce a dollar of output. For example, the manufacture of hydraulic cement is approximately 100 times more energy-intensive than the manufacture of cigarettes and about 50 times more energy-intensive than the manufacture of telephones. As Figure 1 shows, the chemical, primary metal, pulp and paper, and nonmetallic mineral product (including stone, glass, clay and cement) industries consume slightly more than half of all energy used in the manufacturing sector. These energy-intensive industries' combined share of energy consumption in the manufacturing sector has remained fairly steady since the early 1990s, although primary metals (e.g., steel and aluminum) have experienced a modest decline

Figure 1

Industry Share of Manufacturing Energy Consumption and Output



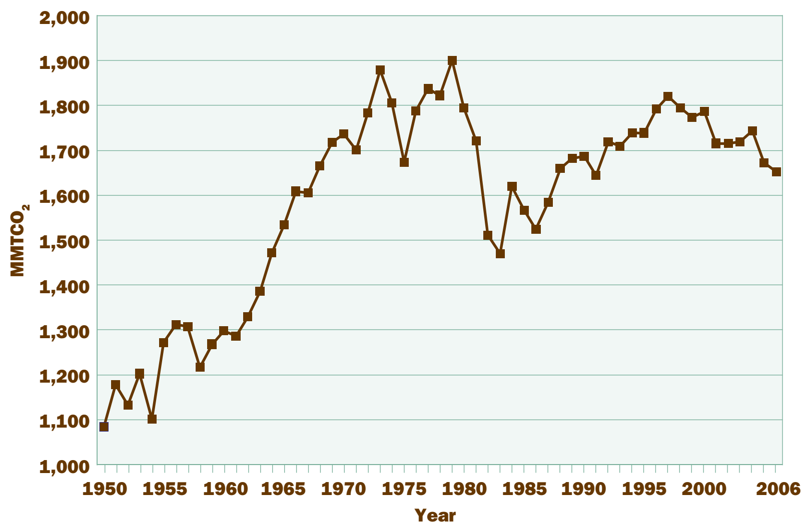
Source: U.S. Energy Information Administration (EIA) *Manufacturing Energy Consumption Survey*, 1991, 1994, 1998, 2002; Bureau of Economic Analysis (BEA) n.d.

reflecting their declining share of manufacturing output over time. Their shares of the manufacturing sector's output—about 16 percent—have likewise remained steady since the early 1990s, and illustrate the relative energy intensity of their production. The energy-intensive industries' share of employment has followed a similar pattern since the early 1990s, consistently comprising about 20 percent of the manufacturing sector's payrolls.

Over the past three decades, the energy-intensity of the U.S. manufacturing sector has improved, with much of this improvement occurring as a result of the oil-shock-induced price increases in the 1970s and early 1980s. Petroleum consumption in the broader industrial sector peaked in 1979, and in 2006 petroleum consumption stood at only 80 percent of this peak value.[3] Overall CO_2 emissions in the industrial sector also peaked in 1979, when this sector represented 39 percent of total U.S. CO_2 emissions from fossil-fuel combustion. After a nearly 25 percent decline in emissions in the first half of the 1980s, industrial sector emissions increased until the late 1990s, but have declined since then (Figure 2). Today, the industrial sector comprises 28 percent of U.S. CO_2 emissions.

Figure 2

U.S. Industrial Sector **Carbon Dioxide Emissions**
1950-2006



Source: U.S. Energy Information Administration (EIA) 2007.

Notes: $MMTCO_2$ refers to Million Metric Tons of carbon dioxide. Energy and carbon dioxide data collected by the Department of Energy for the industrial sector includes a broader set of industries than the manufacturing sector as defined by the Bureau of Economic Analysis (n.d.). This measure includes all fossil-fuel carbon dioxide emissions including on-site fuel combustion and electricity consumption, but excludes process emissions such as from the manufacture of cement.

The declining energy-intensity of output reflects changing production techniques and innovation in manufacturing. Steel production has shifted from blast oven furnace (BOF) production, which comprised 70 percent of U.S. steel output in 1985, to electric arc furnace (EAF) techniques that made up 55 percent of production in 2005 (U.S. Environmental Protection Agency 2007, Office of Technology Assessments 1985). This transition has led to an increase in efficiency but also requires a suitable supply of the recycled scrap required for EAF. Even though BOF allows cogeneration of heat and power, it remains less efficient than EAF, which takes advantage of already formed metal. The energy intensity of U.S. aluminum production has declined by 61 percent over the past 40 years, reflecting technological improvements and the growth of recycling, which requires less energy than manufacture from raw materials (U.S. Department of Energy 2007). The resilience of the paper industry to the energy price shocks of the 1970s and early 1980s reflects its atypical position as a major source of power: the industry fulfills roughly half of its own energy needs via biomass cogeneration. While this partially buffers the industry from fossil-fuel price shocks, it also suggests that it may bear higher costs if renewables or climate change policy increases demand for wood chips and related wood products for biomass co-firing in power plants (McKinsey & Company and Ecofys 2006). Cement production has shifted toward dry process cement that requires less direct energy but more electricity than wet process cement, as the proportion of U.S. kilns using the dry process increased from 38 percent to 70 percent over the 1975–2001 period (Hanle et al. 2004).[4]

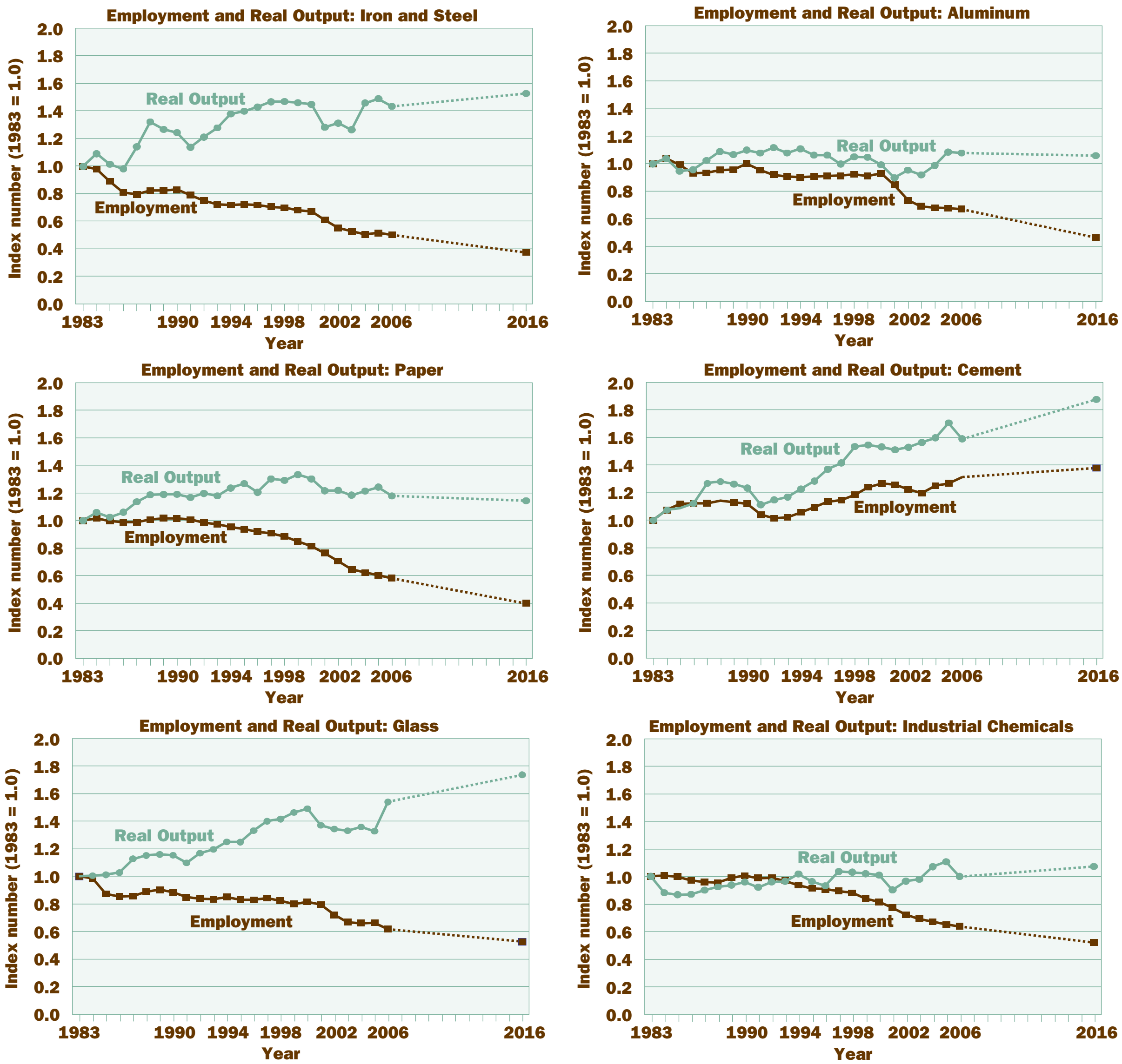
A few snapshots of the energy-intensive manufacturing sector reveal industries that grow slower than the rest of the U.S. economy and, through technological change and competitive pressures, have reduced payrolls over the past few decades. Figure 3 illustrates that output has outpaced employment over the past 25 years in the iron and steel, aluminum, paper, cement, glass, and industrial chemicals industries. These industries, with the exception of cement, have experienced declines in payrolls on the order of 40 percent or more since 1983. This has occurred while some industries (such as iron and steel, glass, and cement) have experienced production increases of 40 percent or more, while other industries (such as aluminum, paper, and chemicals) have witnessed flat or modest growth in output.

