BACKGROUNDER

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Competitiveness Impacts of Climate Policy

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I. Introduction

Evaluating the impacts of climate policy on a country's overall competitiveness is one of the key areas of climate policy research. Competitiveness impacts occur if countries without a greenhouse gas (GHG) reduction system gain a comparative advantage on countries with GHG reduction systems. Two primary goals of the research in this area are to: (a) determine how to define competitiveness impacts and (b) measure their magnitudes.

This backgrounder introduces competitiveness impacts, reviews the current literature on them, identifies the available data sources, and discusses potential limitations of research on competitiveness impacts.

A. Essential Terminology

An introduction to essential terminologies used in the literature is a pre-requisite to understanding results. In this section, we describe these terminologies.

Competitiveness research typically focuses on industries that are most susceptible to foreign competition. These include emissions-intensive, energy-intensive, and/or trade-exposed (*EITE*) industries like aluminum, cement, steel, and paper production.

Studies focusing on country-level competitiveness impacts often estimate changes in *welfare*, which is a measure of the economic well-being of a society. Welfare is calculated using

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This backgrounder is one in a series prepared for the project "Planning for the Ex Post Analysis of U.S. Climate Policy" to inform discussions and assessments of U.S. climate policy. The backgrounders summarize research on the following topics: (i) competitiveness impacts of climate policy; (ii) climate policy, international trade, and emissions leakage; (iii) Kyoto flexibility mechanisms: the Clean Development Mechanism and joint implementation; (iv) land use, land-use change, and forestry; (v) EU Emissions Trading System, and (vi) the U.S. Environmental Protection Agency's Acid Rain Program. Taken together, these backgrounders summarize research on several key aspects of climate policy. In addition to helping inform discussions and assessments of climate policy, the backgrounders are intended to provide informative overviews of each topic to anybody interested in conducting or better understanding climate policy assessment, including researchers, students, and experts in academia, government, nongovernmental organizations, and industry. Funding for this project has been provided by the Alfred P. Sloan Foundation. The authors thank Ray Kopp for comments and suggestions on this backgrounder.

numerous variables, including *gross domestic product* (GDP) or *gross national product* (GNP) and country-level *trade balances* (the difference between imports and exports).

In sector-level studies, the most complete analyses estimate two primary competitiveness impacts: changes in *production* (also referred to as *output*) and changes in *profitability*. In these studies, the former is a result of changes in imports, exports, and domestic consumption. The latter is determined by a number of considerations, including the level of free-allowance allocations and the *pass-through rate*—which is the portion of increased costs that an industry is able to pass along to consumers. However, not all studies quantify these two impacts.

At the most basic level, the competitiveness impacts of GHG reduction systems can be evaluated as an increase in *marginal production costs*. Some studies account for *direct costs* only, which represent the cost of complying with the GHG reduction system. Others account for both direct and *indirect costs,* the latter of which result from increases in the cost of inputs—for example, electricity—resulting from the GHG reduction system.

A handful of studies also estimate changes in employment resulting from the climate policy.

B. Central Research Methodologies

Competiveness research typically uses *partial equilibrium* (PE) or *general equilibrium* (GE) computational modeling. PE models focus on a single market subset and therefore are often used to estimate emissions leakage at the sector level. GE models, which mimic the behavior of entire economies, are composed of many sectors and interacting markets. PE models are best suited for modeling economic relationships that are primarily contained within the modeled sector or part of the economy. GE models are purposed to better capture broader economic impacts, including interrelationships among different economic sectors or effects in different geographic regions or countries. Both PE and GE models require the development of stylized models of economies; these models include various assumptions about market structure, substitution patterns, and production and transportation costs.

Nearly all studies on competitiveness impacts are ex ante studies. Two clear exceptions are Hoffman (2007) and Anger and Oberndorfer (2008); these ex post studies use survey methodologies and regression analyses to examine the competitiveness impacts of the E.U. Emissions Trading System (ETS) on German firms. Other authors (Ruth et al. 2004; Aldy and Pizer 2009) use regression analyses to inform their ex ante modeling of a carbon price.

C. Policies Considered

A relatively large body of research has emerged on the competitiveness impacts of existing GHG policies—the Kyoto Protocol and the E.U. ETS—and those that have been proposed in the United States, including a federal cap, federal tax, and investment-led strategies. The research focus of these policies differs, reflecting broader concerns in the target regions. For example, compared to research surrounding the E.U. ETS, few studies have assessed the economy wide impacts of a federal carbon price; instead, U.S. researchers focus on the manufacturing sector, which has experienced a significant decline and is energy- and trade-intensive.

The Kyoto Protocol, an international agreement linked to the U.N. Framework Convention on Climate Change, was adopted in Kyoto in 1997 and entered into force in 2005. It set targets for industrialized countries and the European Community (collectively referred to as Annex B countries) to reduce GHG emissions between 2008–and2012. Non-Annex B countries (including developing countries) have not committed to reducing GHG emissions.

The E.U. ETS, which has been in operation since 2005, affects all major energy and industrial installations in the European Union.[1] Recently, the E.U. ETS has been expanded to cover emissions from air transportation.[2] The E.U. ETS is the largest GHG trading system in the world, covering 12,000 installations across the European Union and leveraging billions of Euros' worth of investments in carbon mitigation.

Several congressional proposals for a comprehensive federal GHG reduction system have emerged in the United States. Although none of the proposals have succeeded, these federal policy options have been subject to economics research. In addition, some researchers have focused on the effect of policy alternatives to a cap or tax on particular industries.

II. Available Data

The section below describes data sources used to estimate the competitiveness impacts of proposed U.S. GHG reduction systems on U.S. industries (data sources used to study the competitiveness impacts of the E.U. ETS on E.U. industries are covered in greater detail in the "E.U. ETS backgrounder"). In general, U.S. data sources fall into two categories: facility-level

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[1] All facilities that produce heat in excess of 20 megawatts/year are included in the E.U. ETS.

[2] These changes take effect in 2012

and sector-level data. These data are maintained by many different governmental and nongovernmental agencies.

A. Facility-Level Information

The U.S. Environmental Protection Agency (EPA) and the U.S. Energy Information Administration (EIA) both provide facility-level data pertinent to research on competitiveness impacts. These facility-level data are ideal for PE analyses of domestic climate policy, but are also used to supplement industry-level data for research on competitiveness impacts.

1. U.S. Environmental Protection Agency's Greenhouse Gas Reporting Program[3]

On October 30th, 2009, EPA's Mandatory Reporting of Greenhouse Gases Rule was published in the *Federal Register*. The Greenhouse Gas Reporting Program (GHGRP) represents the implementation of this rule. The GHGRP covers (a) suppliers of certain products that would result in GHG emissions if released, combusted, or oxidized; (b) direct emitting source categories; and (c) facilities that inject carbon dioxide (CO_2) underground for geologic sequestration. Facilities that emit 25,000 metric tons or more per year of GHGs are required to submit annual reports to EPA.

On January 11th, 2012, EPA released data from these compulsory annual reports for 2010. This represents the first time comprehensive GHG data reported directly by large U.S. emitters and suppliers have been easily accessible to researchers. The 2010 data,[4] which account for roughly 80 percent of U.S. GHG emissions, cover more than 6,000 direct emitters and more than 700 suppliers[5] from nine industry groups, including: power plants, landfills, metals manufacturing, mineral production, petroleum refiners, pulp and paper manufacturing, chemicals manufacturing, government and commercial facilities, and other industrial facilities.

