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Disaggregated Analysis of Competitiveness and Employment Issues in Energy-Intensive Trade-Exposed Sectors

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Executive Summary

This paper presents and interprets key data on the potential international trade impacts – and consequent impacts on employment – of a change in energy input prices resulting from carbon emission reduction strategies. The report incorporates disaggregated data with a specific focus on the Iron and Steel sector. Key findings include:

- Relative share of U.S. employment in the presumptively eligible energy-intensive, trade-exposed (EITE) sectors is most salient in the broad sectors of “Paper”, “Chemicals”, “Nonmetallic Mineral Products”, and “Primary Metal Manufacturing.”
- Relative share of U.S. trade in the EITE sectors, particularly with respect to “Non Annex I” countries (as defined following the Kyoto Protocol) and “BICSA” countries (Brazil, India, China, and South Africa) is highest in the Chemicals and Iron and Steel sectors.
- Disaggregated data on employment and trade in Iron and Steel may provide insight into employment reallocation. Employment in Iron and Steel has been steadily decreasing for 50 years and over the past 30 years, the majority of employment and establishments for the U.S. steel sector has shifted from high-energy-intensive integrated process production to less-energy-intensive “minimills.”
- Existing economic analysis suggests small effects on employment following simulations of the effect of higher energy input costs resulting from strategies proposed to lessen potential impacts of climate change. Valuable information could be obtained from similar studies using the disaggregated data presented in this paper.

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1. Introduction

This paper discusses the potential impact on U.S. employment and competitiveness of changes in energy-input prices resulting from strategies to mitigate carbon emissions.[1] We present key data on potential domestic effects and international trade shifts that could be affected by changing energy costs, while interpreting multiple charts that show the relative share of U.S. exports in the energy-intensive, trade-exposed ("EITE") sectors. We also provide successive levels of disaggregation with regard to more specific sub-sectors within Iron & Steel, based on both their share of U.S. trade and the relative importance of large, developing countries such as Brazil, India, China, and South Africa ("BICSA").[2] These countries emerged as a negotiating bloc on in the wake of climate change mitigation discussions in Copenhagen in 2009.

The present research joins a slate of recent papers investigating the potential impact of energy-input price changes in the United States resulting from carbon-emission reduction strategies on EITE industries. The U.S. Commerce Department contributed to an interagency report on international competitiveness in EITE sectors in response to a specific letter drafted by five U.S. Senators representing states with large manufacturing sectors.[3] The Interagency Report analyzed anticipated strategies to mitigate the potential impact resulting from restrictions on carbon emissions proposed in H.R. 2454 ("Waxman-Markey"). This paper delves further into the potential impacts of changes in energy-input prices, focusing on disaggregated employment and trade data within the Iron and Steel sector. It also analyzes patterns of international trade

[1] The term "competitiveness" refers to the concept described by Ho, Morgenstern, and Shih (2008) in that "the strength of competition from imports and consumers' ability to substitute other, less carbon-intensive alternatives for a given product play crucial roles in determining the ultimate impacts of domestic production and employment."
[2] These countries have also been referred to as BASIC – see, for example, *Financial Times* on January 19, 2010 and *Washington Post* on February 10, 2010. The BICSA references "BRIC" (Brazil, Russia, India, and China), with the inclusion of South Africa and the exclusion of Russia. Russia may be excluded in this context for two key reasons: first, it signed Kyoto and second, Russia registered the largest absolute drop in emissions from 1990 levels than any other Kyoto Protocol signatory (see *Washington Post* November 30, 2009). For these reasons also, Russia may play a unique and important role in climate negotiations, included in the Section 4 discussion below.
[3] "The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries," December 2, 2009, herein referred to as "The Interagency Report." See: http://epa.gov/climatechange/economics/pdfs/InteragencyReport_Competitiveness-EmissionLeakage.pdf. Other agencies included: Energy Information Administration, Treasury Department, Environmental Protection Agency, National Economic Council, Office of Management and Budget Council on Environmental Quality, Council of Economic Advisors, Office of Energy and Climate Change. The U.S. International Trade Commission provided assistance with technical modeling. Signatories to the letter include: Sen. Evan Bayh (Indiana), Sen. Arlen Specter (Pennsylvania), Sen. Debbie Stabenow (Michigan), Sen. Claire McCaskill (Missouri), and Sen. Sherrod Brown (Ohio).

demarcated by the BICSA countries.

The paper proceeds as follows. Section 2 presents key data on sector-specific employment, recognizing that the relative sensitivity between domestic manufacturing sectors to the changes in the price of energy intensive inputs such as electricity could create substantial labor displacement in the U.S. economy. Section 3 interprets data on EITE-related trade by major economic partners, presenting data that recognizes key climate change negotiating blocs, such as signers of the 1997 Kyoto Protocol, and the large, developing countries of BICSA. To the extent that carbon-emission strategies in the United States are matched by similar actions in other countries, the trade effects associated with these actions will be muted. Because the main mitigation strategies under consideration now that affect energy prices are to control carbon emissions, it makes sense to consider which U.S. trading partners are likely to take similar action. Kyoto signatories are commonly referred to as "Annex I" countries, as defined in the agreement as industrialized countries and economies in transition.[4] Countries that have not signed the Kyoto agreement, or developing countries that have signed Kyoto but were not required to reduce emissions (the "Non-Annex I" countries), might be considered the least likely to match U.S. action on carbon emissions reductions, so the exposure of EITE industry to trade from these countries are particularly relevant.

EITE sectors are defined at the 6-digit NAICS[5] level, which may mask underlying impacts found at further levels of disaggregation, particularly within the steel industry. For example, NAICS industry 331111 is defined as "Iron and Steel," disaggregated from the 3-digit NAICS industry 3311 "Iron, Steel, and Ferroalloy." Section 4 analyzes employment and competitiveness figures at disaggregated levels within Iron and Steel, including 7-digit NAICS "product classes," 7-digit NAICS production processes, and 10-digit HTS[6] trade patterns. Section 5 presents estimations from modeling exercises that suggest the size of employment risk in various sectors. The paper concludes with recommended areas of research.

[4] The 40 Annex I countries include: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States. The European Union is also considered Annex I.

[5] North American Industry Classification System. See: http://www.census.gov/eos/www/naics/.

[6] Harmonized Tariff Schedules. See http://hts.usitc.gov/.

2. EITE Employment

The total number of jobs in all EITE sectors, based on 2007 Economic Census data, is 780,844. Table 1 provides information about the number of jobs in 6-digit NAICS sectors potentially sensitive to changes in energy input prices.[7] The total number of jobs at risk in EITE sectors represents less than 0.5 percent of the U.S. labor force[8] and less than 15 percent of jobs in their own 3-digit NAICS sectors. In all but four 3-digit NAICS sectors containing EITE industries, the vast majority of jobs are not in EITE industries.

[7] Data from Table 1 and definitions of EITE sectors are culled from The Interagency Report."