Recent projections of manufacturing activity through 2016 indicate flat or modest output growth with declines in employment in all industries, except for cement, which should expect increasing output and payrolls (Figueroa and Woods 2007). To put these estimates in perspective, consider the performance of the entire U.S. economy. Over the 1983–2006 period, total U.S. employment has grown 54 percent and Gross Domestic Product (GDP) has increased 109 percent (BEA n.d.; Council of Economic Advisors 2008). The performance of these energy-intensive industries does not cause a major drag on the overall economy because the manufacturing sector as a whole made up about 8 percent of U.S. employment in 2006, and energy-intensive industries provide jobs for less than 1 percent of the U.S. workforce (BEA n.d.).[5]

The slow growth in U.S. manufacturing output reflects two phenomena: slow demand growth and increasing international competition. Just as energy-intensive industries responded to high energy prices by economizing on their use of energy in production, downstream users of these industries' goods have found ways to

Figure 3

Production and Employment Trends in Energy-Intensive Industries, 1983–2016



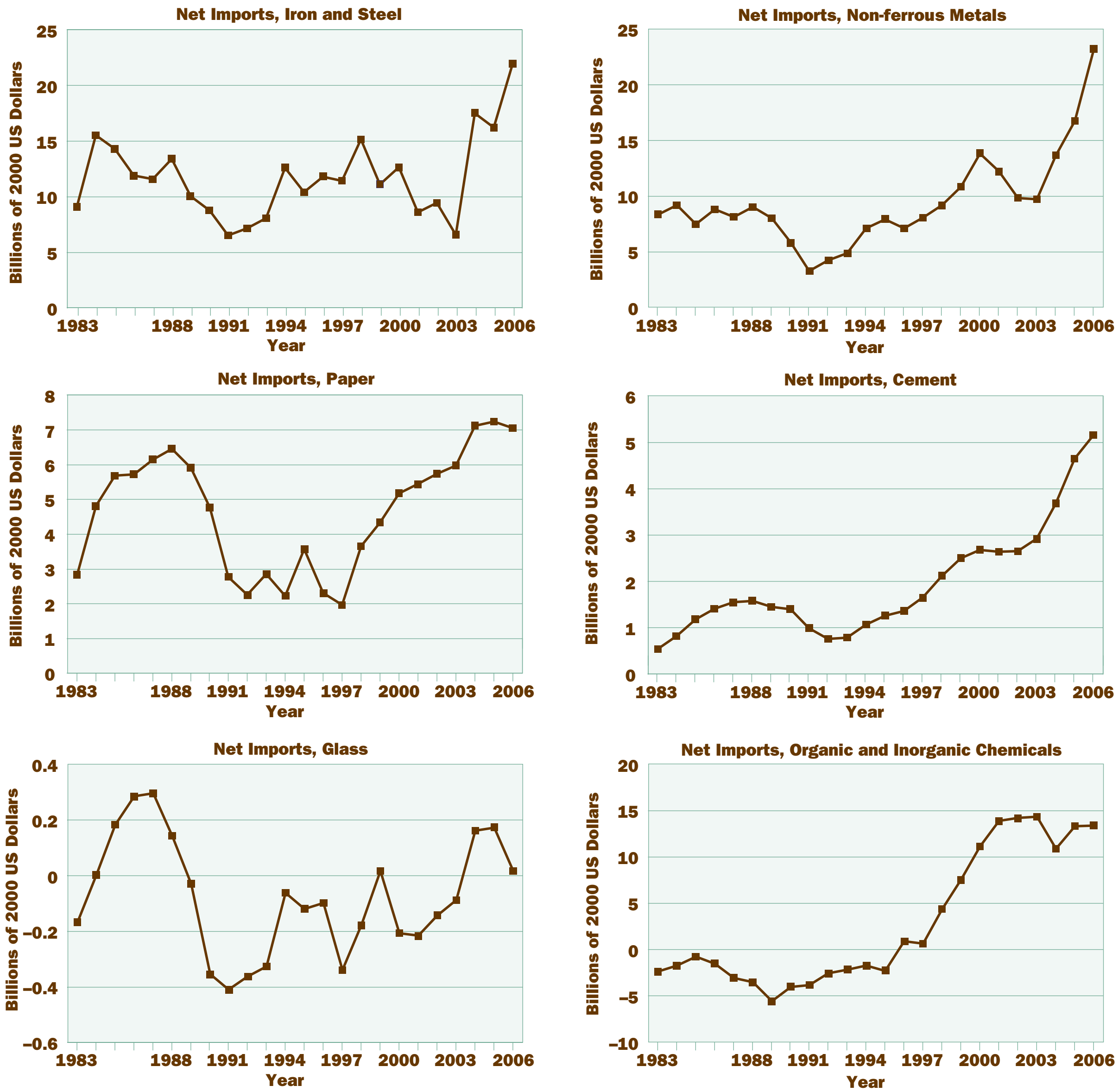
Sources: Figueroa and Woods 2007; Bureau of Labor Statistics n.d.
Notes: Employment and real output are indexed to 1.0 at their 1983 levels. Dotted lines are projections.

efficiently use less of these energy-intensive inputs in the production of their final goods. Some of this may reflect changes in quality (e.g. steel used in automobiles becoming stronger over time) that allows downstream producers to use less of the energy-intensive goods. Some of this may reflect opportunities for substitution, e.g., aluminum or plastic substituting for steel in automobile manufacture.

U.S. energy-intensive manufacturers' share of the domestic market has also declined over time. While net imports can vary significantly from year to year, they do show an increasing trend in recent years for most

Figure 4

Net Imports in Energy-Intensive Industries, 1983–2006



Source: United Nations Statistics Division, various years; *United Nations Comtrade Database.*

energy-intensive industries (Figure 4). For example, the exceptionally rapid run-up in net imports in iron and steel through 2006 reflects the low imports in 2003 due to the temporary imposition of steel tariffs under U.S. anti-dumping laws. Non-ferrous metals, such as aluminum, show a similar increase in net imports with a 250 percent increase over the 2003–2006 period. The cement, organic chemical, and inorganic chemical industries have all experienced substantial run-ups in net imports over the past decade, while the glass and paper markets have had more volatile net imports over time.

III. Review of Relevant Literature

A substantial quantity of research literature has addressed the question of whether environmental regulations adversely affect the competitive position of American industry. The current policy debate reflects issues raised by theoretical analyses suggesting that environmental policy could create so-called "pollution havens" in developing countries:

> "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" (Jaffe et al. 1995, p. 133).

Evaluating this conventional wisdom requires a careful examination of a simple empirical question: Do firms lose market share in response to domestic environmental policies, either by relocating their manufacturing activity to, or by facing lower-cost competition from, countries with lax environmental policies?

Addressing this question necessitates an assessment of the broader context surrounding the choice of firm location. A variety of factors may mitigate or dominate the effect of environmental regulatory costs in determining manufacturing location decisions. First, the availability of relevant factors of production, such as appropriately skilled labor, natural resources, and capital, can play a more significant role than pollution control costs. Pollution-intensive industries tend to be capital-intensive, so capital abundance in developed countries may outweigh the impacts of environmental regulations (Antweiler et al. 2001). Second, transportation costs may discourage relocation to countries far from the major markets for manufactured goods. Ederington et al. (2005) find that transportation costs diminish the impact of pollution abatement costs on net imports: an industry with high transport costs (e.g., at the 80th percentile in the manufacturing sector) experiences a percentage increase in net imports equal to about 20 percent of the impact for an industry with average transport costs (e.g., at the 50th percentile in the manufacturing sector). Firms with a significant share of their investments in large, fixed physical structures also appear to move activity less in response to environmental regulations (Ederington et al. 2005). Proximity to firms that produce inputs or purchase outputs (e.g., industrial parks and related forms of so-called "agglomeration economies") also discourages relocation (Jeppesen et al. 2002). These factors all determine whether an industry is "footloose," or sufficiently mobile that a small change in production costs, such as from an environmental regulation, could drive some firms to relocate to other countries.

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. Recent research by Levinson and Taylor (2008) shows that U.S. 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 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. Extensive literature on the competitiveness effects of variation in environmental policies across the U.S. states has shown more significant impacts on domestic firm relocation resulting from variation in the stringency of environmental regulations (Henderson 1996; Greenstone 2002). The larger *domestic* competitiveness impacts may reflect the fact that labor costs and availability of capital do not vary much across the U.S. states and transportation costs are less important, relative to the international context.

In the wake of the EU Emissions Trading System (ETS) and anticipation of potential U.S. carbon legislation, a wave of papers have addressed the associated competitiveness impacts of climate change policies, with results broadly consistent with our finding of modest impacts for the majority of industries. Given the prospective nature of these analyses, the scholars have undertaken detailed accounting exercises or employed models to simulate the effects of carbon prices on output and related impacts. The accounting-based papers focus on narrowly defined sectors and infer a percentage cost increase from a carbon price at varying proportions of free permit allocation using data on average cost, electricity use (assuming some level of pass-through), and direct CO_2 emissions. Reinaud (2005) examines impacts under a €10 per ton CO_2 price (modeled after the EU-ETS). She estimates that before accounting for any free allocation, energy-intensive industries would experience cost increases ranging from 1.5 percent for EAF steel to 18.6 percent for cement. Applying her assumptions of price elasticity of demand and maintenance of profitability margins, output declines ranging from 2.3 percent for EAF steel to 12 percent for BOF steel. McKinsey & Company and Ecofys (2006) perform a similar EU-ETS-based analysis at €20 per ton CO_2. When properly scaled to a comparable carbon price, assuming linear costs, the McKinsey numbers are of magnitude similar to Reinaud's.