For each facility deemed a supplier, detailed location and emissions data are recorded in an Excel file. Locational data include the facility name, city, state, zip code, address, latitude, and longitude. Data for GHG emissions associated with natural gas, CO_2, and petroleum product

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[3] U.S. Environmental Protection Agency, Greenhouse Gas Reporting Program: http://www.epa.gov/climatechange/emissions/ghgrulemaking.html.

[4] U.S. Environmental Protection Agency, Greenhouse Gas Data Sets: http://www.epa.gov/climatechange/emissions/ghgdata/2010data.html.

[5] Suppliers of fossil fuel products such as petroleum, natural gas, and industrial gases report the total GHG quantity that would result from the complete combustion, oxidation or use of the covered products they supply to the economy.

supply are listed. For suppliers, some types of data are confidential and therefore are not reported.[6]

For each direct emitter, the following categories of information are recorded in an Excel file: location, industry, emissions, sequestration, and monitoring. The locational data are exactly the same data collected for suppliers. The following types of data are collected for the other categories:

Industry Data

- Primary North American Industry Classification System (NAICS) code
- Industry type, as defined by GHGRP

Emissions Data

- Total reported direct emissions
- Total facility emissions, broken down by type of gas (nonbiogenic CO_2, methane, nitrous oxide, trifluoromethane, perfluorocarbons,and biogenic CO_2 emissions)
- Emissions by process, as defined by GHGRP

On-Site CO_2 Collection:

- Whether some CO_2 is collected on-site and used to manufacture other products and therefore is not emitted from the affected manufacturing process units

Sequestration

- Whether some CO_2 is reported as emissions from the affected manufacturing process units and transferred off-site or injected

Monitoring

- Whether the facility employs continuous emissions monitoring [7]

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[6] A reporter's total supplier-level CO_2e is confidential business information (CBI) if the reporter produces, imports, exports, or otherwise supplies just one product and if EPA has determined that the amount of that one product produced, imported, exported, or otherwise supplied is CBI.

In addition, Excel files are available that contain parent company data for each reporting facility and estimates of aggregate GHG emissions for importers and exporters of petroleum products. Also, files that break down data by industry type and state are available.

EPA expects to release 2011 data in early 2013. These data will include information regarding each facility's parent corporation and will cover 12 additional industries.[8] Because of the recent release of 2010 data, this backgrounder does not include any studies that have used data from this program. 2. U.S. Environmental Protection Agency Facility Registration System

EPA's Facility Registration System database[9] provides facility-level contact information and a registration key that can be linked across prominent EPA regulatory systems that are available online.[10] In addition, the Facility Registration System database includes a geospatial download option that provides shape files for download and use in geographic information system–type analyses.

2. U.S. Energy Information Administration Detailed Electricity Data

EIA also maintains energy production information at the state, facility, and generator levels.[11] These data cover electric utilities in the United States and include information on total

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[7] In general, the rule requires direct measurement of emissions from certain units that already are required to collect and report data using a continuous emissions monitoring system (CEMS) under other programs (e.g., the Acid Rain Program, New Source Performance Standards, National Emission Standards for Hazardous Air Pollutants, state implementation plans). In some cases, this may require upgrading existing CEMS that currently monitor criteria pollutants to also monitor CO_2 or add a volumetric flow meter. For facilities with units that do not have CEMS installed, reporters may choose to either (a) install and operate CEMS to directly measure emissions or (b) use facility-specific GHG calculation methods. Examples of facility-specific calculation methods include mass balance and use of facility-specific emissions factors.

[8] These industries include electronics manufacturing, fluorinated gas production, magnesium production, petroleum and natural gas systems, use of electric transmission and distribution equipment, underground coal mines, industrial wastewater treatment, geologic sequestration of CO_2, manufacture of electric transmission and distribution, industrial waste landfills, underground injection of CO_2, and imports and exports of equipment precharged with fluorinated GHGs or containing fluorinated GHGs in closed-cell foams.

[9] U.S. Environmental Protection Agency, Facility Registry System: http://www.epa.gov/enviro/html/fii/index.html.

[10] These regulatory systems include the Air Facility System (AFS), The Hazardous Waste Report, The Brownfields Database, the Comprehensive Environmental Response, Compensation, and Liability Information System database, Enforcement & Compliance History Online, Grants Information and Control System, the Permit Compliance System, the Radiation Information Database, Resource Conservation and Recovery Act Information, the Safe Drinking Water Information System, the Substance Registration System, the Toxics Release Inventory database, and the Toxic Substances Control Act database.

[11] U.S. Energy Information Administration, Electricity Detailed Data Files: http://www.eia.gov/cneaf/electricity/page/data.html.

electricity generation, fuel consumption, emissions, fuel recipients, and many other variables. Often, these data have been collected for at least a decade. In some cases, data have been collected since the 1970s. These data generally provide one of the best publicly available overviews of the electric utility industry. However, some effort may be required to merge multiple databases as much relevant information is split among several annual and monthly surveys. Moreover, some of the data come from surveys so do not represent a census of all facilities. Nevertheless, this information is well suited for researchers interested in assessing electric utility sector in the United States.

B. Sector-Level Data

Sector-level data are often most appropriate for conducting GE analyses of the competiveness impacts of different climate policies. Examples of GE analyses include: Viguier et al. (2003), Klepper and Peterson (2004), Kemfert et al. (2005), Kuik and Hofkes (2010), and Ho et al. (2008). These researchers have primarily relied on one nongovernmental source of data—the Global Trade Analysis Project (GTAP) database—but some have also relied on governmental data sources.

1. The Global Trade Analysis Project Database

Although GTAP was not originally intended for use in modeling climate policy, subsequent updates to the database have greatly expanded its application to modeling global climate and energy policy initiatives. It is the primary source of data for researchers interested in GE analysis of energy and climate policy. More details about GTAP can be found in the "GTAP backgrounder."

2. U.S. Department of Commerce Input–Output Data

Ho et al. (2008) used input–output data from the U.S. Department of Commerce to model interindustry product flows.[12] This database provides a detailed accounting of the flow of goods and services to and from 426 distinct sectors within the United States and is reported at the NAICS level. However, this database is updated only once every five years, with the most recent annual report available for 2002. This presents a significant challenge to researchers producing time-sensitive analyses, as economic conditions in the United States change rapidly from year to

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[12] U.S. Bureau of Economic Analysis, Benchmark Input-Output Data: http://www.bea.gov/industry/io_benchmark.htm.

year. For example, a database reflecting the prerecessionary economy of the United States in 2002 is unlikely to accurately represent the recovering U.S. economy in 2012.

3. Energy Information Administration and U.S. Census Bureau Manufacturer Surveys

A variety of governmental reports are also useful in characterizing the manufacturing industry of the U.S. economy. One such report, produced by EIA, is called the Manufacturing Energy Consumption Survey (MECS)[13]. MECS is a survey conducted every four years of a sample representative of 97 to 98 percent of all U.S. manufacturers.[14] Survey results are reported at the NAICS level and broadly represent how manufacturers use fuel inputs in their production processes. The most recent complete survey available is from 2006, but some early-release estimates for the 2010 survey are now available.