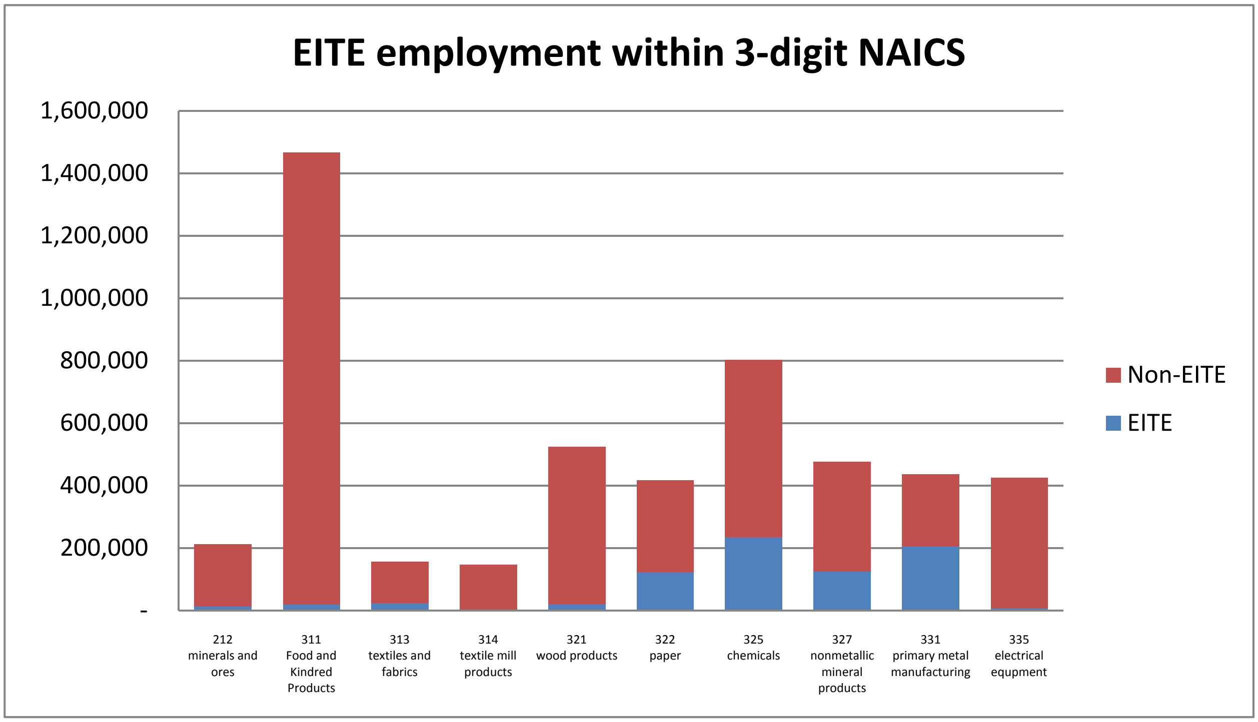
[8] The Bureau of Labor Statistics estimated the U.S. labor force to be 153,124,000 in 2007, which has risen to 153,911,000 in April 2010. See http://www.bls.gov/cps/lfcharacteristics.htm#laborforce.

Table 1: Number of Employees by 6-digit NAICS (2007 Economic Census)

NAICS	Description	Employees	NAICS	Description	Employees	NAICS	Description	Employees
212210	Iron Ores	5,189	**325188**	All Other Basic Inorganic	35,801	**327213**	Glass Containers	14,928
212234	Copper & Nickel Ores	7,288	**325192**	Cyclic Crude & Intmdtes	3,006	**327310**	Cements	17,749
311213	Malts	1,022	**325199**	All Other Basic Organic Chem	70,602	**327410**	Lime & Calcinated Dolomite	4,369
311221	Wet Corn Milling	8,448	**325211**	Plastic Materials, Resins	71,216	**327992**	Ground or Treated Mineral, Earth	6,497
311613	Animal Fats, Oils	9,355	**325212**	Synthetic Rubbers	9,794	**327993**	Mineral Wool & Glass Fibers	18,891
313111	Yarns	24,750	**325221**	Cellulosic Organic Fibers	1,353	**331111**	Iron & Steel	114,315
314992	Tire Cords & Fabrics	3,577	**325222**	Noncellulosic Organic	14,684	**331112**	Em Ferroalloy	2,144
321219	Reconstituted Wood	20,426	**325311**	Nitrogenous Fertilizers	3,920	**331210**	Steel Wire Drawing	17,408
322110	Pulp Mill Products	7,268	**327111**	China Plumbing, Earthenware Bathroom	4,825	**331311**	Alumina Refining	1,611
322121	Paper Mill	75,921	**327112**	China, Fine Earthenware	8,774	**331312**	Prim. Aluminum	9,355
322122	Newsprint Mill	4,917	**327113**	Porcelain Electrical	4,465	**331411**	Secondary Smelting (Aluminum)	1,771
322130	Paperboard Mill	36,641	**327122**	Ceramic Wall & Floor Tiles	6,272	**331419**	Other Aluminum Rolling, Drawing	8,067
325110	Petrochemicals	9,257	**327123**	Other Structural Ceramic	1,650	**331511**	Iron Foundries	51,503
325131	Inorganic Dyes and Pigments	7,606	**327125**	Nonclay Refractory	5,338	**335991**	Carbon and Graphite Mfg	8,666
325181	Alkalies and Chlorine	6,364	**327211**	Drawn, Blown, Float, Flat Glass	10,991		**Total**	**780,774**
325182	Carbon Black	1,591	**327212**	Other Pressed & Blown Glass	21,189			

As shown in Figure 1, the share of EITE employment for three-digit sectors is highest in 322 (Paper), 325 (Chemicals), 327 (Nonmetallic Minerals), and 331 (Primary Metal Manufacturing), which serves as the basis for analysis in subsequent sections of the paper.

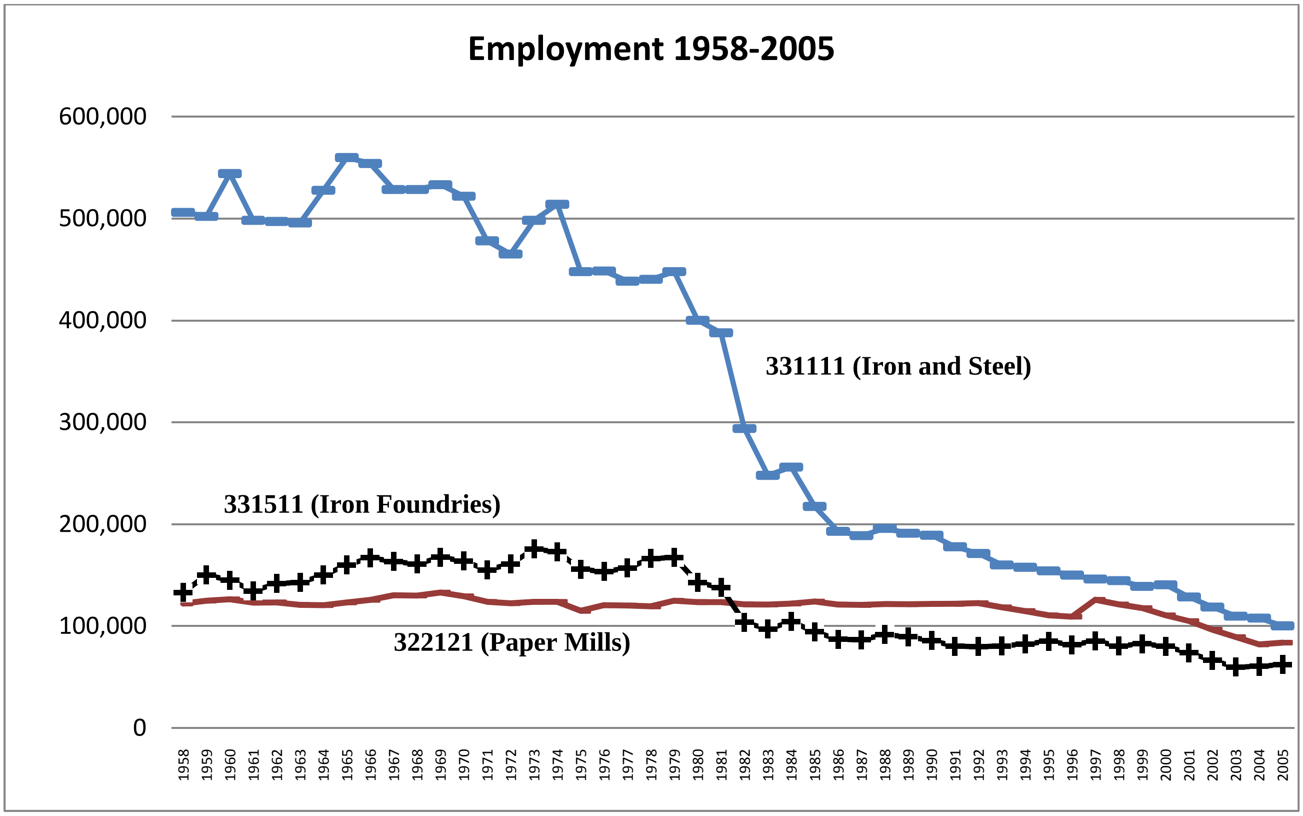
Figure 1: EITE employment within 3-digit NAICS



In addition to low levels of employment relative to industry aggregates, employment in EITE sectors has been trending down for decades. Figure 2 shows select EITE employment from 1958-2005 with 331111 (Iron and Steel) represented by the blue (dashed) line, 331511 (Iron Foundries) represented by the black (crossed) line, and 322121 (Paper Mills) represented by the red (flat) line.[9] Amongst these sectors, the highest level of employment was in Iron and Steel, topping a half-million employees in the 1960s before a substantial drop-off in the early 1980s.[10] Iron Foundries has been historically the second-highest employer, with 167,500 employees as recently as 1980, while employment in Paper Mills has remained relatively constant over the entire time period. None of the other EITE sectors reached 100,000 employees in any year of the survey.