The Carbon Trust (2008) employs a similar approach to that of the Reinaud and McKinsey studies in an evaluation of the United Kingdom (UK) manufacturing sector. Like McKinsey, Carbon Trust assumes a €20 per ton CO_2 allowance price modeled on the EU-ETS. This carbon price would increase the production costs in lime, cement, and iron and steel by more than 25 percent in the UK. Aluminum, inorganic chemicals, and pulp and paper would experience cost impacts on the order of 10 percent at €20 per ton CO_2.

Ho et al. (2008) simulate the output, consumption, and trade impacts of a $10 per ton CO_2 price implemented unilaterally in the United States. They simulate short-term impacts when firms have little opportunity to change production inputs and invest in new, low-carbon capital (in a partial equilibrium analysis) and long-term impacts that account for all adjustments to the CO_2 price (in a general equilibrium model). They find that the CO_2 price drives down manufacturing output by 1.3 percent in chemicals and plastics, 1.1 percent in primary metals, and 0.9 percent in non-metallic minerals. Slightly more than half of the decline in chemicals and plastics production is offset by an increase in net imports from countries that are not implementing greenhouse gas emission mitigation policies. Primary metals would experience a 0.46 percent competitiveness effect and non-metallic minerals a 0.42 percent effect. These results show that the reduction in output results more from a large drop in domestic consumption than from an increase in net imports.

IV. Construction of Competitiveness Measures and Description of Data and Methods

Our analysis estimates the impacts of a domestic cap-and-trade program on various industry impact and competitiveness measures by drawing on the historic effects energy prices have on these measures, which we expect to be similar to the effect of a cap-and-trade. Using regression analysis, we separately estimate the effects of the price of energy on employment, production, and consumption over the 1986–1994 period for more than 400 manufacturing industries. We can use these statistically-estimated relationships to simulate the effects of a \$15 per ton CO_2 price from a unilateral U.S. climate change policy, while assuming no equivalent regulation in other countries. Based on an analysis by the U.S. EIA, such an allowance price would increase industrial sector electricity prices by about 8 percent, which is approximately equal to a one standard deviation increase in energy prices in our sample (EIA 2008). This allowance price is similar to the one the EIA estimated for the Lieberman-Warner cap-and-trade bill (S. 2191) of \$16.88 per ton CO_2 in 2012 (EIA 2008).

The competitiveness debate has witnessed claims of American job loss and declining economic output arising from U.S. emission mitigation policy in the context of inaction or weak action by key trade competitors. As a result, we focus on the impacts of climate change policy on employment and output, but also recognize that falling employment and production in a given industry may not reflect adverse competitiveness impacts of the climate policy. A cap-and-trade program will drive a combination of new technologies to reduce emissions from the current product mix *and* a shift in consumption from carbon-intensive products to low-carbon productions—creating winners and losers within and among industries. An additional decline in production or employment could result from a shift of production overseas. The gross estimates of employment and production changes from a domestic cap-and-trade program reflect the total impact of the policy, part of which owes to a shift in consumption to more carbon-lean products, and part of which comes from adverse competitiveness effects.

To estimate the competitiveness impacts of a cap-and-trade policy, we assess the effects on both production and consumption of domestic manufactured goods, where we define consumption as production plus net imports. Changes in the *consumption* of manufactured goods reflect the impact of domestic climate policy that would occur independently of any trade effects. Examining the difference between production and consumption impacts allows us to estimate just the competitiveness impacts on output. This approach isolates the effect of the increase in U.S. energy prices on net imports, which we express in terms of a percent of production.[6]

The effect of U.S. energy price changes on net imports represents only an approximation of the differential impact on the United States with and without foreign regulation. This analysis assumes that net imports will change when U.S. firms bear greenhouse gas regulations and foreign firms do not—but will *not* change if both face equivalent CO_2 regulation. We also assume that consumption under the U.S.-only and global regulation cases is the same. In this way, the differential effect of a CO_2 price on production in these two cases is determined entirely by the change in net imports, which, based on the first assumption, is precisely the effect measured with U.S.-only regulation. Both of these assumptions could be wrong; net imports of goods may change even if both U.S. and foreign firms incur greenhouse gas emissions mitigation costs. The effect may be positive if domestic firms are more affected by regulation and negative if foreign firms are more affected. Assuming that global regulation increases net imports—reflecting either greater relative energy-intensity in domestic production or, more likely, relatively more burdensome domestic regulation—then our estimates of the change in net imports from U.S.-only regulation forms an upper bound on the competitiveness effect. It is also possible that U.S. consumption may decline more with foreign regulation, versus U.S.-only policy, as manufactured goods become more expensive overall. Our estimates would represent an upper bound on the true competitiveness effect in this case.

All of the preceding discussion focuses on output. Unfortunately, we cannot construct *any* notion of a true competitiveness measure of employment impacts. While the consumption-net import decomposition of production provides a vehicle for distinguishing consumption shifts from competitiveness impacts on production under a unilateral U.S. climate policy, no similar means for decomposing domestic employment changes exists. Thus, the gross employment effects we report should be considered *extreme* upper bounds on the competitiveness impacts of a domestic cap-and-trade program because they confound competitiveness impacts with shifts in consumption patterns that would happen even with global regulation.

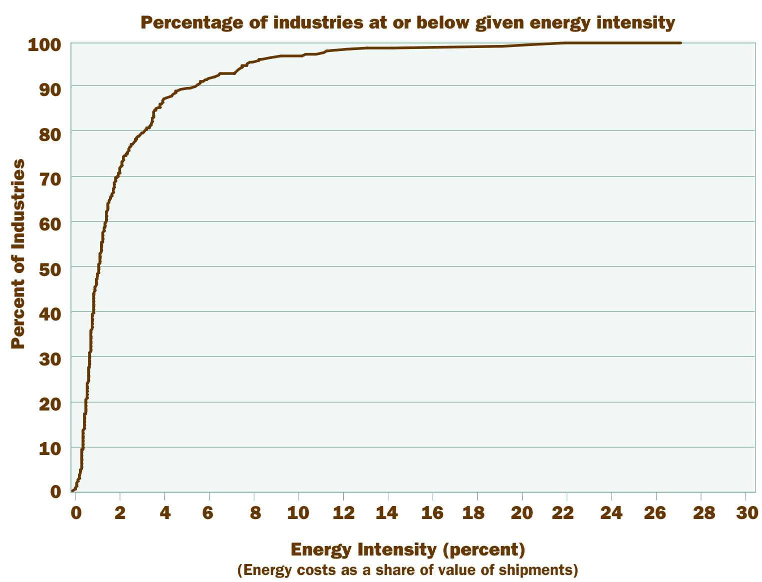
The data we use to estimate these effects are rich in sectoral detail, with 400-plus industries in the manufacturing sector. For example, our analysis includes 11 classifications *within* the iron and steel sector. The data do not cover mining or agriculture, and we exclude petroleum refining from the analysis because of both the difficulty separating feedstock and energy use and its unique links to the petroleum market. We undertake our analysis with the relevant data in logarithms because these sectors differ vastly in size. Our models estimate and predict changes in percent terms, rather than in actual dollars or jobs, which facilitate comparability even among different-sized sectors. The reported impacts represent percent changes from the respective base levels for each of the 400-plus industries.

Along these lines, it is important to note that the regression analyses also control four other factors that could influence employment, production, and consumption of manufactured goods. The analysis controls for industry-specific tariff rates, human capital, physical capital, and the common temporal effects noted above (such as changes in GDP, world oil prices, and other global trends) as well as industry-specific effects that do not change over time.[9] In total, this allows us to investigate the effects of energy prices on nearly 450 manufacturing industries over the 1986–1994 period.

We also make a critical distinction in our analyses on how the energy intensity of an industry affects its responsiveness to a change in energy prices. When we estimate the energy price-employment relationship for the entire manufacturing sector without accounting for the energy intensity of industrial output, for example, we find no statistically meaningful effect. Decomposing this relationship as a function of energy intensity helps to illustrate the interesting variation across the manufacturing sector. For example, one might expect that firms in relatively energy-lean textiles could respond differently to a 10 percent increase in energy prices than relatively energy-intensive steel firms. Our analysis allows us to estimate the relationships between energy price and competitiveness measure for distinct components of the manufacturing sector as a function of their energy intensity. Specifically, we allow the responsiveness to linearly vary over the observed range of energy-intensity values with “kinks” in the linear relationship at different points—specifically between each quintile (20 percent) of industries, and at the 90th and 95th quantiles. Figure 5 presents the distribution by energy intensity of the nearly 450 industries in the manufacturing sector.

Figure 5

Distribution of 400-plus Industry Classifications by Energy Intensity



Source: Constructed by authors from U.S. Census Bureau *Annual Survey of Manufactures* (various editions).

V. Simulation of Near-Term Effects of a CO_2 Mitigation Policy

After conducting the statistical analysis described in the preceding section, we use the estimated relationships between energy prices and our industry impact and competitiveness measures—which vary with energy intensity—to simulate the effects of a cap-and-trade program. The simulation focuses exclusively on a cap-and-trade program that covers the carbon content of fossil fuels, but not process emissions. Fossil-fuel combustion makes up about 98 percent of total U.S. CO_2 emissions, so this is not an important issue in most industries, with the exception of the cement industry. Our results may underestimate the impact on the cement industry if a future cap-and-trade program covers process emissions in that industry.

We assume that the cap-and-trade program delivers an allowance price of $15 per ton CO_2 in 2012. Recent modeling work by EIA (2008) indicates that such an emission price would increase the cost of electricity in the industrial sector by about 8 percent. This CO_2 price—as an increase in electricity prices—represents approximately a one standard deviation increase in electricity prices given the historic price variation we observe. It would strain the credibility of our approach to use an effective price change that exceeded the values used to estimate the model parameters. Thus, extrapolating impacts for higher CO_2 prices is beyond the scope of this analysis since it would reflect an out-of-sample prediction.[10] Based on these estimated model parameters, this energy price increase then drives the production, consumption, competitiveness, and employment impacts in our simulation.