Another useful profile of the manufacturing industry is the Annual Survey of Manufactures (ASM),[15] provided by the U.S. Census Bureau. Conducted yearly,[16] the ASM covers all manufacturing establishments with one or more paid employees[17] and with sector NAICS codes between 31 and 33. The ASM surveys 50,000 manufacturing establishments, representing approximately 15 percent of all domestic manufacturers, and collects data related to employment, payroll, worker hours, payroll supplements, cost of materials, selected operating expenses, value added by manufacturing, capital expenditures, inventories, and energy consumption. In addition, ASM provides estimates of the value of products produced by domestic manufacturers.

Together, the MECS and ASM are the most important annual governmental reports available on the U.S. manufacturing industry; as such, they are heavily used by researchers interested in the competitiveness impacts of climate policy.

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[13] U.S. Energy Information Administration, Manufacturing Energy Consumption Survey: http://www.eia.gov/emeu/mecs/contents.html.

[14] For the 2006 survey, 15,500 manufacturers were sampled.

[15] U.S. Energy Information Administration, Annual Survey of Manufacturers: http://www.census.gov/econ/overview/ma0300.html.

[16] In years that end in a 2 or 7, results of the ASM are reported in the manufacturing section of the U.S. Census Bureau's Economic Census.

[17] Establishments that use leased employees for manufacturing are also covered by the ASM.

III. Research on the Competitiveness Impacts of Greenhouse Gas Reduction Systems

Research on competitiveness impacts has primarily focused on the impacts of the E.U. ETS and various U.S. climate policy proposals, but an early study focused on the Kyoto Protocol. Research on the E.U. ETS includes both ex ante and ex post assessments of the competitiveness of European industries. These studies consist of GE and PE analyses, as well a handful of studies with novel research approaches (including one survey of German electricity firms). By contrast, research on competitiveness impacts resulting from proposed U.S. climate policy primarily consists of PE analyses (sometimes combined with regression analyses) of specific industries, with few GE analyses simulating the entire U.S. economy.

A. The Kyoto Protocol

Wiese (1998) investigate the competitiveness impacts of the Kyoto Protocol on the United States. Specifically, the author estimates increases in unit production costs for certain U.S. manufacturing sectors, assuming that the United States returns emissions to 1990 levels by 2020[18] with a market-based permit system that results in a carbon price of $139. Focusing on the short term—in which firms cannot substitute factors of production and rising costs of nonenergy goods are not accounted for—the author finds significant cost increases, especially relative to cost increases associated with Kyoto compliance in Canada. Specifically, the study finds that unit production costs increase per ton of output: $138 for aluminum, $96 for pulp and paper, and $60 for primary steel. These changes represent increases that are 150, 45, and 40 percent higher, respectively, than the production cost increases associated with Kyoto compliance in similar Canadian sectors. Although these are nationwide averages, the study finds that cost increases are particularly high in the Midwestern states. Furthermore, the study finds that, for all manufacturing sectors considered[19] (with the exception of lime), U.S. production costs increase more than Canadian production costs. The study concludes by stating that claims of minimal competitiveness impacts of Kyoto compliance among Annex 1 countries “could widely miss their mark.” Table 1 summarizes this study, including data sources.

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[18] The proposed Kyoto target was actually 7 percent below these reductions, meaning that, all else being equal, the author’s estimates of unit production cost increases are understated.

[19] The author also estimates cost increases for chemical fertilizers, hydraulic cement, inorganic chemicals, and petroleum refining.

Table 1. Research on the Competitiveness Impacts of the Kyoto Protocol

Study	Region	Industry focus	Key data	Model	Main results
Wiese (1998)	United States	Manufacturing: aluminum, pulp and paper, steel, lime, chemical fertilizers, cement, inorganic chemicals, and petroleum	U.S. Department of Energy, U.S. Department of Commerce, EIA, data from trade associations, Canadian Industrial Energy End-Use Data and Analysis Centre	PE	Assuming that the U.S. returns emissions to 1990 levels by 2020 using a market-based system, resulting in a carbon price of $138, U.S. manufacturing unit production costs increase relative to those in Canada. Specifically, unit production costs increase 150%, 45%, and 40% more, respectively, for the aluminum, pulp and paper, and primary steel sectors. With the exception of lime, relative unit production costs also increase in all other sectors considered: chemical fertilizer, hydraulic cement, inorganic chemicals, and petroleum refining.

Notes: EPPA, Emissions Prediction and Policy Analysis; IEA, International Energy Agency; IMF, International Monetary Fund.

B. The European Union Emissions Trading System

Research on the competitiveness impacts of the E.U. ETS consists primarily of ex ante GE analyses. However, two ex post studies of German E.U. ETS firms have been conducted using surveys and regression analyses. Table 2 summarizes these studies.

Viguier et al. (2003) estimate competitiveness impacts of the E.U. ETS on the European Union in 2012. The study assumes that each country satisfies its Kyoto obligation according to the E.U. Burden Sharing Agreement.[20] by implementing country-level cap-and-trade systems that allow intra-country trading only. Such a policy approach would lead to a unique carbon price for each country. In 1995 U.S. dollars, the study estimates a carbon price range from $91 in the United Kingdom to a high of $385 in Denmark. In addition, the study estimates that all but two

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[20] Under the Kyoto Protocol, the European Union agreed to a target reduction in GHG emissions of 8 percent below 1990 levels for the 2008–2012 period. Although targets were specified for each E.U. country in the protocol, it allowed the development of an alternative burden-sharing scheme to be developed by the European Union as long as the aggregate 8 percent target was met. In 1998, at an Environmental Council meeting by the member states, reduction targets were adopted based on the understanding that lesser burdens should fall on "cohesion countries" (Greece, Ireland, Portugal, and Spain) relative to other member states to account for their need for economic development (Viguier et al. 2003).

countries experience an increase in terms of trade (ranging from –0.77 to 2.70 percent), whereas all countries experience a decrease in GNP (ranging from –1.01 to –7.19 percent); these changes lead to decreases in welfare—or welfare costs—for each country, ranging from 0.6 to 5.0 percent.

Klepper and Peterson (2004) use their Dynamic Applied Regional Trade (DART) model to analyze changes in welfare and output resulting from the E.U. ETS in the both ETS and non-ETS sectors of the E.U. economy in 2012. The study produces ranges of estimates based on two levers: program design (whether trading is allowed intracountry, and whether it is allowed intercountry among E.U.-15 or among E.U.-15 and accession countries[21]) and allowance distribution (including determining total and distributional allocation).