[9] Becker and Gray (2009) accessed at http://www.nber.org/data/nbprod2005.html
[10] Yudken and Bassi (2009) explain the large drop in employment by lost capacity and productivity improvements.

Figure 2: Employment levels 1958-2005[11]



3. Trade and Competitiveness by EITE Sector and Partner

One of the main issues associated with unilateral actions restricting carbon emissions is that higher energy input costs may cause U.S. production to shift to countries that have not matched the U.S. regulation. Such production shifts that result in lower global emissions reductions than otherwise would have occurred are referred to as "leakage."[12] The potential impact of proposed carbon-reducing strategies on energy prices and, consequently, on EITE industry production and employment plays a key role in identifying mitigating strategies that can address the leakage issue.

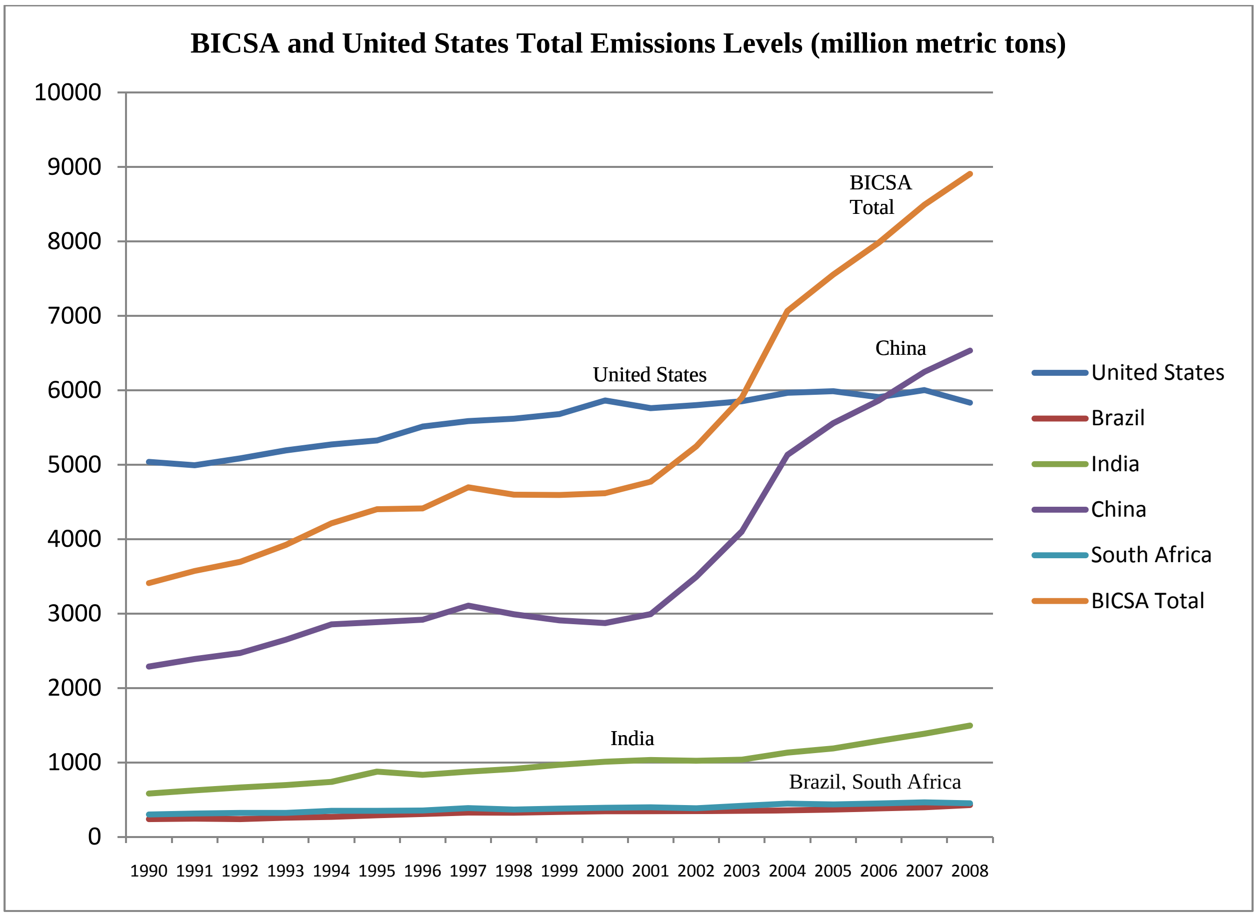
Regulation of carbon emissions could raise energy input costs in a manner that negatively impacts employment within EITE sectors by shifting production to lower-emitting domestic

[11] Becker and Gray (2009) accessed at http://www.nber.org/data/nbprod2005.html
[12] See, among others, Hufbauer, Charnovitz, and Kim (2009).

sectors or to overseas countries without reciprocating carbon-emission restrictions.[13] Negative impacts on competitiveness are manifested in international trade through diminished exports or by imports that substitute for domestic production. Table A-1 in the appendix ranks the EITE sectors according to their levels of employment; note that EITE sectors with the largest levels of employment also generally have large trade exposure.

Two of the three largest trading partners of the United States – Canada and Mexico – committed to reducing carbon emissions in the Kyoto Protocol. China, a "Non-Annex I" signatory to the Kyoto Protocol, did not. As shown in Figure 3, China and the BICSA countries are significant carbon emitters. China surpassed U.S. emissions levels in 2006, while BICSA as a group passed the United States in 2003.

Figure 3: BICSA and U.S. Total Emissions Levels[14]



[13] See, for example, Hufbauer, Charnovitz, and Kim (2009), The Interagency Report (2009), and Fischer and Morganstern (2009).

[14] Data provided by Energy Information Administration: International Energy Statistics

This section presents a series of charts that provide a visual representation of the potential impacts on competitiveness for U.S. industries due to export exposure in selected sectors across various regions with a particular emphasis on Non-Annex I countries and BICSA. Figures referenced in this section, shown in the appendix, parse the EITE sectors according to both their overall trade volume and the export share of BICSA countries to demonstrate relative exposure of U.S. domestic industries and potential impacts on competitiveness and employment.

Appendix Table A-2 ranks the six-digit NAICS sectors according to the size of the volume of U.S. total exports, including information about the percentage of all exports in the sector to BICSA countries and the extent to which BICSA exports make up all Non-Annex I exports. The greatest total of exports are the same sectors – 322 (Paper), 325 (Chemicals), 327 (Nonmetallic Minerals), and 331 (Primary Metal Manufacturing) – that were also shown in Figure 1 to have the largest share of employment.

Figures F-1 to F-4, shown in the appendix, provide information about U.S. trade exposure in select EITE sectors based on key regional groups motivated by previous research and current negotiations.[15] These figures use the following regions: Europe-32; Canada; Mexico; Annex I CIS[16] (Russia); Other Annex I; BICSA; Other Non-Annex I. Europe-32 refers to the 32 non-CIS European countries that are Kyoto signatories (including Turkey). Canada and Mexico are separated due to their role as leading trade partners of the United States. The "Other Annex I" countries are New Zealand, Australia, and Japan. Of particular interest are both absolute trade shares of BICSA and the relative trade share of all non-Annex I countries in order to isolate country-source challenges to energy regulation.

Figure F-1 shows the 2009 U.S. export and import shares, respectively, by 3-digit NAICS codes for EITE industries, with total volumes for the 3-digit sectors listed at the bottom. The BICSA countries represent from 9 percent to 18 percent share of exports and from 4 percent to 34 percent of imports, while all non-Annex I countries represent from 21 percent to 43 percent share of exports and from 9 percent to 37 percent of imports. This figure shows large

[15] Fischer and Morganstern (2009) display the 2004 U.S. import shares of 3-digit manufacturing industries, demarcated by BrIC (Brazil, India, China), Other (Non-Annex I), Mexico, Canada, Europe, and Other Annex I. The Interagency Report produces a similar chart showing the distribution of 2008 U.S. international trade by origin and destination countries demarcated by the European Union, Other Annex I (Australia, New Zealand, Japan), Canada, Mexico, China, India, and "Other" (Non-Annex I).