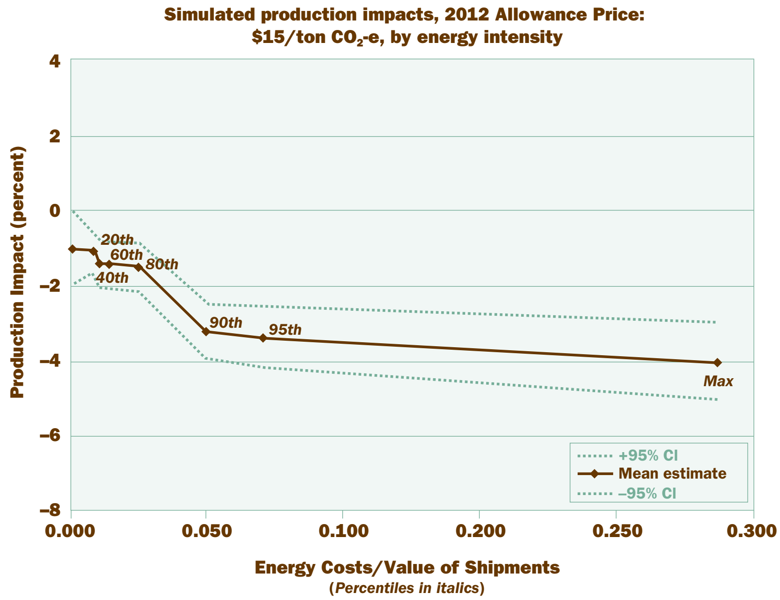
Figure 6 illustrates the impacts of a $15 per ton CO_2 price on production in the manufacturing sector, as a function of energy intensity. The horizontal axis shows the energy intensity as measured by the ratio of energy costs to the value of shipments. The percentiles of the distribution of manufacturing industries by energy intensity are presented in italics. As evident by the distribution in Figure 6, most industries have low energy costs relative to their production. The 20th, 40th, 60th, and 80th percentiles all fall below about 0.03 for this energy expenditure to value of shipments ratio. Moving to the top of the energy intensity distribution, however, we find that the industries are more dispersed and the energy intensity of the industry at the 90th percentile is nearly double the intensity of the industry at the 80th percentile. Industries above the 95th percentile have energy expenditures equal to nearly 10 percent or more of the value of shipments. Appendix C lists those industries at our above the 95th percentile of energy intensity in our dataset.

The estimated production effect at $15 per ton CO_2 is represented by the solid line, with the 95 percent confidence interval in dashed lines. If we ignore energy intensity, the average effect of a $15 per ton CO_2 price is a 2 percent decline in the value of shipments. For the bottom 80 percent of the energy intensity distribution, we find a fall in production of less than 2 percent. The most energy-intensive industries bear more substantial declines, on the order of about 4 percent or more for those in the top 10 percent of energy intensity.

These declines in production could reflect increasing market share by foreign competitors and/or lower domestic consumption of these manufactured goods. To investigate this question, we estimate the impact of the energy price increase expected under a $15 per ton CO_2 price on consumption, as measured by the sum of production and net imports. Figure 7 shows the consumption effects by energy intensity, and they follow similar

Figure 6

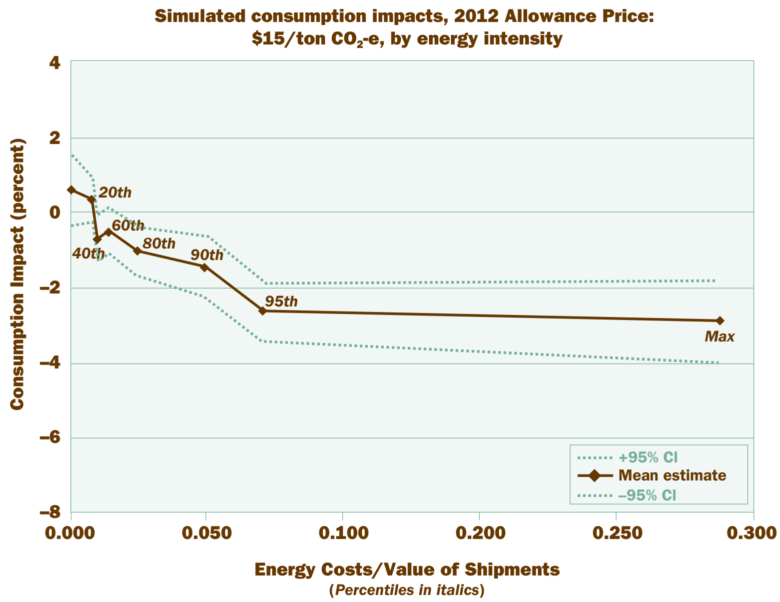
Simulated **Production Effects** of a $15 per ton CO_2 Price



Note: Constructed by authors based on our statistical analysis and the change in electricity prices predicted under a carbon pricing policy in EIA (2008).

Figure 7

Simulated **Consumption Effects** of a $15 per ton CO_2 Price



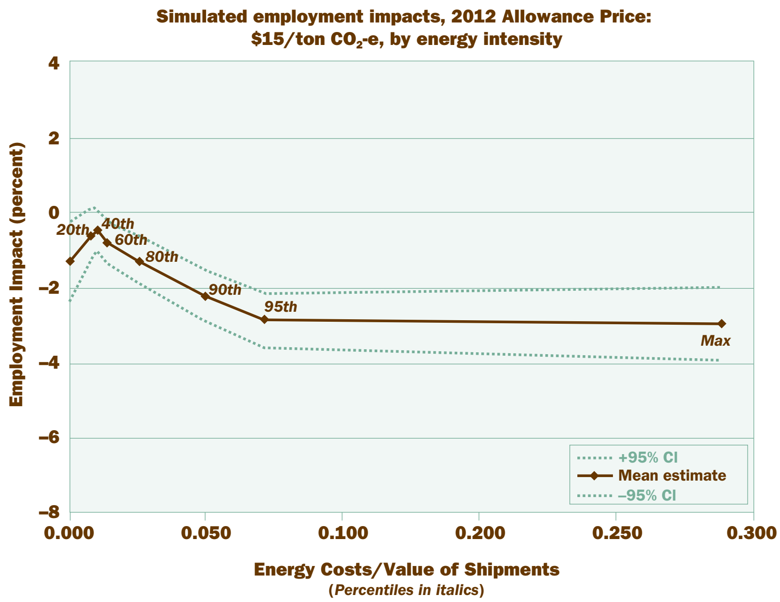
Note: Constructed by authors based on our statistical analysis and the change in electricity prices predicted under a carbon pricing policy in EIA (2008).

trends to production. For the least energy-intensive industries, the decline in consumption is near zero and only statistically different from zero for those near the 80th percentile of the distribution. The most energy-intensive industries exhibit consumption declines on the order of 2 to 3 percent. This clearly shows that the bulk of the estimated change in production is arising from changes in consumption, and not from net imports or presumed competitiveness effects.

Figure 8 illustrates the impacts of a $15 per ton CO_2 price on employment in the manufacturing sector, as a function of energy intensity. The estimated employment effect at $15 per ton CO_2 is represented by the solid line, with the 95 percent confidence interval in dashed lines. For the bottom 80 percent of industries in the energy intensity distribution, the effects on employment are small (less than 1 percent) and not statistically different from zero. Only the most energy-intensive industries would experience a job decline, on the order of slightly less than 2 percent for the industry at the 90th percentile of energy intensity, and less than 3 percent for those in the top 5 percent of energy intensity.

Figure 8

Simulated Employment Effects of a $15 per ton CO_2 Price



Note: Constructed by authors based on our statistical analysis and the change in electricity prices predicted under a carbon pricing policy in EIA (2008).

Table 1 shows these results for all manufacturing and for specific sectors of the most energy-intensive industries. This table also presents the estimated competitiveness impacts by subtracting the consumption decline from the production decline for each industry.[11] The energy-intensive industries of iron and steel, aluminum, pulp and paper, cement, glass, and industrial chemicals would bear declines in production on the order of 1.6 percent to 3.4 percent, typically in excess of the manufacturing sector average decline of 1.3 percent. Most of the lower production reflects lower consumption, not an influx of net imports. The consumption declines range from about 0.9 percent to 2.7 percent. The competitiveness effects are fairly

Table 1

Predicted impacts of a $15 per ton CO_2 2012 allowance price on various manufacturing sectors

Industry	Production	Consumption	Competitiveness	Employment
Industrial Chemicals	–2.7%	–1.8%	–0.9%	–1.5%
Paper	–3.3%	–2.4%	–0.9%	–2.1%
Iron & Steel	–2.7%	–1.9%	–0.8%	–1.6%
Aluminum	–2.0%	–1.4%	–0.7%	–1.0%
Cement	–1.6%	–0.9%	–0.7%	–0.4%
Bulk Glass	–3.4%	–2.7%	–0.6%	–2.3%
Manufacturing average	–1.3%	–0.6%	–0.7%	–0.2%

Notes: Constructed by authors based on our statistical analysis and the change in electricity prices predicted under a carbon pricing policy in EIA (2008). Impacts are based on 2001 industry energy intensity, weighted by 2001 employment among constituent 4-digit SIC industries.

similar across energy-intensive industries, with declines of about 0.6 percent to 0.9 percent. For example, in the bulk glass industry, less than one-fifth of the decline in production results from an increase in net imports. Some more narrowly defined industries would experience competitiveness impacts outside this range. For example, we estimate that cold rolled steel (SIC 3316) would expect a 0.3 percent competitiveness effect, while synthetic rubber (SIC 2822) would bear a 1.7 percent effect. Finally, the average decline in manufacturing employment at $15 per ton CO_2 is 0.2 percent; the energy-intensive industries of iron and steel, aluminum, pulp and paper, cement, glass, and industrial chemicals would experience employment declines of 0.4 percent to 2.3 percent. Appendix D provides results for all four-digit (SIC72) energy-intensive industries. It is interesting how the employment and production effects are more pronounced for energy-intensive industries than for the manufacturing sector as a whole, but the competitiveness impacts are 1.8 percent or less across manufacturing.