Regarding output, Klepper and Peterson (2004) find that, compared to intracountry trading only, all energy-intensive sectors gain from the ETS, which allows for inter-country trading among E.U. 15 and assession countries. Of these sectors, those that participate in the ETS benefit most dramatically. When trading is allowed for energy sectors within the ETS, the change in output for these sectors changes from nearly –5 percent (in the case of intracountry trading only) to around –2 percent. Overall, compared to unilateral action, the ETS allows participating sectors to roughly halve their output losses. Unilateral action decreases output in the non-ETS energy sectors (coal extraction and gas production and distribution) by over 11 percent and decreases output in energy-intensive ETS sectors (pulp and paper products, iron, metal, and steel) by over 1 percent. The introduction of an ETS provides some relief also to these sectors, though only modestly relative to ETS sectors. Overall, E.U. ETS reduces total E.U. output by 0.3 percent. A notable outlier includes energy-intensive sectors outside the ETS; the largest decline (11 percent) in output comes from the region containing Belgium, the Netherlands, and Luxembourg. This output loss is associated with high emissions–intensity industries like fertilizer production.

Regarding economic welfare, although unilateral actions reduce welfare across the European Union by 1.1 percent, an ETS using the least cost approach for allocating allowances reduces welfare by 0.9 percent, a comparative improvement. However, E.U. welfare decreases by 1.1 and 1.2 percent, respectively, under an ETS using a historical and forecasting allocation

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[21] Accession countries include Bulgaria, Romania, the Czech Republic, Hungary, Poland, Slovakia, Slovenia, Malta, and Cyprus. Under the E.U. ETS, these countries received hot-air credits—allowances in excess of their business-as-usual emissions.

approach. Klepper and Peterson (2004) find that the welfare gains from trading within the ETS are offset by distortions created through the divergence of abatement costs between sectors inside and outside of the E.U. ETS. Furthermore, all countries except France, Greece, Portugal, and Spain benefit from trading compared to unilateral action. The magnitude of the benefit depends on the strictness of each country's requirement under the burden sharing agreement and the differences in abatement costs between it and other member states. The largest benefit accrues to Belgium, the Netherlands, Luxembourg, Austria, and Ireland. However, the welfare costs for all countries are still negative overall, compared to business as usual (no unilateral action or ETS). The one exception is the accession country group, which—if allowed to use "hot-air" credits—could reap positive welfare from the ETS.

Kemfert et al. (2006) conduct a GE analysis to estimate the impact of the E.U. ETS on welfare, GDP, and trade balance in E.U. countries. The study assumes that the countries reduce emissions according to their national allocation plans. They assess three cases: no trading, intracountry trading only, and a full regional emissions trading scheme—meant to represent the E.U. ETS. Compared to the case of no trading, a regional emissions trading policy improves GDP for all countries in the European Union. However, the effect of trading will bring about some positive trade balance for certain countries (like Great Britain, Germany, and the Czech Republic) and some negative trade balance for others (Belgium, Denmark, the Netherlands and Sweden). To calculate welfare, the authors consider allocations of allowances and changes in GDP and trade. Although trading brings about substantial efficiency gains for most regions, when trade effects are accounted for, the welfare of 2 out of the 19 E.U. countries analyzed (Italy and the Netherlands) decreases. However, the welfare of the remaining 17 E.U. countries analyzed increases, indicating overall economic benefits from the E.U. ETS relative to reaching the same emissions reductions through no trading or intracountry trading only.

Kuik and Hofkes (2010) conduct a GE analysis to estimate cost increases and trade impacts of the E.U. ETS on the steel and mineral industries. The authors also assess the effectiveness of two border adjustment policies at minimizing adverse competitiveness impacts. Specifically, the authors consider a domestic-baseline policy, which requires importers to surrender allowances based on direct emissions per unit of similar product in the European Union, and a foreign-baseline policy, which requires importers to surrender allowances based on the average direct CO_2 emissions per unit of production in the foreign, or exporting, country. Regarding indirect costs, the study finds the following increases to the steel and mineral sectors: an 11.6 percent rise in electricity price, a 1.3 percent rise in the costs of own-use mineral products, and a 2.3 percent rise in the costs of own-use steel scrap. Compared to the direct costs of obtaining emissions allowances, indirect costs constitute 60 and 40 percent, respectively, of costs to the steel and minerals sector.

Regarding trade impacts, under a scenario with no border tax adjustments, Kuik and Hofkes (2010) estimate that competing imports increase by 9.0 percent (steel) and 4.1 percent (mineral products) while exports decrease by 8.1 percent (steel) and 3.8 percent (mineral products) in the European Union. Domestic supply also decreases by 2.0 percent (steel) and 1.6 percent (mineral products). However, trade improves under border tax adjustments. Overall, the use of border adjustment policies increases the total volume of E.U. steel sales by 0.8 percent (a movement from –2.5 percent under an E.U. ETS without border adjustment policies to –1.3 percent under an E.U. ETS with a foreign-baseline policy); the use of such policies increases mineral product sales by 0.6 percent (a movement from –1.6 percent under an E.U. ETS without border adjustment policies to –1.0 percent under an E.U. ETS with a foreign-baseline policy). Moreover, the effectiveness of the two border adjustment policies is uneven. The foreign-baseline policy is generally more effective at minimizing adverse competitiveness impacts than is the domestic-baseline policy. Compared to an E.U. ETS without border adjustment policies, a foreign-baseline policy decreases steel imports to the E.U. by nearly 15 percent (from nearly 9 percent to nearly –4 percent) and decreases mineral products imports by 8 percent (from 4 percent to –4 percent). On the other hand, compared to an E.U. ETS without border adjustment policies, a domestic-baseline policy decreases steel imports to the E.U. by about 5 percent (from nearly 9 percent to slightly over 4 percent) and decreases mineral product imports by over 4 percent (from slightly over 4 percent to below 0 percent.

Demailly and Quirion (2008a) use a PE analysis to estimate production and profitability impacts of the E.U. ETS on the iron and steel industry. The study explicitly analyzes the sensitivity of results with respect to five inputs: marginal abatement cost curves, trade elasticities, demand elasticities, pass-through rates, and the updating of allowance allocations. The authors argue that, although they are strong determinants of outcomes, assumptions regarding the latter two are often implicit in the literature. The authors choose three values from the literature for each of these assumptions (low, medium, and high) and run 243 simulations of their model to assess every possible combination of variables. They find that marginal production costs increase by 3.5 percent or less and consumption decreases by 2 percent at worst. The associated impact on trade is a decrease in exports of less than 5 percent and increase in imports of less than 7 percent. However, profit margins are estimated to rise slightly with a mean of 0.5 percent. In fact, the author’s results suggest that free allocations to the iron and steel industry could probably be reduced below 90 percent without a negative impact on profit margins.

Demailly and Quirion (2008b) use a PE analysis to estimate the production and welfare impacts of the E.U. ETS on the cement, steel, electricity, and aluminum industries.[22] The study also analyzes the effectiveness of five different combinations[23] of allowance auctioning and border tax adjustments on reducing adverse competitiveness impacts. Assuming a 15 percent E.U. ETS reduction by 2015 compared to 2005 levels, the authors find that production decreases by 0.5–1.5 percent for the cement industry, 0–1 percent for steel, 0–0.5 percent for electricity, and 0–0.75 percent for aluminum. Generally, output-based free-allowance allocation has the smallest effect on production.