[16] Commonwealth of Independent States. Russia is represented with Belarus and Ukraine in "Annex I CIS." Note that the values for this region are dominated substantially by Russia. The other CIS countries are included here rather than Europe due to their historical geo-economic integration with Russia.

percentages of imports in 212 (Minerals and Ores) but does not emphasize the total values of imports for the sectors, which are labeled at the bottom in $1,000's.

An alternative representation of exposure may be found in Figure F-2, which compares respective sizes of 4-digit NAICS sectors.[17] As shown, the trading landscape is dominated by a few 4-digit sectors, particularly 3221 (Pulp, Paper, and Paperboard), 3251 (Basic Chemicals), 3252 (Resin and Synthetic Rubber), 3311(Iron and Steel and Ferroalloy), 3314 (Nonferrous Metal except Aluminum), and 3359 (Electrical Equipment). Note that some 4-digit sectors are heavily influenced by both exports and imports. This pattern holds at further disaggregated levels. Note also that the 4-digit EITE sectors with the largest total volumes also provide, in general, the largest shares of other non-Annex I volumes.

To facilitate comparisons, Figures F-3 and F-4 present the breakdown of trading patterns for 6-digit EITE sectors within 3221, 3251, 3252, 3311, and 3314 using regional color-coding. Figure F-3 presents information about 3251 (Basic Chemicals) and 3252 (Resin, Synthetic Rubber, etc), the chemical sectors that dominated Figure 2 in terms of volume of exports. Note that the vertical axis measures over $30 billion in total volume of U.S. exports. The United States exports more than $1 billion in 325188 (Other Basic Inorganic) and over $4 billion in 325199 (Other Basic Organic Chemicals) and 325211 (Plastics and Resins).

Figure F-4 presents information for 3221 (Pulp, Paper, and Paperboard), 3311 (Iron and Steel and Ferroalloy) and 3314 (Nonferrous Metal except Aluminum). The figure suggests that salient sectors for analysis are 322121 (Paper Mill), 331111 (Iron and Steel), and 331419 (Other Aluminum Rolling and Drawing). The next section disaggregates Iron and Steel data.

4. NAICS 331111 and the Steel-Making Process

Steel production can be broadly characterized by two major processes: Basic Oxygen Furnace (BOF), also known as "integrated mills", and Electric Arc Furnace (EAF), or "minimills." Integrated Mills make iron in a blast furnace using processed coal, or "coke", as a

[17] The number below the sector description is the percentage of exports accounted by the BICSA countries; the only two that represent more than 20% of the market for U.S. exports, 3253 (Agricultural Chemicals) and 3315 (Foundries) account for a total of only $1.7 billion in trade. The number below the sector description is the percentage of imports accounted by the BrIC countries; the largest of these, 51% in 3315 (Electric Lighting Equipment) only represents about $500,000 worth of imports, whereas, as shown below, BrIC imports in the 6-digit sector 331111 (Iron & Steel) alone tops $11 billion. These numbers do not provide information about relative intensity of carbon emissions in particular sectors.

main energy source, and then the basic oxygen furnace converts the iron into steel. Electric furnaces, on the other hand use mostly recycled steel (“ferrous scrap”) and electricity to create steel; over the last decade, EAF steel production has increased from 43 percent to 58 percent of the U.S. total.

The BOF process yields substantial amounts of direct emissions, while the EAF process yields primarily indirect emissions through its use of electricity as a main input. The 6-digit NAICS representation does not demarcate according to production process. Accordingly, legislation such as H.R. 2454 considers entities using “integrated iron and steel making technologies including coke ovens, blast furnaces, and other iron-making technologies” (integrated/BOF) and “entities using electric arc furnace technologies” (minimill/EAF) to be in the same eligible industrial sector; however, the Interagency Report, drafted in direct consideration of proposals in H.R. 2454, points out that the proposed domestic climate change legislation recognizes the different production processes (integrated/BOF versus minimill/EAF) as separate sectors for determining allocation rates for mitigating strategies. That is, the two production processes are part of the same EITE sector but may be eligible for different allocations based on their energy intensity.

Data on steel-making production processes may be gleaned from the five-year Economic Census reports. The 6-digit NAICS classification officially provides the most specific industry information, the Economic Census supplements this information with 7-digit NAICS “product classes.” Employment information at the level of product class has not yet been produced for the 2007 Economic Census, so Table 2 provides information about employment at the 7-digit NAICS classification from the 2002 Economic Census. As can be seen, the largest employment within the 6-digit “Iron and Steel” sector is 3311115 and 3311117, generically “hot rolled steel,” for a total of 81,129 employees.

Table 2: Iron & Steel Employees, 7-digit NAICS (2002 Economic Census)[18]

NAICS	Meaning of Products and services code	Employees	# Corresponding HTS codes
3311111	Coke oven and blast furnace products, made in steel mills	4,933	358
3311113	Steel ingots and semifinished shapes and forms, steel mills	7,531	358
3311115	Hot rolled steel sheet/strip (incl. tinplate/etc.), steel mills	51,146	358
3311117	Hot rolled steel bars/bar shapes/plates/piling/etc., steel mills	29,983	358
331111B	Steel pipes/tubes, steel mills prod. semifinished shapes/plate	6,334	358
331111D	Cold rolled steel sheet/strip, steel mills/hot roll. sheet/strip	9,259	358
331111F	Cold fin. steel bars/shapes, steel mills/hot rolled bars/etc.	3,292	358
331111L	Other steel mill products, incl. steel rails, exc. wire products	3,131	358
331111H	Seamless rolled ring forgings, ferrous, made in steel mills	20-99	76
331111J	Open die & smith forgings (hammer/press), ferrous, steel mills	1000-2499	76
3311119	Steel wire, including galvanized & other coated wire, steel mills	778	29
	Total:	**118,847**	

Pierce and Schott (2009) develop a concordance between the 7-digit NAICS "product classes" and 10-digit HTS codes. As Pierce and Schott point out, a primary challenge for such a concordance is the "many to many" problem, in which multiple 7-digit NAICS (or 5-digit SIC) codes correspond to multiple 10-digit HTS codes. The 7-digit NAICS codes 3311111, 3311113, 3311115, 3311117, 331111B, 331111D, 331111F, and 331111J correspond to the same set of 358 10-digit HTS codes, 331111H and 331111J correspond to another unique set of 76 10-digit HTS codes, and 3311119 represents its own 29 10-digit HTS codes. Unfortunately, no concordance is available to provide information about trading patterns for the different steel-making processes. End users of steel products are indifferent as to whether they were created through blast-oxygen furnaces or electric arc "minimills" (except for possible price differentials), and trade data are classified according to end use.

The U.S. steel industry is the third largest in the world, behind China and Japan, with crude steel production of 102.2 million net tons in 2008, down from a high of 109.9 million tons during the previous economic cycle.[19] Over the last decade, the U.S. share of world steel production has fallen sharply – from 12.7 percent to 6.9 percent – as production rose rapidly in

[18] http://factfinder.census.gov/servlet/IBQTable?_bm=y&-NAICS2002=331111&-ds_name=EC0231I5&-_lang=en
[19] Yudken and Bassi (2009), pg 80, citing *World Steel 2008*

developing countries, particularly China and India, where steel demand has been increasing. By contrast, in the United States, demand had been comparatively flat, before virtually collapsing after the 2008 financial crisis. However, the United States does not have the capacity to meet domestic demand and therefore relies on imports to supplement its domestic production. Over the last decade, import penetration has averaged over 20 percent, and while imports have fallen during the current recession, imports from China remain a serious concern for U.S. steelmakers, particularly given fluctuations in global steel markets.[20] China's steel producing capacity has more than doubled in recent years and now accounts for about half of total world steel production.

The steel-making process offers a key narrative on competitiveness and leakage effects resulting from reduction of carbon emissions. Unilateral U.S. carbon reduction strategy that results in relatively higher coal prices (for the BOF process) and electricity prices (for the EAF process) could shift production overseas, resulting in job losses for the U.S. steel industry. To the extent that those countries rely more on the BOF process, overall global carbon emissions would actually increase. The regulatory action in this situation could potentially shift jobs out of the U.S. steel industry while increasing global carbon emissions.