An important caveat to these results is that they assume similar behavior among industries with similar energy intensity. Therefore, we cannot rule out the possibility that some individual industries with a particular energy intensity will face a larger impact than the average that we have calculated.

Despite the possibility of individual exceptions, these results suggest that consumers of energy-intensive goods, on average, do not respond to higher energy prices by consuming considerably more imports. Instead, they economize on their use of these higher-priced manufactured goods, perhaps by using less of the good in the manufacture of their finished products or by substituting with other, less energy-intensive materials. Consumers appear to pursue only modest substitution with imports, suggesting that the imported versions of domestically-produced goods may be imperfect substitutes. Other determinants of trade flows—such as transport costs, tariffs, etc.—may limit the substitution possibilities. Our findings show that attempting to "protect" U.S. manufacturing firms from international competitive pressures through various policies may have only a limited impact on these firms. The estimated competitiveness impacts, while fairly modest at $15 per ton CO_2, suggest the need to target policies to those most likely to face adverse impacts.

VI. Discussion of Policies for Addressing Competitiveness Concerns

Having estimated the effect on the U.S. manufacturing industry from U.S.-only greenhouse gas regulation, interest naturally shifts to the design of policy to mitigate these adverse consequences. Our results suggest that the competitiveness impacts of unilateral domestic greenhouse gas mitigation do not have a significant economic impact on U.S. manufacturing as a whole or even when broken down by energy intensity. This analysis, however, does not rule out more significant impacts on narrowly defined industries where energy intensity alone cannot predict particular competitive pressures from abroad. We also find that a significant portion of the decline in domestic production from unilateral domestic policy arises from a shift in consumption, from energy-intensive to more energy-saving goods, and not from the substitution of unregulated foreign imports.

What does that mean for the design of policies to address competitiveness concerns? The wide array of approaches to address competitiveness fall into three categories: broad-based measures, targeted measures outside a cap-and-trade program, and targeted measures within a cap-and-trade program (Morgenstern 2007).[12] None of the approaches is perfect; each has advantages and disadvantages that we briefly consider below. An immediate observation, however, is that, given the modest magnitude of the competitiveness impacts on overall manufacturing in our $15 per ton simulations, the potential economic and diplomatic costs of such policies may outweigh competitiveness benefits and justify no action. At the very least, any competitiveness benefits must be carefully weighed against the broader policy objectives of domestic climate change policy—including environmental effectiveness, cost-effectiveness and efficiency, and promoting international coordination and cooperation.

A. Broad-Based Approaches

A broad-based approach to combating competitiveness impacts could condition the stringency of U.S. action on the level of effort by our major trade partners. For example, the European Union's position that it will reduce emissions 20 percent below 1990 levels by 2020 absent comparable action by other countries, but will consider reductions of 30 percent if other countries adopt suitable policies, ties EU action to that of other countries (European Commission 2008). This avoids the competitiveness impacts associated with the 30 percent reduction targets by only pursuing that level of effort when other countries have taken suitable action and competitiveness effects by definition would vanish. The advantage of this approach is that it does not require identifying vulnerable industries and associated measures to scale a targeted intervention. On the other hand, it does not avoid the competitiveness impact associated with the lesser action—in the EU case, a 20 percent reduction.

In a similar fashion, a country could set a series of emission targets but indicate that it will reserve the right to pursue less aggressive targets in the absence of comparable efforts by major trade partners. This so-called "off-ramp" would prevent the imposition of tighter, more costly targets, but in doing so lower the environmental effectiveness of the climate policy. A variety of other mechanisms have been proposed in the context of broader discussions of cost containment, and could be used to fine-tune the domestic level of effort in response to foreign action (Tatsutani and Pizer 2008).

While addressing the *overall* cost of a program—that is, the level of effort the United States is willing to pursue relative to other nations as a matter of fairness or equity—these approaches constitute a rather blunt tool to address *competitiveness* concerns given the much narrower need. They would impact all sources of greenhouse gas emissions to protect a very small fraction of U.S. emissions and economic activity. Such a mechanism presents a stark trade-off between mitigating competitiveness and achieving environmental goals.

B. Targeted Measures Outside an Emission Mitigation Program

Instead of affecting all sources, policymakers could pursue a more targeted approach by *removing* vulnerable industries from the cap-and-trade program.[13] The domestic policy could (a) exclude energy-intensive industries completely, (b) subject these industries to alternative domestic-only command-and-control regulation, or, (c) subject them to internationally-coordinated performance standards. By taking energy-intensive industries out of a unified, domestic, market-based approach, however, it becomes impossible to trade off lower-cost emission reductions in one sector for higher-cost reductions somewhere else. Without pricing emissions, this approach also fails to encourage consumers to shift away from energy-intensive products, a shift we found to be larger than the competitiveness effect and unrelated to the presence or absence of foreign regulation. These two effects will raise the cost of reducing emissions, potentially to several times the cost otherwise.[14]

Identifying the vulnerable sectors for exclusion also presents challenges. As an all-or-nothing approach, policymakers cannot scale the remedy to the degree of vulnerability and many industries may request exclusion. Furthermore, excluding some industries that rely on electricity as a major factor of production—for example, aluminum production—may prove difficult because the cap-and-trade program would almost certainly cover electricity producers.

Completely excluding a sector from regulation represents the simplest approach within this category of targeted approaches. Such a policy introduces higher costs, by undermining cost-effectiveness, and inequities, as the excluded industry does not have to undertake any effort to address its emissions, while undermining the environmental effectiveness of the domestic climate policy. By pursuing alternative, command-and-control regulations (e.g., technology or performance standards) such sectors can be required to reduce emissions. The competitiveness effects from such a regulatory approach may be greater or less than a market-based approach, depending on the stringency of the command-and-control regulations and the design of the market-based policy.

Employing command-and-control standards as a part of an international, harmonized system of standards could provide another avenue for attempting to address competitiveness impacts (Bodansky and Diringer 2007). Such proposals have received interest in recent United Nations Framework Convention on Climate Change discussions (International Institute for Sustainable Development (IISD) 2008). However, applied broadly, this approach still risks considerably higher costs for a given international emission goal by establishing separate, industry-specific standards that cannot be traded off among one another, or with a cap-and-trade program covering the remaining emission sources, in order to achieve cheaper emission reductions. By failing to price the emissions that occur in spite of mitigation efforts, this approach also fails to achieve the noted shift away from energy-intensive products, again missing an opportunity for cheaper reductions.

C. Targeted Measures Under an Emission Mitigation Program

The last category of approaches focuses on some forms of redress *within* a unified carbon-pricing program. Like the former category of approaches, this requires identifying vulnerable industries; however, it may not be quite as difficult as a choice of excluding industries from the cap-and-trade because these approaches can be scaled to the level of vulnerability. First, the carbon-pricing program could generate revenues from an allowance auction that could finance targeted relief to energy-intensive firms and their employees. This relief could take the form of lower tax rates on capital for these firms and lower payroll taxes on their workers and/or transition assistance to workers who lose their jobs in identified vulnerable industries. Since the competitiveness impacts implicitly reflect a wedge in the costs between domestic and foreign firms, such an approach could deter relocation by focusing on another wedge affecting relative competitive position (the tax wedge). At the same time, by distorting the prices paid for capital and labor across industries, this approach could distort factor markets in a costly way.

Second, the domestic mitigation program could include a provision that effectively increases the costs to foreign producers for competing in the U.S. market. Extending the regulation on the emissions of greenhouse gases to cover imports from countries without comparable regulation could mitigate some of the competitiveness impacts of the domestic program in the U.S. market. However, this approach does not address any competitiveness impact U.S. manufacturers may face in export markets. In addition, it poses several design challenges. First, the carbon pricing program should create a suitable measure on which to base import regulations, given the potential difference in products, production techniques, and potentially complicating regulatory features (e.g., free allocation or other benefits given to domestic producers). This measure should ideally place the same cost burden on foreign producers as would arise if they operated within the United States. Second, the mechanism should provide incentives for other countries to pursue their own domestic climate change policies (and/or firms to pursue mitigation activities) without leading to a broader escalation of trade barriers (even a trade war), a violation of World Trade Organization (WTO) rules, or undermine efforts to secure agreement in international climate talks (see Hauser et al. 2008). Economists have frequently argued this concern over triggering a trade war and instead have advocated for design of such an instrument in a multilateral context rather than a U.S.-only effort (e.g., Frankel 2008). It is important to note that an international agreement that does not, in principle or practice, either cap global emissions or place a similar carbon price on manufacturers in all countries, will not "solve" the competitiveness problem in terms of eliminating the potential for manufacturing and emissions to shift to countries with lower carbon prices.

Third, a cap-and-trade system could simply give vulnerable industries a free allowance allocation—perhaps both to industry and labor interests.[15] The free allocation could phase down over time as competitive pressures wane with broader mitigation efforts globally. Some have also suggested granting *gratis* allocations on the condition that recipient firms meet some form of performance standards. In this way, those firms and constituents receive compensation based on the differential effect of domestic-only regulation. The estimated competitiveness impacts in this analysis could provide a basis for the amount of the *gratis* allowance allocation necessary to offset output losses associated with reduced competitive position under climate policy. For example, if primary aluminum production is associated with a 0.8 percent decline through competitiveness impacts (see Table 1), then the government could grant free allowances equal in value to 0.8 percent of their output. Free allocation, however, does not provide any incentive to prevent production, jobs, and emissions from moving overseas in response to a U.S.-only approach; it simply compensates those most adversely affected.