Reinaud (2004) conducts a static analysis to estimate the impact of the E.U. ETS on iron and steel, paper pulp, cement, and aluminum profit margins. To arrive at estimates for profit margins, the study also calculates costs increases (direct and indirect) and changes in demand. Assuming a 90 percent and a 98 percent free allocation of allowances, the author finds a carbon price of €10 decreases profit margins for all industries considered. Specifically, the profit margins decrease by 2.1–6.8 percent for steel producers, 0.4–0.5 percent for newsprint, 5–8.1 percent for cement producers, and 7 percent for aluminum. The latter estimate does not contain a range because the aluminum industry is not covered and therefore does not receive free allowances.

Similarly, McKinsey & Company and Ecofys (2006) conduct a static analysis for the electricity, steel, pulp and paper, cement, oil refining, and aluminum production industries. To arrive at estimates for profit margins, the authors first calculate cost increases. Assuming 90 percent free allocation, the authors find that a carbon price of €20 increases margins for the electricity industry by 10–40 percent and for oil refining by 2.6–12.6 percent. On the other hand, such a carbon price decreases margins for steel producers (0.6–1.7 percent) and for pulp and paper producers (0–6.2 percent).

Two ex post studies analyze the competitiveness impacts of the E.U. ETS. Anger and Oberndorfer (2008) perform a regression analysis in an attempt to identify a significant

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[22] Taken together, these industries represent approximately 90 percent of E.U. ETS emissions (Demailly and Quirion 2008b).

[23] The allowance allocation approaches considered were: output-based allocation (where firms receive free allowances proportional to current output); grandfathering (where all allowances are distributed freely, without accounting for new information); auctioning (where all allowances are auctioned); auctioning with border tax adjustments (where all allowances are auctioned, but exporters of E.U. goods get refunded for their CO_2 charge); and output-based allocation in the cement and steel sectors and auctioning in the electricity sector.

relationship between allowance allocation in the first phase of the E.U. ETS and revenues and employment of ETS firms in Germany. They found no significant relationship. The authors mention that these results may be due to the low overall burden of emissions regulation within the E.U. ETS.

Hoffman (2007) surveys managers at prominent German electricity firms. The study finds that these firms incorporate allowance prices into their operations and, furthermore, that these prices drive investment in low-risk, quick-payback projects like retrofits to reduce emissions. However, the study finds that CO_2 prices have not fundamentally changed the firm's energy portfolios or research and development (R&D) investments.

Table 2. Research on the Competitiveness Impacts of the European Union Emissions Trading System

Study	Region	Industry focus	Key data	Model	Main results
Viguier et al. (2003)	European Union	Economywide	EPPA, IEA, IMF, Eurostat	GE	Assumes intracountry trading only. Results vary by country: change in welfare of –0.6% to –5.0%; change in terms of trade of –0.77% to 2.70%; change in GNP of –1.01% to –7.19%.
Klepper and Peterson (2004)	European Union	Economywide	DART, EIA	GE	Depending on policy for allowance allocation and scope of trading: overall welfare change of –1.2% to –0.7%. For an E.U.-wide trading scheme: changes in output of –2% for ETS sectors, –10% for non-ETS energy sectors, and 0% for nonenergy, non-ETS sectors.
Kemfert et al. (2006)	European Union	Economywide	GTAP-E	GE	Compared to a no-trading policy, and varying by country, the E.U. ETS: improves GDP by 0% to 0.33%, changes in trade balance by –$13 million to + $35million, and changes in welfare from –$172 million to +$1,312 million.
Kuik and Hofkes (2010)	European Union	Steel and mineral production	GTAP-E, Beckman et al. (2009)	GE	Depending on border tax adjustment policy: competing steel imports change by –4% to +9%, and competing mineral product imports change by –1% to +4%.

Carbon Trust (2008)	European Union	United Kingdom: manufacturing sectors	Department for Business, Enterprise and Regulatory Reform, 2007 Energy Statistics Publication; Department for Environmental Food and Rural Affairs, Compliance and Results, Analysis of the U.K. Results; E.U. ETS, Community Independent Transaction Log	PE	Phase III of E.U. ETS (2012–2020) will have minimal impact on over 90% of U.K. manufacturing activities. The only industries expected to be significantly impacted by E.U. ETS are cement/clinker, steel from blast oxygen furnaces, and aluminum.
McKinsey & Company and Ecofys (2006)	European Union	Cement, aluminum, steel, electricity, oil, pulp and paper	Publicly available data and McKinsey estimates	PE, static	Assuming 95% free-allowance allocation and a carbon price of €20, the average margin—as a fraction of total cost—of firms: changes by +10% to +40% for various electricity generators, +2.6% to +12.6% for oil refiners, -0.6% to -1.7% for steel producers, 0% to -6.2% for pulp and paper producers, by 1.7% to –3.8% for cement producers.
Reinaud (2004)	European Union	Cement, aluminum, steel, pulp and paper	IEA, Arcelor, Eurofer, WBCSD/WRI, Datastream, CEPI, JP Morgan, Cembureau, ABN AMRO, EAA, Alcan	PE, static	Assuming 90% and 98% free allocation and a carbon price of €10, the margins of an average firm decrease by 2.1% to 6.8% for steel producers, 0.4% to 0.5% for newsprint, 5% to 8.1% for cement producers, and 7% for aluminum.
Demailly and Quirion (2008a)	European Union	Steel and iron	IEA, ECSC, Eurostat	PE	Sensitivity analysis produces the following results: profits in the iron and steel market increase by a mean of 0.5%, marginal production costs increase by less than 3.5%, and consumption decreases by 2% at worst; it is very likely that E.U. exports drop by less than 5% and E.U. imports increase by less than 7%; finally, the compensating rate of free allowances that ensures that profits

					remain constant is likely to be under 90%.
Demailly and Quirion (2008b)	European Union	Cement, aluminum, iron and steel, electricity	CASE , PRIMES	PE	Depending on aggressiveness of emissions targets and the particular combinations of BTA policies and allowance allocation approaches: production decreases by 0% to 2% for cement, 0% to 2% for aluminum, 0% to 1% for iron and steel, and 0% to 1% for electricity; global welfare decreases by around 2.75% to 4.25%; and E.U. welfare decreases by around 2.5% to 4%.
Anger and Oberndorfer (2008)	European Union	German firms regulated by the E.U. ETS	E.U. ETS, Community Independent Transaction Log; AMADEUS; CREDITREFORM	RA	Evidence that allowance allocation in the E.U. ETS does not have a significant impact on the revenues of or employment by regulated German firms.
Hoffman (2007)	European Union	German electricity firms regulated by the E.U. ETS	Interviews with management of German electricity firms	Survey	German firms incorporate allowance prices into their operations. These prices drive investment in retrofits—low-risk, quick-payback projects—to reduce CO_2 emissions, but have not yet fundamentally changed the firm's energy portfolio or R&D investments.

Notes: CASE, Cement, Aluminum, Steel and Electricity Model; CEPI, Confederation of European Paper Industries;; EAA, European Aluminum Association; PRIMES,a partial equilibrium model of European Union energy markets; WBCSD, World Business Council for Sustainable Development; WRI, World Resources Institute.