The U.S steel industry remains one of the largest energy consumers in manufacturing and could face substantial difficulties if faced with a steep rise in energy costs that might result from carbon emission reduction strategies. The impact across the industry would be uneven, with energy-intensive production by the integrated process particularly affected because of its heavy reliance on coal. Electric furnace operations would be squeezed, to a lesser extent, by higher electricity costs.[21] In Europe, BOF produces about 75 percent flat products and 25 percent long products, primarily for global markets, while EAF produces about 85 percent long products and 15 percent flat products, mostly for regional markets.[22] According to the U.S. Department of Energy, energy costs account for about 20 percent of the total cost to manufacture steel. Coke and coal accounted for about 38 percent of energy requirements, followed by natural gas (27 percent), and electricity (13 percent).

[20] See Yudken and Bassi (2009), pg 85

[21] As previously noted, the BOF process yields substantial amounts of direct emissions, while the EAF process yields only indirect emissions through its use of electricity as a primary input. BOF products are primarily high-value, cold-rolledflat products (see Carbon Trust 2004); EAF products are mainly long products for construction purposes (see McKinsey and ECOFYS 2006).

[22] McKinsey and ECOFYS (2006)

The competitiveness of electric furnace operations could be adversely affected by higher electricity costs resulting from higher costs of burning fossil fuels, given that estimated energy requirements to produce a ton of steel in an electric furnace are 675 KWh. The steel industry purchased 55 million kWh in 2008; the Steel Manufacturers Association estimates that steelmakers spend $3 billion for electricity in a typical year, including more than 64 percent by minimills.[23]

Bleischwitz, Fuhrmann, and Huchler (2007) compare the potential cost increases in the EU under a proposed carbon price of €20/ton of CO2.[24] Given allowances and no pass-through of carbon costs, BOF could experience a cost increase of 16 to 17 percent, providing a clear incentive to shift production outside of any national or supra-national regions covered by the carbon price.[25] Under assumptions of 95 percent free allowances and pass-through of costs, the cost increases will be closer to 1 percent. McKinsey and ECOFYS (2006) estimate BOF steel producers might lose 1.7 percent of their revenue, and EAF producers 0.6 percent of revenue.[26]

Because it is far more energy intensive, a substantial increase in energy costs would affect integrated steelmaking more than EAF production. A 2005 Department of Energy study estimated that the average energy intensity of the integrated process was nearly three times greater than EAF production (16.5 MBtu/ton vs. 5.7 MBtu/ton). Iron-making is particularly energy intensive. About 1.1 to 1.4 tons of metallurgical coal is required to produce one ton of coke. Integrated mills consumed 15.7 million tons of coke in blast furnaces (22.1 million tons of coal) to make iron in 2008.

EAF steel is produced from scrap metal, which is currently scarce (or "bottlenecked") on global market due to high demand in China.[27] Because of this scarcity, the price of scrap metal is sufficiently high that EAF steel is not an economically viable replacement for BOF steel.[28] According to McKinsey and ECOFYS (2006), BOF steel faces continued issues of

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[23] In a press release dated March 25, 2010, the American Iron and Steel Institute quotes industry representatives testifying before the U.S. Congress that EAF/minimill producers could face a potential doubling of electricity costs, possibly as high as $40/steel ton.
http://www.steel.org/AM/Template.cfm?Section=Industry_News&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=37653

[24] Citing Huschler's 2007 Master's Thesis at the College of Europe, Bruges.

[25] The assumptions of allowances and no-pass-through recognize sector-specific mitigation strategies that have been proposed in Europe. "Pass-through" refers to the extent to which consumers bear the burden of increasing prices. In comparison, McKinsey and ECOFYS (2006) estimate that 6% of additional costs for BOF steel will be passed to consumers and 66% of EAF costs will be passed through.

[26] Revenue defined as Earnings Before Interests and Taxes (EBIT)

[27] See, among others, Yudken and Bassi (2009), pg 91.

[28] McKinsey and ECOFYS (2006)

"debottlenecking" in the EU, where the capacity flow requires constant improvement. In the United States, according to Environmental Protection Agency ("EPA") data, BOF production has declined from 70 percent of steel in 1985 to 45 percent in 2005. According to the American Iron and Steel Institute's 2008 Annual Statistical Report, the share of BOF production continued to decline to 42.6percent in 2008, indicating a smaller share of a smaller market.

BOF steel is processed using iron and/or coal as inputs, the latter through coke ovens. A blast furnace yields a liquid "pig iron" which contains substantial carbon that is released in the blast oxygen furnace, yielding liquid steel.[29] The EAF process also yields liquid steel from recycled materials such as scrap and iron ore. Table A-4, in the appendix, provides a chart with definitions according to the 1997 Economic Census for data on various steel-making processes. The same categories are used in the 2002 Economic Census but definitions are not provided. Based on these definitions of 7-digit NAICS steel-making, Table 3 provides information about employment in the various processes. No information is provided in the 2002 Economic Census for 331112, "Partially Integrated With a Blast Furnace."

Table 3: Employees by Steel-Making Process, 2002[30]

NAICS	Description	Establishments	Employees
3311111	Iron & steel mills - fully integrated	9	32,740
3311113	Iron & steel mills - partially integrated without blast furnace	48	25,769
3311114	Iron & steel mills - nonintegrated	316	60,338
	Total:	**373**	**118,847**

We use HTS codes to gain substantive disaggregation within the Iron and Steel sectors by trading partners and regions. In general, the HTS classification system provides more disaggregated information than the NAICS classification system, and 4-digit HTS codes provide more disaggregation than 6-digit NAICS codes. Table A-3, listed in the appendix, ranks 4-digit HTS Iron and Steel industries by the size of their exports to BICSA countries.

[29] Significantly higher carbon costs may encourage integrated mills to shift production from energy-intensive iron and steel making facilities to imported semi-finished steel ("slabs") to supply their rolling mills, which are less energy intensive.
[30] 2002 Economic Census

In a similar vein, Table 4 breaks down Iron and Steel exports by their 10-digit classification as established in Table 2 above. Set (i) refers to the first set of 7-digit NAICS product classes, with 358 corresponding HTS codes; set (ii) refers to the second set, with 72 corresponding HTS; and set (iii) refers to the third set of the table, with 29 corresponding HTS. Trade with BICSA countries is only 3 percent in the listed data, with barely 10 percent of trade with Non Annex I countries.

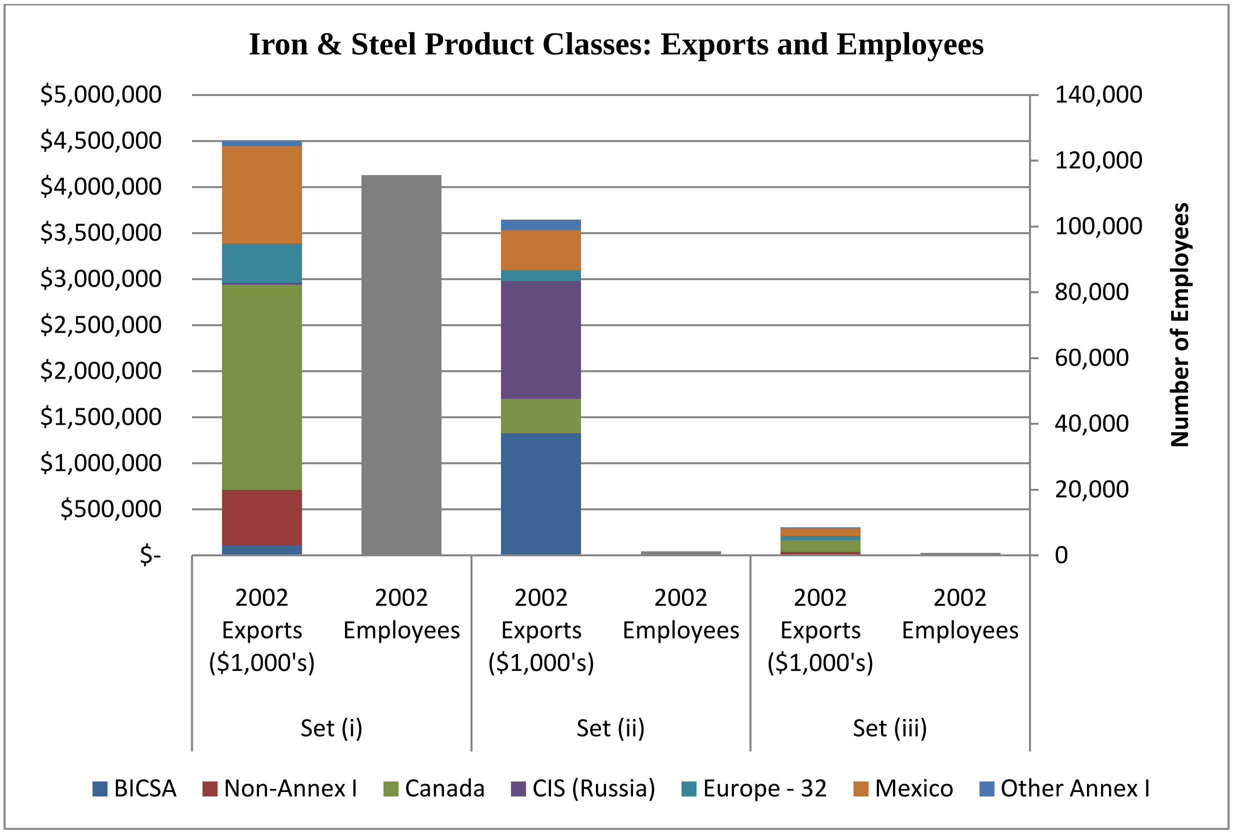
Table 4: 10-Digit HTS Iron and Steel Exports by 7-digit NAICS ($1,000's), 2002[31]