Finally, the cap-and-trade program could lower the costs to domestic producers by allocating emission allowances in a manner that subsidizes production.[16] Giving away allowances for free in proportion to domestic production would lower the effective cost of production and close the price wedge between domestic and foreign firms. The implicit cost to emit greenhouse gases associated with consumption of goods treated this way will be lower than the marginal cost of abatement associated with producing these goods because of the production subsidy through free allocation. Of course, in doing so, the program risks increasing costs for all other firms covered by the cap-and-trade system, since they would have to face a higher allowance price if the cap remains whole.[17] Effectively, we lose the opportunity to shift production away from energy-intensive manufactured goods, as the price of these goods is subsidized by the targeted allocation. Like the import approach, the challenge lies in creating a suitable measure as a basis for the provision of allowances (e.g., a "rate" of allowances per unit of production). Firms produce a wide variety of products with a variety of production techniques.

The key disadvantage of this approach relative to the import approach is that it fails to encourage a domestic shift away from energy-intensive manufactured goods and the associated emission reductions. Energy-intensive goods are priced at the lower, unregulated foreign import price (through effective domestic subsidies) rather than the higher, regulated domestic production price (through import regulation). This approach has two advantages over the import obligation, however, because the relevant information for constructing the measure exists within the United States and it simultaneously tackles export markets as well as imports. While this approach may appear less likely to generate escalating trade barriers or WTO violations, that is not necessarily true.[18]

Summarizing, the competitiveness impacts from a unilateral U.S. climate policy on domestic manufacturers as a whole, and even differentiated by energy intensity, are small for a $15 per ton CO_2 price. The bulk of the effect on domestic manufacturing comes from a shift in domestic consumption—a desirable effect from the perspective of seeking a cost-effective policy and one that has nothing to do with the presence or absence of foreign regulation. This suggests that broad-based approaches are best used to address overall cost and fairness concerns—not competitiveness. A targeted approach, in turn, should be focused narrowly on those industries with concerns that go beyond merely being energy-intensive; namely those industries that are both energy-intensive and face clear international competition.

Targeted approaches include both excluding industries from national market-based programs as well as addressing concerns from within such a national program. Excluding industries risks missing out on cost-effective emission reductions, which this study suggests may be large relative to competitiveness effects. Both of the targeted approaches that operate within a market-based program—free allocation and import regulation—have strengths and weaknesses. Import regulation can do a better job of achieving cost-effective reductions domestically, but does not address competitiveness impacts in export markets; free allocation can address competitiveness in both domestic and export markets, and may be more compatible with ongoing efforts to promote free trade, but fails to encourage a shift away from energy-intensive goods.

VII. Conclusions and Suggestions for Further Work

Efforts to establish mandatory controls on U.S. greenhouse gas emissions, particularly through a market-based cap-and-trade program, have been stymied in part due to concerns that a U.S.-only approach would substantially disadvantage U.S. industries. One way to explore this question is to look at whether past increases in energy prices, of the sort that might be associated with U.S. climate policy, have had noticeable trade-related effects. Doing this for 400-plus industries over 20 years, we estimate that a cap-and-trade policy with a 2012 allowance price of $15 per ton CO_2, comparable to the 2012 allowance price for the Lieberman-Warner bill (S. 2191) estimated by EIA (2008) in its core case analysis ($16.88 per ton CO_2), would have trade-related competitiveness effects of approximately 0.7 percent in the U.S. manufacturing sector as a whole. While more energy-intensive industries would experience larger output declines from higher energy prices, these effects reflect shifts in consumption to less energy-intensive goods much more than a shift to cheaper imports. Thus, even among these industries, the analysis suggests only modest competitiveness impacts on average at a price of $15 per ton CO_2.

There are a variety of limitations to these estimates. First, they cannot really be used to extrapolate to higher CO_2 prices. Historical experience simply does not tell us what might happen when prices go higher—because we have not seen an isolated, equivalent change in energy prices in available data.[19] Second, our estimates represent near-term impacts over one to a few years. Unfortunately, volatility in energy prices as well as the confounding nature of other events makes it difficult to estimate long-term impacts.[20] Arguably, with more time to adjust, U.S. industry could fare better (if they can reduce energy usage) or worse (if they have more time to move operations). Third, even with our disaggregated data and flexible model, we still cannot flexibly capture all of the features relevant for every industry in every international trading situation. The effects for some firms and sectors could be different than what we have estimated. Fourth, in using historical data, we are necessarily assuming the past is a useful guide to future behavior. To the extent there have been, or will be, substantial institutional changes, this assumption is flawed. Finally, our analysis has focused on the historic influence on net imports arising from domestic energy price increases as a measure of the difference between U.S.-only versus global action. To the extent net imports change significantly even with global action, our estimates will not capture these effects.

How do we interpret these results? An underlying question in the concerns over competitiveness impacts has focused on the opportunities to substitute imports for domestically-produced goods bearing the costs of a climate policy. Our work suggests limited substitution at least over horizons of several years and for prices around $15 per ton CO_2. As domestic costs increase, we find the decline in domestic consumption—even for the most energy-intensive goods—substantially exceeds the shift to imports.

The potential responses to competitiveness concerns fall into three groups: broad efforts to condition the target on global action, thereby mitigating the overall competitiveness impact; targeted efforts to exclude or otherwise treat vulnerable industries outside a single cap-and-trade program; and targeted efforts to ameliorate effects on vulnerable industries while keeping them *within* a single cap-and-trade program. Given the important role for substitution away from energy-intensive goods and the relatively narrow scope for competitiveness effects, our results suggest focusing on the latter. Broad efforts, while useful to address overall cost and fairness concerns, are likely too blunt to be helpful in addressing competitiveness. Complete exemption lacks any ability to scale the remedy to the concern. Perhaps, not surprisingly, it is these latter approaches that have received the most attention. They, in turn, fall into two categories: efforts to raise foreign product prices at the border, and efforts to reduce costs for domestic producers.

There are clearly two areas for further work: continuing to examine the historical experience for information about how higher prices at home and/or abroad affect domestic industries, and continuing to evaluate policy mechanisms to identify those that can address these impacts with minimal increase in overall costs or other unintended consequences.

Appendix A

Data

Employment is expressed as the natural logarithm of the number of employees (1,000s) (Bartlesman et al. 2000).

Production is expressed as the natural logarithm of value of industry shipments (millions of constant 1987 dollars). This measure is deflated using piship, the dataset's value of shipments price deflator (Bartlesman et al. 2000).

Net imports (share of value of shipments) are expressed as imports minus exports deflated using U.S. GDP implicit price deflator and then scaled by value of shipments, as deflated using U.S. GDP implicit price deflator (Feenstra 1996; Bartlesman et al. 2000).

Consumption is expressed as the natural logarithm of the sum of the value of shipments and levels of net imports (Feenstra 1996; Bartlesman et al. 2000).

Energy intensity is expressed as the total cost of electricity and fuels as a share of value of shipments (Bartlesman et al. 2000).

Electricity prices are expressed as the natural logarithm of the quantity of purchased electric energy divided by cost of purchase electric energy. Data for 1987–1994 were converted from SIC (1987 revision) to SIC (1972 revision) using the concordance provided by John Haveman (n.d.) and U.S. Census Bureau (various editions). Data from 1978 were provided by Gray (2007).

The average tariff is expressed in percentage points, and represents the average industry-level tariff based on the total duties collected multiplied by 100 scaled by total customs value (Magee n.d.; Feenstra 1996). We converted data for the 1989–1994 period into SIC 1972 classification using the concordance provided by Haveman (n.d.).

The physical capital share is represented by one minus the ratio of total payroll to value added (Bartlesman et al. 2000).

The human capital share is calculated as total payroll minus payments to unskilled labor, scaled by industry value added. Payments of unskilled labor are estimated from the *Current Population Survey* as the number of workers, multiplied by average annual income of workers with less than a high school diploma (U.S. Census Bureau, various editions; Bartlesman et al. 2000).

Appendix B

Methods

These results reflect statistical analyses of the U.S. manufacturing sector over the 1986–1994 period (with some complementary analyses over the 1974–2001 period). We evaluated the effects of industry-level electricity prices on three measures of competitiveness: employment, value of shipments (output), and consumption defined as value of shipments plus net imports. In these regressions, we also account for industry-level average tariffs by year, physical capital share of value added, the human capital share of value added, industry fixed effects (to capture time-invariant characteristics of industries that may affect these measures of competitiveness), and year fixed effects (to account for common shocks, such as those from monetary policy, that would affect all industries in a given period of time). We use electricity prices as our primary measure of energy prices because electricity expenditures represented a majority of energy expenditures for 88 percent of all manufacturing industries in our sample. It is also an informative index of fossil-fuel prices, since all three types of fossil fuels are used to generate electricity in our sample.

For our primary analyses, we estimate a series of regressions using a sample of U.S. industries at the 4-digit industry (SIC 1972) level of disaggregation. This provides a sample of nearly 450 industries over the 1986–1994 period. The basic regression specification takes this form:

$$Y_{it} = \alpha_i + \alpha_t + f(price_{it};\beta) + \delta' X_{it} + \varepsilon_{it}$$

where Y_{it} represents an industry and year-specific outcome measure—the natural logarithm of employment, value of shipments, and consumption; the α's are fixed effects for industries (i), and years (t); $price_{it}$ is the natural logarithm of the average electricity cost in 1987 dollars; X_{it} is a vector of additional determinants of the industry outcome measures, including tariffs and factor intensity variables (to estimate the returns to human capital and physical capital).