C. United States Climate Policy

Apprehension that climate change legislation will further undermine the global competitiveness of an already weakened U.S. economy is one of the main obstacles to passing comprehensive climate change legislation in the United States. This fact, against the backdrop of a declining manufacturing sector, has prompted many authors to analyze the U.S. manufacturing sector. Although all research is ex ante and most is conducted using PE analyses, some estimates are reinforced by regression analyses of historical trends (Aldy and Pizer 2009; Davidsdottir and Ruth 2004; Ruth et al. 2004). One study (Ho et al. 2008) conducts PE and GE analyses to represent short-, medium-, and long-term impacts. In addition, some literature (Davidsdottir and Ruth 2004; Ruth et al. 2004) assesses the effectiveness of policy alternatives to—or hybrids of—a carbon tax. Table 3 summarizes the studies on the competitiveness impacts of U.S. climate policy.

Recently, Bassi et al. (2009) estimate the competitiveness impacts of three proposed cap-and-trade policies[24] on the steel, aluminum, paper and pulp, petrochemical, and chlorine alkalis sectors to 2030. In their core scenario, the authors assume the following: U.S. action is unilateral, industry cannot pass through any increased costs resulting from a carbon price to consumers, and industries do not invest in energy efficiency. Under these conditions, the study estimates higher production costs for all sectors; costs increase most for iron and steel (6–18 percent) and chlor-alkali (4–17 percent) and least for secondary aluminum manufacturing (0.4–2.0 percent). In addition, the authors estimate profit losses between 3 percent (the lowest value for paper) and 75 percent (the highest value for iron and steel). The study estimates losses in domestic shares between 0.2 percent (the lowest value for petrochemicals) and 11.9 percent (the highest value for iron and steel). Finally, the study highlights that if other prominent trading partners price carbon and pass through their costs to consumers, U.S. firms perform substantially better and could pass through their costs, even increasing profits under the base case scenario. In addition, a carbon price leaves the door open for significant energy efficiency gains that could mitigate competitiveness impacts. Free-allowance allocations improve the profitability of firms in all scenarios.

Some researchers have predicted the impact of U.S. climate change legislation to be less severe. Morgenstern et al. (2004, 2007), Aldy and Pizer (2009), and Ho et al. (2008), analyze a large set of U.S. sectors to determine the manufacturing and economywide competitiveness impacts of U.S. climate policy.

Morgenstern et al. (2004) perform a static analysis to calculate cost increases to U.S. manufacturing industries resulting from a $1 increase in carbon price. The study finds that percentage increases in, and aggregate values for, total costs vary among manufacturing industries by two and four orders of magnitude, respectively. Furthermore, the study concludes that over two-thirds of the resulting total cost increases are imposed on only 10 industries. In both measurements of cost increases, petroleum is hardest hit; in this sector, total costs increase by an estimated 71 percent, or $947 million for every $1 increase in carbon price.

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[24] More accurately, the authors model a "low-CO_2 price policy" based on the Low-Carbon Economy Act of 2007 (S. 1766) and a "mid-CO_2 price policy" and "high-CO_2 price policy," both based on the Climate Security Act of 2007 (S. 2191) except that the latter does not include international carbon offsets.

Aldy and Pizer (2009) perform a regression analysis[25] using data on competitiveness impacts associated with U.S. electricity prices on more than 400 U.S. manufacturing industries over a 20-year period. From this analysis, the study estimates the industry-specific price elasticities and calculates the competitiveness impacts of a unilateral U.S. carbon price of $15. The authors find limited impact. Overall, the study estimates a 0.7 percent increase in net imports as well as decreases in production, consumption, and employment of 1.3, 1.6, and 0.2 percent, respectively. Energy-intensive and/or trade-exposed industries face more severe impacts regarding net imports (up to a 0.9 percent increase for chemicals and paper) as well as production, consumption, and employment (reductions of up to 3.4, 2.7, and 2.3 percent, respectively, for bulk glass). However, the authors note that these production decreases are more attributable to reduced domestic consumption than to the loss of market shares to foreign competitors. Finally, the authors are careful to point out that their results cannot really be used for extrapolating to higher CO_2 prices because such increases have not occurred and are not part of their regression analysis.

Assuming a unilateral U.S. carbon price of $10, Ho et al. (2008) simulate short-term competitiveness impacts using a PE analysis—where firms have little opportunity to change input, capital, or prices—and longer-term impacts using a GE analysis. Regarding output in manufacturing industries, the authors find that the greatest initial reductions occur in chemicals and plastics (–1.74 percent), primary metals (–1.57 percent), and nonmetallic minerals industries (–1.20 percent). Although the initial reductions are relatively large in these industries, they shrink over time.[26] Furthermore, when impacts are measured in terms of profit, these firms rebound strongly, if not completely. Within the nonmanufacturing economy, the production of electric utilities declines initially (–1.35 percent) but does not substantially worsen over time (–1.17 percent) compared to coal or oil mining, which experience long-run production losses of 7.85 and 2.09 percent, respectively. Agriculture experiences modest but persistent declines in production (–0.54 percent in the short and –0.68 percent in the long run), and the service sector is nearly unscathed. As in Aldy and Pizer (2009), the study's long-run results show that reductions in output result more from a large drop in domestic consumption than an increase in net imports.

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[25] The authors control for four other factors that could influence the competitiveness aspects of U.S. manufacturing firms: industry-specific tariff rates; human capital; physical capital; and common temporal effects, including GDP, world oil prices, and other global trends.

[26] An important exception to this trend is petroleum refining, which experiences short-run output losses of 0.78 percent but long-term losses of 5.36 percent.

For example, whereas imports in the manufacturing sector change between –0.28 and 0.14 percent and exports change between –0.5 and 0.12 percent, the range of consumption changes is much larger: between –5.88 and 0.10 percent.

A vein of research by Ruth and Davidsdottir explores the impacts of different climate policies (carbon taxes, investment-led policies like tax preferences or R&D, and mixtures of the two) on the production, emissions, and energy use of particular industries. Table 3 also summarizes this research. As an alternative to GE models—which assume equilibrium and perfect mobility of various factors of production—the authors consider a capital stock with time lags between investments and deployment of new capital that does not likely attain equilibrium. The authors argue that this representation of capital more accurately reflects the real world. Without a representation of capital, the authors argue that GE models may overestimate the reductions from a particular policy. This finding has implications for policy instrument choice. Overall, this vein of research calls for the matching of policies to specific industries as a prerequisite to maximum cost-effectiveness.

Davidsdottir and Ruth (2005) focus on how the pulp and paper industry evolves under different climate policies from 2004 to 2020. In the course of the analysis, the study also estimates aspects of competitiveness impacts, including the change in production, energy costs per unit output, and the present value of energy expenditures and carbon payments. Specifically, the study assesses four comparable[27] policies: a carbon price of $75, a 71.1 percent tax on energy, an "investment-led" policy that decreases the carbon intensity of new capital by about 40 percent, and a "smart policy" that combines the carbon price and investment-led policies. Regarding output, the study finds that the carbon price has the largest impact (reducing production by 0.6 percent) followed by the energy tax (which reduces production by 0.5 percent). The investment-led and smart policies both have a positive impact on production, which increases under these policies by 0.1 and 0.2 percent, respectively, as a result of the declining energy costs that result from these policies. Regarding the present value of energy expenditures, the smart policy outperforms the carbon and energy taxes; energy expenditures increase by around $3 billion under the smart policy, whereas they increase by around $14 billion and $19 billion, respectively, under the carbon and energy taxes. Similarly, energy costs per unit are comparatively lower under the smart policy. These conclusions indicate that climate

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[27] The authors ensure compatibility by choosing policies that lead to the same amount of cumulative carbon emissions as estimated between 2000 and 2020, and the same cumulative amount of prevented carbon emissions between 2000 and 2020, as results from a $75 increase in the cost of carbon.

policies must be tailored for particular industries. In the case of the paper and pulp industry, it is evident that a carbon or energy tax alone does not significantly induce substantial efficiency gains through new capital investments (mainly because energy expenditures are relatively unimportant in this industry and the capital investment cost is high), though such a policy does lead to fuel switching. However, a smart policy combines the fuel-switching incentives that a carbon tax contains with the incentives to invest in new capital (and thereby increase energy efficiency) that investment-led policies excel at. Overall, the smart policy leads to more dramatic carbon reductions while reducing the competitiveness impacts on the paper and pulp industry.