	Total	BICSA	Non-Annex I	Canada	CIS (Russia)	Europe - 32	Mexico	Other Annex I
Set (i)	$4,495,397	$118,808	$591,781	$2,231,868	$18,588	$427,162	$1,055,547	$51,646
Set (ii)	$3,644,525	$110,382	$433,409	$1,325,082	$4,948	$372,024	$1,279,558	$119,122
Set (iii)	$305,234	$9,731	$32,847	$127,181	$96	$46,407	$80,010	$8,958

Figure 4 juxtaposes the 2002 export data in the subsets of NAICS 331111 with the number of employees listed in Table 2. Note a large ratio of exports per employee in set (ii) of the product classes.

[31] 2002 Economic Census

Figure 4: Iron and Steel Product Classes: Exports and Employees



5. Modeling Exercises

The data collected for this paper provides information and/or complementary analysis to sophisticated, general-equilibrium analyses of regulation-driven changes in energy costs. Computable general equilibrium (CGE) models have illuminated cross-sector variances for climate legislation and proposed mitigating strategies, including the Interagency Report's estimation (which is based largely in part on Fischer and Fox (2007)), and Ho, Morganstern and Shih (2008)'s estimates, both using variations of the Global Trade Analysis Project (GTAP).[32] These models provide estimates at various levels of sector disaggregation for the effects of climate change reduction strategies on multiple variables, including output and production cost.

[32] https://www.gtap.agecon.purdue.edu/

Ho, Morganstern, and Shih (2008) estimate potential output changes using GTAP's sectors that match 3-digit NAICS sectors for short-run, medium-run, and long-run scenarios, defined according to how firms can adjust prices, reallocate capital, or incorporate energy-efficient technology. Ho, et al., assume that short run changes in output correspond proportionally to employment, and thus, in Table 5 we provide estimates on employment changes in relevant EITE sectors. In the long run, the models assume that labor markets adjust to offset losses with gains in other sectors. This study simulates the impact of a $10-per-ton price of CO2.

Table 5: Potential employment changes based on H/M/S (2008) estimates

NAICS Sector		Employees[33]	Percent Estimated Employment Change[34]			Corresponding Change in Employment Numbers[35]		
			SR	MR	LR	SR	MR	LR
311	Food	18,825	-0.38	0.06	0.08	-72	11	15
313-314	Textile	28,327	-1.13	-0.52	-0.32	-320	-147	-91
315	Apparel		-1.03	-0.1	0.05			
321-322	Lumber,wood, paper	145,173	-0.53	-0.25	-0.1	-769	-363	-145
324	Petroleum refining		-0.78	-5.64	-3.86			
325	Chemicals and plastics	235,194	-1.74	-0.81	-0.47	-4,092	-1,905	-1,105
327	Nonmetallic mineral	125,938	-1.2	-0.67	-0.42	-1,511	-844	-529
331	Primary metals	206,174	-1.57	-1.1	-0.69	-3,237	-2,268	-1,423
336	Transportation equipment		-0.33	-0.44	-0.3			
332	Fabricated metals		-1.14	-0.32	-0.15			
333	Other machinery		-1	-0.05	0.21			
335	Electrical machinery	8,666	-0.72	-0.55	-0.33	-62	-48	-29
		768,297				**-10,064**	**-5,563**	**-3,306**

The Interagency Report specifically analyzed the effects of mitigation strategies incorporated into H.R. 2454 ("Waxman-Markey") on 2-digit EITE sectors. For Iron and Steel, the report finds an increase in marginal production costs of two to three percent based on specific proposals for H.R. 2454. Computable General Equilibrium simulations conducted for the report

[33] 2007 Economic Census
[34] Ho, Morganstern, and Stern (2008)
[35] Author's calculations

indicate that these cost increases could be eliminated through strategies such as output-based allocations and allocations to local energy providers.

6. Suggested Future Work

The volumes and export shares presented in this paper provide direction for companion analysis of the impact of increased energy-input costs on U.S. domestic competitiveness and employment, as well as potential effects on overall carbon emissions through various inputs and energy intensity of the different sectors. Data from the Bureau of Labor Statistics for the listed 6-digt NAICS sectors and disaggregated 4-digit HTS sectors could indicate vulnerabilities of domestic industries, and EPA data on emissions could provide further light on leakage and CO2 reduction.

Existing economic analysis suggests small effects on employment following simulations of increased energy-input prices resulting from domestic carbon emission reduction strategies. This paper presents disaggregated data in the Iron and Steel sector that might prove valuable for incorporation in multi-sector computable general equilibrium models. Such analysis could provide further insight into expected competitiveness shifts within the domestic steel sector resulting from higher energy-input costs in the United States.

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Appendix

Table A-1: Ranking Employees with Trade (in $1,000's)

(Employees from 2007 Economic Census; Total Trade in 2008 dollars from USITC DataWeb)

NAICS	Description	Employees	Total Trade	NAICS	Description	Employees	Total Trade
331111	Iron & steel mills	114,315	$57,000,655	**325131**	Inorganic dye & pigment mfg	7,606	$3,076,660
325211	Plastics material & resin mfg	71,216	$38,380,722	**212234**	Copper & Nickel Ores	7,288	$1,780,295
325199	All other basic organic chemical mfg	70,602	$57,151,293	**322110**	Pulp mills	7,268	$8,772,304
331511	Iron foundries	51,503	$2,076,992	**327992**	Ground or treated mineral & earth mfg	6,497	$583,469
322130	Paperboard mills	36,641	$240,057	**325181**	Alkalies & chlorine mfg	6,364	$2,694,000
325188	All other basic inorganic chemical mfg	35,801	$21,660,701	**327122**	Ceramic wall & floor tile mfg	6,272	$1,421,889
313111	Yarn spinning mills	24,750	$1,904,796	**327125**	Nonclay refractory mfg	5,338	$874,709
327212	Other pressed & blown glass & glassware mfg	21,189	$3,719,614	**212210**	Iron Ores	5,189	$2,161,689
321219	Reconstituted wood product mfg	20,426	$2,074,822	**322122**	Newsprint mills	4,917	$6,105,744
327993	Mineral wool mfg	18,891	$1,317,963	**327111**	Vitreous china plumbing fixture & bathroom accessories mfg	4,825	$951,918
327310	Cement mfg	17,749	$896,213	**327113**	Porcelain electrical supply mfg	4,465	$453,788
331210	Iron & steel pipe & tube mfg from purchased steel	17,408	$2,417,663	**327410**	Lime mfg	4,369	$62,597
327213	Glass container mfg	14,928	$1,231,906	**325311**	Nitrogenous fertilizer mfg	3,920	$8,710,649
325222	Noncellulosic organic fiber mfg	14,684	$3,543,850	**314992**	Tire cord & tire fabric mills	3,577	$543,086
327211	Flat glass mfg	10,991	$2,083,098	**325192**	Cyclic crude & intermediate mfg	3,006	$12,954,590
325212	Synthetic rubber mfg	9,794	$6,152,277	**331112**	Electrometallurgical ferroalloy product mfg	2,144	$5,596,031
311613	Rendering & meat byproduct processing	9,355	$1,314,954	**331411**	Primary smelting & refining of copper	1,771	$6,922,532
331312	Primary aluminum production	9,355	$8,849,269	**327123**	Other structural clay product mfg	1,650	$54,113
325110	Petrochemical mfg	9,257	$17,457,699	**331311**	Alumina refining	1,611	$1,580,656
327112	Vitreous china, fine earthenware, & other pottery product mfg	8,774	$2,485,032	**325182**	Carbon black mfg	1,591	$501,605
335991	Carbon and Graphit Mfg	8,666	$3,962,339	**325221**	Cellulosic organic fiber mfg	1,353	$1,251,511
311221	Wet corn milling	8,448	$3,079,391	**311213**	Malt mfg	1,022	$475,031
331419	Other nonferrous metal primary smelting & refining	8,067	$44,098,655		**Total**	**780,774**	**$364,062,477**