The function of price we specify in our regressions is a piecewise linear spline function that estimates distinct energy price elasticities for different components of the distribution of industries based on their average energy intensity in the sample period. The presented results focus on a 7-segment spline that estimates energy price elasticities for industries in the first, second, third, and fourth quintiles of the energy intensity distribution, as well as those in the eighth decile (80th to 90th percentile), and 19th and 20th semi-deciles (90th to 95th percentile and greater than 95th percentile).

While not presented here, we have also estimated these relationships controlling for the costs of environmental regulations (based on Ederington et al. 2005), but find that this has no discernible effect on our estimated energy price-competitiveness measure elasticities. We also find that our results are robust to choice of time period over 1974–2001. Finally, we assess the dynamic effects of electricity costs on competitiveness by accounting for contemporaneous and past electricity prices, but find that the dynamic effects (up to three years) are statistically equivalent to the contemporaneous effects.

Identifying the effect of domestic versus foreign energy price movements

A key challenge is to estimate the effect of changes in U.S. energy prices on domestic manufacturing *controlling for changes in foreign energy prices.* In turn, this allows us to estimate the effect of U.S. climate regulation assuming no foreign regulation. If we do not properly control for foreign energy price changes in the first part of this exercise, however, our estimate of the effect of domestic climate regulation in the second part would likely include a foreign energy price change. This would bias the estimate, depending on the historic relationship between domestic and foreign price changes. Most likely, it would *underestimate* the competitiveness effect, as foreign energy prices tend to move with domestic prices and our estimates would reflect (at least in part) the effect of global regulation versus the intended estimate of U.S.-only regulation.

How do we properly control for foreign energy price? Ideally, we would estimate a statistical model with both domestic and foreign energy prices. Unfortunately, foreign energy price data is sparse—both in terms of data over countries and time. Even the available data tends to be suspicious in terms of quality. An alternative strategy is to ignore the aggregate U.S. energy price trends—which are likely correlated with international energy prices—and instead look at differences in price trends among U.S. industries and the differential effect on their behavior. Focusing on one composite fuel—electricity—the differential price trends among industries are driven primarily by regional variation in both industry location and energy prices. By looking at differential behavior across U.S. industries facing different domestic energy prices changes, we ascertain what should be common foreign price changes. That is, we ask the question, when some industries face higher domestic prices than others, how does that affect their production and corresponding imports?

Consider, for example, the stylized data in the left panel below for two industries, *a* and *b* (imagine: chemicals and steel), and two time periods, 1 and 2 (imagine: 1984 and 1985). We first have to control for the fact that industry *b* has higher output; otherwise, there would appear to be almost no relationship between energy prices and output. We do this by asking how *changes* in energy prices over time lead to *changes* in output, rather than looking at absolute levels of either. Doing this, we see that both firms find positive increases in output associated with positive changes in energy prices over time, as period 2 prices and output are both higher than period 1 for both industries. This suggests a *positive* relationship between energy prices and output.

As noted above, however, these broad increases in domestic energy prices over time likely reflect, in part, global energy price trends. Therefore, this relationship misrepresents and underestimates a competitiveness effect because the whole purpose is to isolate US-only energy price increases. In this stylized example, it is even possible to find a rise in production from increasing global energy prices if U.S. firms are more energy efficient.

We now turn to our trick of focusing on difference among industries. As noted above, our data shows that different industries face different energy price changes, based on regional variation—that is, industries located in different places face different energy, particularly electricity, prices. We can therefore compare industries that have larger energy price increases to those that have smaller price increases. This comparison washes out any global price effect, as such global changes would impact both industries in the same way.

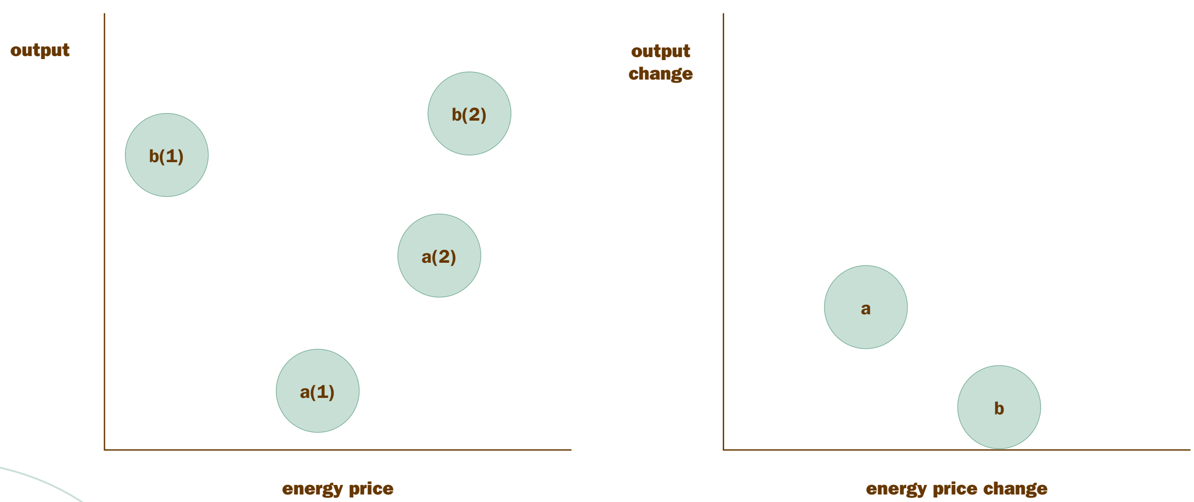
The right panel shows what happens. Viewed individually, industry *a* and *b* both show positive price and output increases as we noted before (both data points are in the positive quadrant for changes in output and prices). However, industry *b* has a much larger price increase and a much smaller output increase. If we look at the relationship across these industries—that is, a line connecting the two points—we conclude that those facing larger price increases have small output effects, suggesting a *negative* relationship.

This "difference-in-differences" approach is a common technique in empirical economics to control for a variety of trends over time—for example, foreign energy prices—that would be the same across industries where we have independent data.

One caveat to our strategy is that the effect of price differences among industries (what we estimate) might be different than the effect of climate regulation that raises all prices (what we want to simulate). Either producers or consumers might find it easier to substitute supply or demand, respectively, in response to a relative price change among industries (what we estimate) versus an aggregate price change (what we want to simulate). Depending on whether this substitutability is more on the consumer or producer side, we would tend to under- or over-estimate the competitiveness effect. However, so long as substitution with imports is generally larger than substitutability across goods for producers or consumers, this effect should be small.

Figure B1

Stylized effect of energy price changes over time and across industries, highlighting the effect of differencing out common effects over industries and time



Appendix C

Top 5 Percent Most Energy-Intensive Manufacturing Industries

Table C1

U.S. industries top 5 percent by 2001 energy intensity

Energy Intensity	Industry	Energy Intensity	Industry
0.270	Alkalies and chlorine	0.109	Paperboard mills
0.219	Lime	0.104	Wet corn milling
0.204	Industrial gases	0.103	Structural clay products, not elsewhere classified
0.191	Primary production of aluminum	0.093	Malt
0.189	Nitrogenous fertilizers	0.089	Blast furnaces (including coke ovens), steel works, and rolling mills
0.143	Cement, hydraulic	0.085	Inorganic pigments
0.131	Brick and structural clay tile	0.084	Industrial organic chemicals, not elsewhere classified
0.123	Glass containers	0.084	Minerals and earths, ground or otherwise treated
0.114	Electrometallurgical products	0.081	Particleboard
0.114	Flat glass	0.080	Mineral wool
0.112	Gypsum products	0.079	Building paper and building board mills

Source: Constructed by authors from the U.S. Census Bureau *Annual Survey of Manufactures* (various editions).

Note: Energy intensity defined by the total cost of electricity and fuels as a share of value of shipments.

Appendix D

Predicted Impacts of a $15 per ton CO_2 Price on Disaggregated Energy-Intensive Industries[21]

Predicted impacts of a $15 per ton CO_2 2012 allowance price on iron & steel industries

Industry	Production	Consumption	Competitiveness	Employment
Gray iron foundries	–3.2%	–1.7%	–1.4%	–1.7%
Malleable iron foundries	–3.2%	–1.7%	–1.4%	–1.7%
Iron and steel forgings	–2.8%	–1.4%	–1.4%	–1.4%
Steel foundries, not elsewhere classified	–2.6%	–1.4%	–1.2%	–1.3%
Electrometallurgical products	–3.4%	–2.7%	–0.6%	–2.3%
Blast furnaces (including coke ovens), steel works, and rolling mills	–3.3%	–2.7%	–0.6%	–2.3%
Steel springs, except wire	–1.4%	–0.9%	–0.5%	–0.4%
Steel wire drawing and steel nails and spikes	–1.6%	–1.2%	–0.5%	–0.8%
Steel pipe and tubes	–1.4%	–1.0%	–0.4%	–0.5%
Cold rolled steel sheet, strip, and bars	–1.4%	–1.1%	–0.3%	–0.6%
Steel investment foundries	–1.4%	–1.1%	–0.3%	–0.6%
Industry group average	–2.7%	–1.9%	–0.8%	–1.6%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on aluminum industries

Industry	Production	Consumption	Competitiveness	Employment
Primary production of aluminum	–3.6%	–2.8%	–0.8%	–2.3%
Aluminum foundries (castings)	–2.1%	–1.3%	–0.8%	–1.0%
Secondary smelting and refining of nonferrous metals	–1.9%	–1.2%	–0.7%	–0.9%
Aluminum rolling and drawing, not elsewhere classified	–1.4%	–0.8%	–0.6%	–0.4%
Aluminum sheet, plate, and foil	–1.7%	–1.2%	–0.5%	–0.8%
Aluminum extruded products	–1.7%	–1.2%	–0.5%	–0.8%
Industry group average	–2.0%	–1.4%	–0.7%	–1.0%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on bulk cement industries