Ruth et al. (2004) assess the effectiveness of three policies at reducing carbon emissions in the iron and steel, pulp and paper, and ethylene industries. Specifically, the study analyzes a carbon price of $75, an investment-led policy that reduces the emissions intensity of aggregate capital by 10 percent, and a hybrid policy represented by a $25 carbon tax and an investment-led policy that reduces the emissions intensity of aggregate capital by 5 percent. Importantly, the study accounts for capital vintage effects. For the iron/steel and paper/pulp industries, the study finds that the pure carbon tax policy is most effective at reducing carbon emissions. In these industries, a carbon tax promotes a strong technological substitution (switching to electric arc furnace technologies in the iron and steel industry) and autogeneration (the self-production of energy in the pulp and paper industry) that outperforms investment-led policies. However, the authors warn that if key assumptions are relaxed for the paper and pulp industry, investment-led policies may hold a comparative advantage.[28] For the ethylene industry, a pure carbon tax does not lead to noticeable emissions reductions because process energy (the energy covered by a carbon tax) is a small share of total energy use. Instead, an investment-led policy or a carbon tax on feedstock energy would be superior at reducing emissions.

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[28] Specifically, if emissions from landfills and autogeneration are taken into account, investment-led policies may be superior. A higher carbon price reduces recycling rates, which means that more paper heads to the landfill, creating methane—a potent GHG. In this study, autogeneration is assumed to be carbon-neutral, which is not likely to be the case in reality.

Table 3. Research on the Competitiveness Impacts of United States Climate Policies

Study	Region	Industry focus	Key data	Model	Main results
Ho et al. (2008)	United States	Economywide: manufacturing and nonmanufacturing industries	Department of Commerce, Input-Output tables; EIA, MECS and Annual Energy Review; Economic Research Service; GTAP	PE, GE	Assuming a carbon price of $10 and depending on short-, medium-, and long-run timeframes: production decreases by 0.11% to 5.36% for manufacturing sectors and by 0.05% to 11% for nonmanufacturing sectors; domestic manufacturing sectors will be the hardest hit initially, with the greatest declines in domestic production in the petroleum refining, chemicals and plastics, primary metals, and nonmetallic minerals industries. In the long run, the manufacturing sector's imports change by –0.28% to 0.14%, exports change by –0.5% to 0.12%, and consumption changes by –5.88% to 0.10%, depending on the specific industry. For nonmanufacturing industries, imports change by –4.32% to 0.13%, exports change by –0.34% to 6.65%, and consumption changes by –10.5% to 0.06%.
Aldy and Pizer (2009)	United States	Economywide: manufacturing	NBER; U.S. Census Bureau, ASM, current Population Survey; EIA, MECS; EPA, Energy Trends in Selected Manufacturing Sectors	PE, RA	Assuming a carbon price of $15, the average manufacturing firm: increases net imports by 0.7%, decreases production by 1.3%, decreases consumption by 0.6%, and decreases employment by 0.2%. Particular industries are more sensitive than others. The average paper firm increases net imports by 0.9% and decreases production, consumption, and employment by 3.3%, 2.4%, and 2.1%, respectively. The average bulk glass firm increases net imports by 0.6% but decreases production, consumption, and employment by 3.4%, 2.7%, and 2.3%, respectively.
Morgenstern et al. (2004)	United States	Economywide: manufacturing	U.S. Census Bureau, ASM; Bureau of Economic Analysis; EIA, MECS, State	Static	A carbon price imposes a dramatic cost on a few industries within the manufacturing sector. For a $1 increase in carbon price, the total cost to the

			Energy Price and Expenditure Report, Electric Power Monthly, and 2001 Annual Energy Outlook		petroleum refining industry increases by 0.71% or $947M—the highest of any industry. The top 10 affected manufacturing industries account for two-thirds of the total cost increase.
Bassi et al. (2009)	United States	Steel, aluminum, chemicals, paper	IIM-CP model; NEMS model; industry data; EIA, 2008 Annual Energy Outlook and MECS; U.S. Census Bureau, ASM; U.S. International Trade Commission	PE	Modeling three different unilateral cap-and-trade policies to 2030 and assuming no energy-efficiency improvements or ability to pass through costs to consumers, production costs increase by 0.4% to 18%, domestic shares decrease by 0.2% to 11.9%, and profits decrease by 3% to 75%, depending on the industry.
Davidsdottir and Ruth (2004)	United States	Paper and pulp	American Forest and Paper Association; Federal Reserve Bank of St. Louis; U.S. Department of Commerce; Energetics; EIA, Annual Energy Outlook, Annual Energy Review, MECS, Industrial Sector Demand Module of NEMS.	PE, RA	Depending on policy, output changes by –0.6% to +0.2%. A purely price-based policy may fall short in affecting the evolution of capital stock toward increased efficiency and is therefore less cost-effective. In contrast, a policy that combines a carbon price with incentives that advance adoption of higher-efficiency technology will stimulate a more dramatic slowdown in carbon emissions rates while reducing impacts on productivity of the industry.
Ruth et al. (2004)	United States	Paper and pulp, iron and steel, ethylene	American Forest and Paper Association; Iron and Steel Maker; Oil and Gas Journal; EIA, MECS, Industrial Sector Demand Module of NEMS.	PE, RA	A carbon tax is more effective at reducing emissions in the iron and steel and paper and pulp industries than in the ethylene industry. In the case of ethylene, an investment-led policy is superior at reducing emissions.

Notes: NBER, National Bureau of Economic Research; MECS, Manufacturing Energy Consumption Survey; NEMS, National Energy Modeling System.

IV. Limitations

The potential limitations of competitiveness research originate especially from the availability of data, mismatches between models and actual policies, uncertainties in key parameters, and bias and/or omissions in research methodology. Although most of the research focuses on the impacts of carbon price through a cap or tax, some studies—like Davidsdottir and Ruth (2004) and Ruth et al. (2004)—also focus on investment-led strategies, including subsidies and R&D, and find reduced competitiveness impacts compared to a pure carbon price policy.