Table A-2: BICSA and Non-Annex I Share of U.S. Exports

NAICS		Total U.S. Exports	BICSA Share Total	BICSA Share Non-Annex I
Minerals and Ores		**$3,023,186**	**17%**	**88%**
212210	Iron Ores	$1,244,235	1%	29%
212234	Copper & Nickel Ores	$1,778,951	29%	91%
Food and Kindred Products		**$3,608,642**	**3%**	**6%**
311213	Malts	$258,106	3%	17%
311221	Wet Corn Milling	$2,286,171	2%	5%
311613	Animal Fats, Oils	$1,064,365	4%	8%
Textiles and Fabrics		**$1,346,669**	**1%**	**1%**
313111	Yarns	$1,346,669	1%	1%
Textile Mill Products		**$125,650**	**11%**	**44%**
314992	Tire Cords & Fabrics	$125,650	11%	44%
Paper		**$12,916,113**	**13%**	**33%**
322110	Pulp Mill Products	$4,839,955	18%	49%
322121	Paper Mill	$7,118,134	9%	23%
322122	Newsprint Mill	$847,377	17%	34%
322130	Paperboard Mill	$110,647	2%	4%
Chemicals		**$88,032,576**	**15%**	**36%**
325110	Petrochemicals	$1,984,688	6%	20%
325131	Inorganic Dyes and Pigments	$2,011,522	14%	33%
325181	Alkalies and Chlorine	$2,046,287	19%	30%
325182	Carbon Black	$304,888	22%	61%
325188	Other Basic Inorganic	$9,888,601	12%	31%
325192	Cyclic Crude & Intmdtes	$5,368,450	18%	46%
325199	Other Basic Organic Chem	$32,507,288	13%	33%
325211	Plastic Materials, Resins	$27,469,958	16%	37%
325212	Synthetic Rubbers	$4,110,402	22%	52%
325221	Cellulosic Organic Fibers	$957,290	33%	48%
325222	Noncellulosic Organic	$1,383,202	12%	38%

NAICS		Total U.S. Exports	BICSA share Total	BICSA share Non-Annex I
Nonmetallic Mineral Products		**$5,540,581**	**10%**	**30%**
327111	China Plumbing, Earthenware Bathroom	$109,704	6%	20%
327112	China, Fine Earthenware	$597,245	5%	22%
327113	Porcelain Electrical	$152,303	3%	10%
327122	Ceramic Wall & Floor Tiles	$43,513	1%	6%
327123	Other Structural Ceramic	$17,114	3%	4%
327125	Nonclay Refractory	$451,756	10%	33%
327211	Drawn, Blown, Float, Flat Glass	$1,315,136	9%	20%
327212	Other Pressed & Blown Glass	$1,438,606	14%	40%
327213	Glass Containers	$262,238	2%	29%
327310	Cements	$107,425	1%	4%
327410	Lime & Calcinated Dolomite	$25,754	1%	21%
327992	Ground or Treated Mineral, Earth	$207,794	12%	31%
327993	Mineral Wool & Glass Fibers	$811,993	14%	43%
Primary Metal Manufacturing		**$41,598,809**	**9%**	**44%**
331111	Iron & Steel	$16,655,979	11%	39%
331112	Em Ferroalloy	$228,203	7%	70%
331222	Steel Wire Drawing	$450,986	9%	39%
331311	Alumina Refining	$612,250	9%	52%
331312	Prim. Aluminum	$996,149	2%	31%
331411	Secondary Smelting (Aluminum)	$640,107	15%	54%
331419	Other Aluminum Rolling, Drawing	$20,993,531	7%	50%
331511	Iron Foundries	$1,021,604	21%	48%
Electrical Equipment		**$1,133,353**	**15%**	**48%**
335991	Carbon and Graphite Product Manufacturing	$1,133,353	15%	48%
	Total	**$157,325,579**	**12%**	**36%**

Table A-3: Rank of 4-digit HTS Iron and Steel by exports to BICSA countries (in $1,000's)
(2008 data collected from USITC dataweb)

HTS	HTS Definition	BICSA	Non-Annex I	HTS	HTS Definition	BICSA	Non-Annex I
7304	tubes, pipes and hollow profiles, seamless, of iron	$554,285	60%	**2704**	coke and semicoke of coal, of lignite or of peat	$13,686	8%
7225	flat-rolled alloy steel (other than stainless) pro	$410,323	39%	**7212**	flat-rolled iron or nonalloy steel products, less	$10,210	9%
7208	flat-rolled iron or nonalloy steel products, 600 M	$224,637	18%	**7305**	tubes and pipes nesoi (welded etc.), having intern	$9,660	13%
7220	flat-rolled stainless steel products, less than 60	$112,488	45%	**7214**	bars and rods of iron or nonalloy steel nesoi, not	$6,589	11%
7302	railway or tramway track construction material of	$66,455	39%	**7301**	sheet piling of iron or steel, whether or not dril	$6,315	52%
7306	tubes, pipes and hollow profiles nesoi (open seame	$65,056	22%	**7209**	flat-rolled iron or nonalloy steel products, 600 M	$6,223	7%
7210	flat-rolled iron or nonalloy steel products, 600 M	$62,567	17%	**7221**	bars and rods of stainless steel, hot-rolled, in i	$4,732	40%
7228	bars and rods nesoi, angles, shapes and sections o	$56,529	20%	**7215**	bars and rods of iron or nonalloy steel nesoi, not	$4,593	25%
7205	granules and powders, of pig iron, spiegeleisen, i	$43,873	44%	**7211**	flat-rolled iron or nonalloy steel products, less	$4,592	5%
7219	flat-rolled stainless steel products, 600 MM (23.6)	$36,814	11%	**2619**	slag, dross (other than granulated slag), scalings	$4,315	52%
7226	flat-rolled alloy steel (other than stainless) pro	$34,406	25%	**7227**	bars and rods of alloy steel (other than stainless	$3,164	28%
7216	angles, shapes and sections of iron or nonalloy st	$29,545	14%	**7213**	bars and rods of iron or nonalloy steel, hot-rolle	$2,505	26%
7206	iron and nonalloy steel ingots or other primary	$25,652	62%	**2618**	granulated slag (slag sand) from iron or steel man	$908	43%
7217	wire of iron or nonalloy steel	$24,769	22%	**3103**	mineral or chemical fertilizers, phosphatic	$460	64%
7222	bars and rods of stainless steel nesoi; angles, sh	$22,059	26%	**2706**	mineral tars, including reconstituted tars	$249	34%
7224	alloy steel (other than stainless) in ingots, othe	$20,413	30%	**7201**	pig iron and spiegeleisen in pigs, blocks or other	$215	7%
7218	stainless steel ingots, other primary forms and	$17,412	36%	**2705**	coal gas, water gas, producer gas and similar gase	$5	57%
7207	semifinished products of iron or nonalloy steel	$15,392	70%				

Table A-4: U.S. Census Definitions of 7-digit NAICS

3311111 Iron and Steel Mills - Fully Integrated.
Establishments primarily engaged in smelting iron ore in a blast furnace to produce pig iron in molten or solid form; then converting pig iron into steel by removal of the carbon in the iron through combustion in a basic oxygen or electric furnace; then producing iron and steel basic shapes, such as plates, sheets, strips, and bars, and other related products, such as pipes, tubes, and wire.
3311112 Iron and Steel Mills - Partially Integrated With a Blast Furnace.
Establishments primarily engaged in smelting iron ore in a blast furnace to produce pig iron in molten or solid form; then converting pig iron into steel by removal of the carbon in the iron through combustion in a basic oxygen or electric furnace; then producing ingots and/or semifinished shapes, such as blooms, billets, and rods.
3311113 Iron and Steel Mills - Partially Integrated Without a Blast Furnace.
Establishments primarily engaged in converting pig iron, direct reduced iron, and/or scrap into steel by removal of the carbon in the iron through combustion in a basic oxygen or electric furnace; then producing iron and steel basic shapes, such as plates, sheets, strips, and bars, and other related products, such as pipes, tubes, and wire.
3311114 Iron and Steel Mills - Nonintegrated.
Establishments primarily engaged in producing iron and steel basic shapes, such as plates, sheets, strips, and bars, and other related products, such as pipes, tubes, and wire from purchased ingots and/or semifinished shapes, such as blooms, billets, and rods.