Industry	Production	Consumption	Competitiveness	Employment
Lime	–3.7%	–2.9%	–0.8%	–2.3%
Concrete block and brick	–1.3%	–0.6%	–0.8%	–0.2%
Cement, hydraulic	–3.5%	–2.8%	–0.7%	–2.3%
Concrete products, except block and brick	–1.3%	–0.6%	–0.7%	0.0%
Ready-mixed concrete	–1.3%	–0.6%	–0.7%	0.0%
Gypsum products	–3.4%	–2.7%	–0.6%	–2.3%
Industry group average	–1.6%	–0.9%	–0.7%	–0.4%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on industrial chemicals industries

Industry	Production	Consumption	Competitiveness	Employment
Phosphatic fertilizers	–3.5%	–1.7%	–1.8%	–1.8%
Synthetic rubber (vulcanizable elastomers)	–3.5%	–1.8%	–1.7%	–1.8%
Industrial inorganic chemicals, not elsewhere classified	–3.6%	–2.1%	–1.5%	–2.0%
Plastics materials, synthetic resins, and nonvulcanizable elastomers	–3.1%	–1.6%	–1.5%	–1.5%
Alkalies and chlorine	–4.3%	–3.3%	–1.1%	–2.6%
Synthetic organic fibers, except cellulosic	–2.4%	–1.4%	–1.0%	–1.2%
Industrial gases	–4.1%	–4.5%	–1.3%	–2.6%
Fertilizers, mixing only	–1.4%	–0.5%	–0.9%	0.1%
Nitrogenous fertilizers	–4.1%	–3.2%	–0.9%	–2.6%
Industrial organic chemicals, not elsewhere classified	–3.7%	–3.0%	–0.7%	–2.5%
Inorganic pigments	–3.7%	–3.0%	–0.6%	–2.5%
Pesticides and agricultural chemicals, not elsewhere classified	–1.5%	–0.9%	–0.6%	–0.4%
Chemicals and chemical preparations, not elsewhere classified	–1.5%	–1.0%	–0.5%	–0.5%
Cellulosic man-made fibers	–1.6%	–1.2%	–0.3%	–0.7%
Employment-weighted average	–2.7%	–1.8%	–0.9%	–1.5%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on household chemicals industries

Industry	Production	Consumption	Competitiveness	Employment
Carbon black	–3.5%	–1.7%	–1.8%	–1.7%
Surface active agents, finishing agents, sulfonated oils and assistants	–3.4%	–1.7%	–1.7%	–1.7%
Perfumes, cosmetics, and other toilet preparations	–1.0%	0.5%	–1.5%	–0.4%
Pharmaceutical preparations	–1.1%	0.4%	–1.5%	–0.3%
Specialty cleaning, polishing, and sanitation preparations	–1.1%	0.4%	–1.5%	–0.3%
Soap and other detergents, except specialty cleaners	–1.1%	0.4%	–1.5%	–0.2%
Printing ink	–1.1%	0.4%	–1.5%	–0.2%
Paints, varnishes, lacquers; enamels, and allied products	–1.1%	0.4%	–1.5%	–0.2%
Biological products	–1.2%	–0.1%	–1.2%	0.1%
Adhesives and sealants	–1.3%	–0.4%	–1.0%	0.1%
Cyclic (coal tar) crudes, and cyclic intermediates, dyes, and organic pigments (lakes and toners)	–3.6%	–2.7%	–0.9%	–2.3%
Medicinal chemicals and botanical products	–1.5%	–0.6%	–0.9%	–0.2%
Gum and wood chemicals	–2.1%	–1.4%	–0.7%	–1.0%
Explosives	–1.5%	–0.8%	–0.7%	–0.3%
Employment-weighted average	–1.1%	0.1%	–1.2%	–0.3%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on paper industries

Industry	Production	Consumption	Competitiveness	Employment
Paper mills, except building paper mills	–3.2%	–2.3%	–1.0%	–2.0%
Pulp mills	–3.2%	–2.3%	–0.9%	–2.0%
Paperboard mills	–3.4%	–2.7%	–0.6%	–2.3%
Industry group average	–3.3%	–2.4%	–0.9%	–2.1%

Predicted impacts of a $15 per ton CO_2 2012 allowance price on bulk glass industry

Industry	Production	Consumption	Competitiveness	Employment
Flat glass	–3.4%	–2.7%	–0.6%	–2.3%
Industry group average	–3.4%	–2.7%	–0.6%	–2.3%

Endnotes

1. This analysis could also inform the consideration of the competitiveness effects of a carbon tax, which has been proposed in several bills in the United States House of Representatives in the 110th Congress.

2. Most of these costs would likely be passed on to consumers of these firms' goods.

3. Energy and carbon dioxide data collected by the U.S. Department of Energy for the industrial sector includes a broader set of industries than the manufacturing sector as defined by the Bureau of Economic Analysis.

4. Cement production is the primary source of CO_2 process emissions, which account for about 2 percent of U.S. CO_2 emissions. Our subsequent analysis presented below will not account for the effect of a carbon price on process emissions. The analysis focuses exclusively on the impact of a carbon price on the carbon embedded in fossil fuels, and would thus yield underestimates of the impact of a climate policy that covered CO_2 from fossil fuels and industrial processes in the cement industry.

5. This reflects the 2006 employment estimates for iron and steel (NAICS codes 3311, 3312), aluminum (3313), paper (3221), cement (3273, 3274, 3279), glass (3272), and chemicals (3311, 3312).

6. An equivalent approach is to simply look at the change in net imports as a share of domestic production directly. While delivering nearly identical results, the analysis of production and consumption as separate factors is more robust than the analysis of net imports as a share of production. For those industries with very high net import shares, the analysis runs into trouble when small changes in production create extremely large changes in the share.

7. We have also undertaken analyses over the 1974–2001 period. We have excluded the 1974–1985 period because it was the era of high energy prices and before what macroeconomists now refer to as the Great Moderation (Blanchard and Gali 2007; Stock and Watson 2002). Our primary analysis concludes with 1994 because of data limitations on net imports. It is not possible to create industry-specific series for net imports after 1994. We extend our employment and production analyses through 2001 in sensitivity analyses. We find that our results are robust to the choice of time period. Refer to Aldy and Pizer (2008) for more details.

8. One concern in our policy simulations is that regulated electricity prices will not change as much as deregulated prices if allowances are given away freely. As the trend in both U.S. proposals and EU policy is toward allowance auctions, however, this seems increasingly unlikely.

9. Technically, the common temporal effects are captured by year-specific indicator variables and not measures of GDP and oil prices. Likewise, industry-specific effects are captured by industry-specific indicator variables. Appendix A and Appendix B provides additional details on the estimation strategy.

10. We do not know if these relationships are linear over a small or large range of carbon prices, and if the relationship becomes non-linear, theory cannot clarify whether the relationship would become convex or concave. We are particularly concerned that there are likely to be thresholds; modest energy price increases will be accommodated, but at some point industries will make discrete decisions to move operations.

11. In constructing the group aggregates, we estimate each of the component-industry percentage change based on that industry's energy intensity, and then add up these changes based on the component-industry's share of employment within the industry group.

12. Also refer to Aldy and Pizer (2009) for a survey of these ideas.

13. Likewise, some energy-intensive firms could be excluded from a carbon tax system.

14. See Pizer et al. 2006, Edmonds et al. 2006, and Richels et al. 2007.

15. Likewise, a tax policy could provide a carbon tax credit comparable in value to free allowance allocation. For example, the carbon tax program could exempt some specified percentage of historic emissions before applying the tax to a firm's emissions.

16. This would be identical to providing firms with an intensity-based exemption; that is, making firms liable for emissions only above an established emission rate (where the exemption rate would be equivalent to the allocation rate above).

17. So long as a firm's emissions are a function of their economic production, allocating some *gratis* allowances based on production will depress the effective price on carbon for the recipient firm relative to the emission market allowance price. The lower effective price on carbon for these firms will spur less emission abatement than would be expected at the prevailing market allowance price. This requires non-recipient firms to undertake additional abatement under the national cap, thereby driving up their costs of compliance relative to a policy without *gratis* allocation as a function of production of energy-intensive firms. To get a sense of the rough order of magnitude, if 10 percent of the allowances were given out this way, and emission reductions from shifting consumption (which is moderated by this approach) is around 5 percent—the upper end of our estimates—we would raise prices consistent with tightening the cap by 0.5 percent.

18. It would be hard, for example, for other countries to provide similar incentives to their manufacturers absent greenhouse gas regulation as it would require public funds (Hauser et al. 2008).

19. It is important to note that our analysis identifies the effect of energy prices on impact and competitiveness measures after controlling for economy-wide factors. It is the residual variation after accounting for economy-wide energy price shocks, for example, that drives our results.

20. Additional analyses examining the effects of electricity prices on impact and competitiveness measures over as many as three years show very similar (and statistically indistinguishable) results as the contemporaneous analyses presented here. Refer to Aldy and Pizer (2008) for more details.

21. Impacts are based on 2001 industry energy intensity. Industry group average is weighted by 2001 employment. Competitiveness impact may not exactly equal the difference between production and consumption impacts due to rounding.

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notes

This report provides a quantitative assessment of the potential competitiveness impacts of mandatory climate policy on U.S. industry. The Pew Center on Global Climate Change was established by the Pew Charitable Trusts to bring a new cooperative approach and critical scientific, economic, and technological expertise to the global climate change debate. We inform this debate through wide-ranging analyses that add new facts and perspectives in four areas: policy (domestic and international), economics, environment, and solutions.

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