A. Insufficient Data Availability

Some studies (e.g., Reinaud 2004; Davidsdottir and Ruth 2004; Ruth et al. 2004) use private industry data to inform their analyses. Although these data sources provide specific details about an industry, they are not publicly available and may be cost-prohibitive for many researchers, with annual statistical overviews of each industry costing from a few hundred dollars[29] to a few thousand dollars[30] per report. The excessive cost of these databases limits the degree to which industry-specific data can be used by researchers and reduces the likelihood of the replication of these studies. Moreover, private data on a sector might be incomplete, only providing detail on an industry subset or a portion of individual firms. To fully assess the competitiveness impacts of GHG reduction systems, researchers need facility-level data for all firms in an industry.

B. Matching Models and Policies

Some of the discrepancy among estimates produced by U.S. studies is probably due to researchers modeling different policies with different provisions and levels of stringency. Furthermore, models do not typically include important facets of potential legislation. Instead, even cap-and-trade policies are modeled as constant taxes, even though prices would fluctuate. Moreover, specific policy features like the inclusion of carbon offsets, price collars, and banking and borrowing are often not considered in modeling efforts. All of these discrepancies increase uncertainty in estimates of competitiveness impacts.

C. Uncertainty in Key Parameters

As Demailly and Quirion (2008a) shows, five key parameters significantly affect estimates of competitiveness impacts: marginal abatement cost curves, elasticities of demand, elasticities of trade, pass-through rates, and allowance allocation methods. Often, estimates of these parameters are not based on observation (derived via econometrics) and are not well-bound; this leads to a significant range in uncertainty regarding competitiveness impacts.

The unprecedented scale of emissions reductions that are projected to be achieved under existing and proposed GHG policies complicates estimates of competitiveness impacts.

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[29] The American Iron and Steel Institute's *2010 Annual Statistics Report* costs $400 for an electronic copy and $450 for a hard copy.

[30] The American Forest and Paper Association's *Annual Statistics of Paper, Paperboard and Wood Pulp* costs $2,660.

Generally, uncertainty in abatement cost increases with the quantity abated because of the lack of a historical record on which to base estimates. To address this uncertainty, most studies make assumptions regarding the particular shape of the marginal abatement cost curve, whereas others are more rigorous. For example, Aldy and Pizer (2009) inform their PE model by performing a regression analysis to estimate the historical relationship between energy prices and competitiveness impacts during a 20-year period. However, the authors' estimates are bound by the range of changes in energy prices observed in their data set and, therefore, competitiveness impacts cannot be extrapolated to carbon prices above $15.

Some authors have explicitly considered how uncertainty in abatement costs impacts particular aspects of competitiveness. In their analysis of the iron and steel industry, Demailly and Quirion (2008a) find that the quantity of abatement, leakage rates, and profits in the iron and steel market are all sensitive to assumptions regarding marginal abatement cost curves.

Price elasticities of demand for energy and manufacturing goods also are important—yet uncertain—determinants of competitiveness impacts. In a critique of GTAP, Beckman et al. (2009) find that its estimated energy demand is too price-elastic. They recommend replacing GTAP elasticities with those econometrically estimated in the literature. Estimates from GTAP are likely to be overly optimistic in terms of reductions that result from increases in prices; this, in turn, may have implications for competitiveness impacts. Demailly and Quirion (2008a) cite ranges between 0 and –0.62 for the price elasticity of demand for steel. Furthermore, the authors find that estimates of production, profits in the steel market, and the compensating rate of free allowances are sensitive to this uncertainty.

Many studies incorporate the so-called Armington elasticities that represent elasticities of substitution between similar goods from different countries (Armington 1969). These elasticities differ based on the origin of the goods to remedy unrealistic projections of capital movement between countries. This parameter has an important influence on projections of imports and exports. In their analysis of the iron and steel industry, Demailly and Quirion (2008a) cite ranges between 0.55 and 3.3 for the price elasticity of imports and exports for the iron and steel sector. They find that production levels, profits in the steel market, compensating rates of free allowances, and leakage rates are sensitive to these elasticities. Although most current research uses Armington elasticities, some studies (for example, Demailly and Quirion 2005 drop this assumption of heterogeneous elasticities based on origin for certain industries.

Demailly and Quirion (2008a) highlight the importance of two parameters that are often implicit in studies: the pass-through rate and allocation methods. The authors argue that these parameters are of utmost importance to the estimation of competitiveness impacts.

The pass-through rate is the portion of increased marginal costs that regulated firms can pass on to consumers. Typically, domestic and foreign consumption pass-through rates are unique. Generally, the assumption of perfectly competitive markets leads to a lower rate of pass-through, whereas the assumption of a monopolistic market can lead to higher pass-through rates, even that exceed increases in marginal costs. Some studies—like Reinaud (2004) and McKinsey & Company and Ecofys (2006)—simply assume competitive markets and that increase in marginal costs are completely passed through to consumers. Other studies, like Bassi et al. (2009),[31] incorporate an extremely wide range of assumptions for pass-through rates, thereby providing bounds for competitiveness impacts. In their analysis of the iron and steel sector, Demailly and Quirion (2008a) find that varying assumptions regarding pass-through rates result in significant differences in estimates for the price of steel, steel production, profits in the steel market, and the compensating rate of free allowances. In fact, compared to all other variables, changing assumptions regarding the pass-through rates leads to the highest variability.

Most studies assume that it is profit-maximizing for a firm to include the opportunity cost of emissions in its marginal costs. However, if allowance allocations are updated based on a firm's output or emissions—as they are in some E.U. countries, like France—this may not hold true (Demailly and Quirion 2008a). Instead, a firm may be incentivized to maintain relatively higher levels of production or emissions to gain free allowances. Under the assumption of updating, Demailly and Quirion (2008a) find significant changes in production levels (losses are mitigated) and the compensating rate of free allowances (which significantly increases).

D. Research Methodologies

Most GE models consider long-term impacts on competitiveness, whereas most PE analyses focus on short-run impacts. In their PE analysis, Aldy and Pizer (2009) hint at this disparity by pointing out that some domestic industries may perform better with time, as firms adjust to lower energy and carbon use.[32] On the other hand, some industries may perform worse as more operations move overseas. Either way, it is clear that differences among studies in the time period considered further complicate the interpretation of results. One study, Ho et al. (2008), attempts to rectify this difficulty by performing both PE and GE analyses.

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[31] Bassi et al. (2009) assume either a 100 percent or a 0 percent pass-through rate for their analysis.

[32] Ho et al. (2008) predict that competitiveness distortions will be most severe in the short run, but long-run impacts decrease as producers shift to less energy-intensive inputs and consumers adjust their purchases to avoid more expensive, carbon-intensive products.

V. Conclusions

Current research on competitiveness reveals relatively modest impacts of carbon pricing on entire economies. A more inclusive GHG reduction system, with many participating regions and countries, decreases competitiveness impacts. Current research also reveals that EITE sectors are particularly sensitive to competitiveness impacts. In these sectors, estimated production and profit losses can be significant. Border tax adjustment policies are potentially very effective at ameliorating these impacts. Thus, it seems properly designed GHG reduction systems can ensure relatively modest competitiveness impacts for all sectors.

Current research is not without limitations and there is ample opportunity for further contributions. Recent work has highlighted the importance of assumptions regarding pass-through rates and allocation methodologies. In addition, uncertainty is still large in a number of key variables. More generally, current results may not hold as abatement efforts increase in response to higher carbon prices. Overall, these limitations and opportunities will continue to present challenges to researchers and policymakers.

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