Figure F-1: U.S. Export/Import Shares by 3-digit NAICS codes for EITE industries

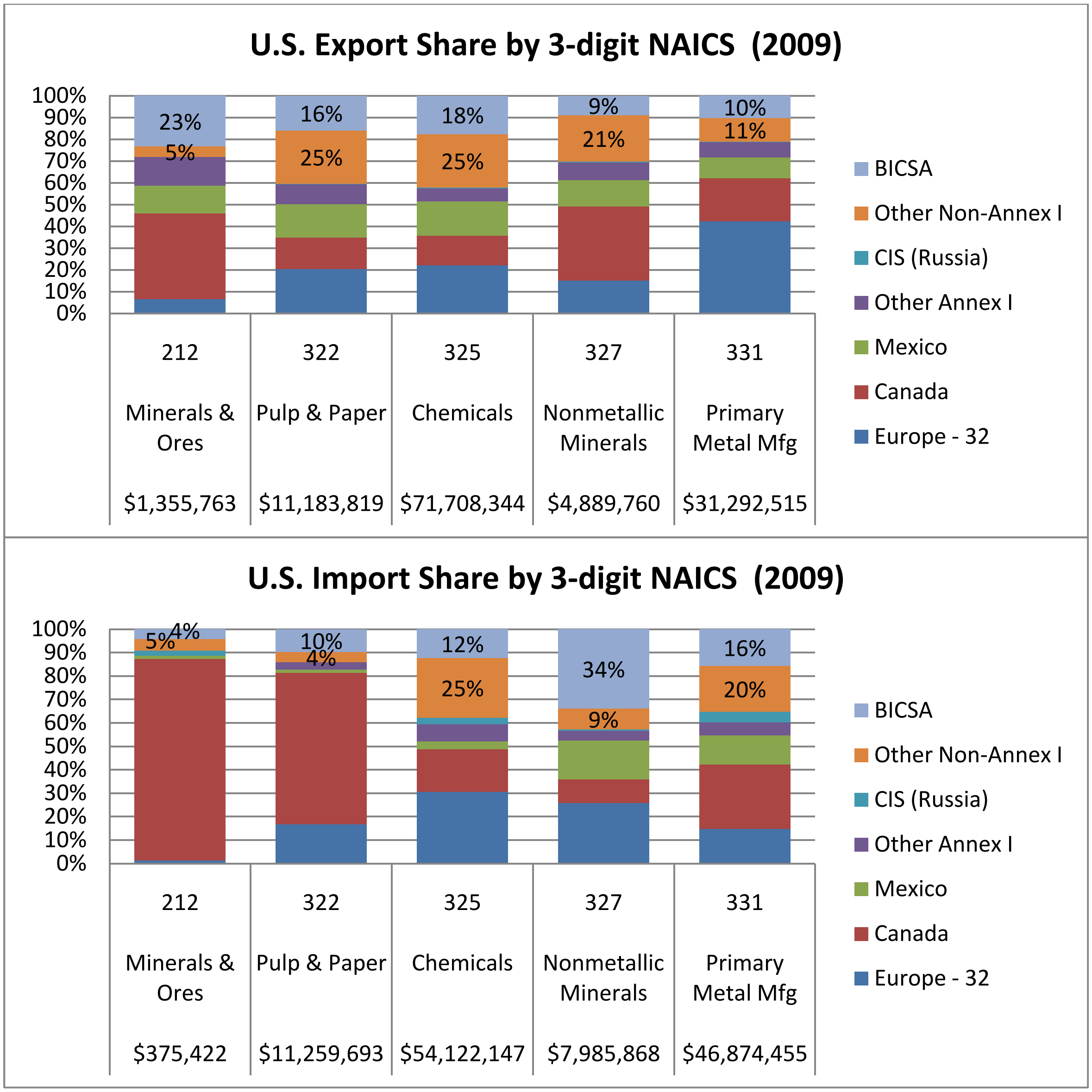


Figure F-2: 4-digit NAICS trade exposure by region

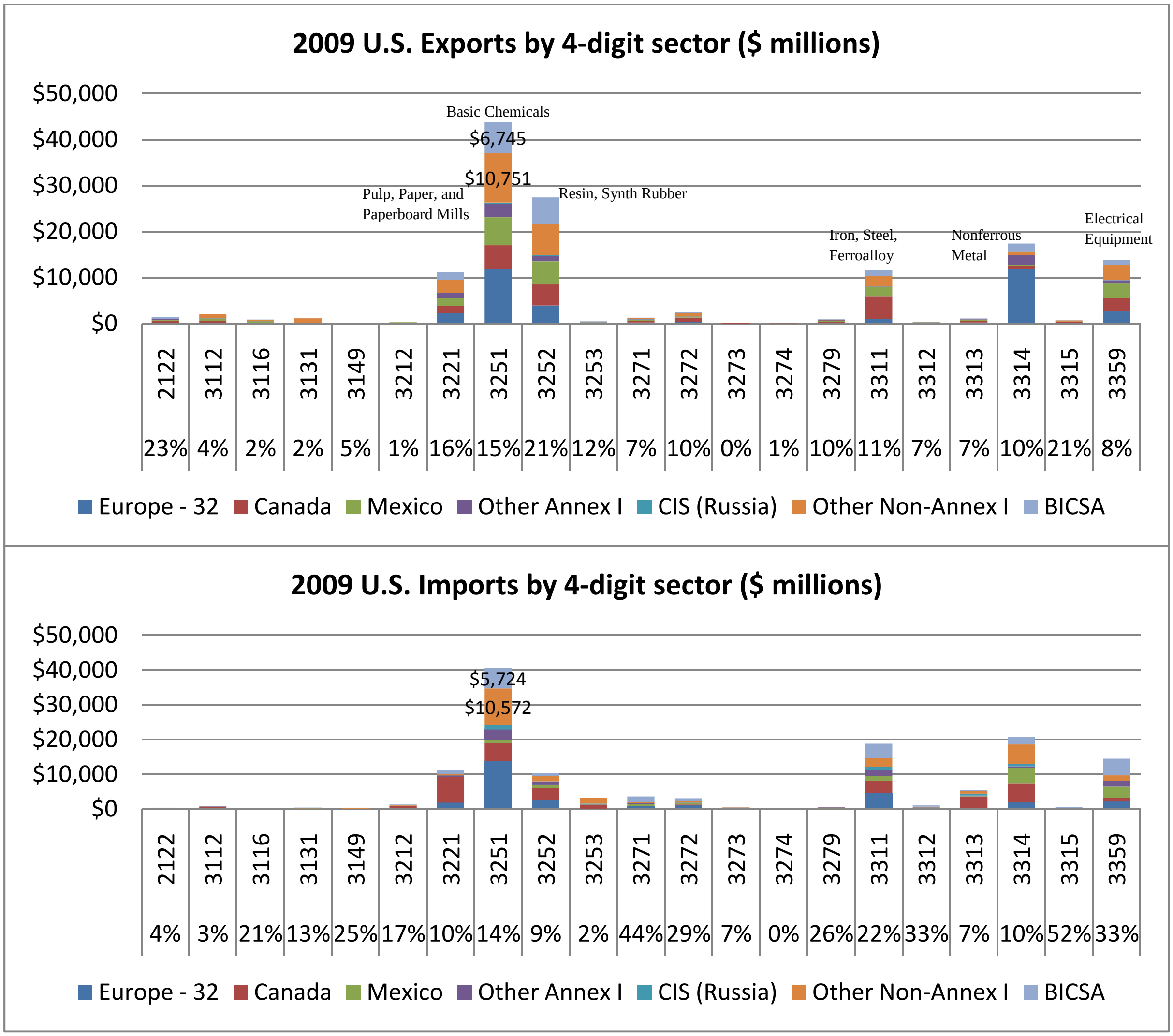


Figure F-3: 6-digit NAICS 3251 Basic Chemicals and 3252 (Resin, Synthetic Rubber, etc)

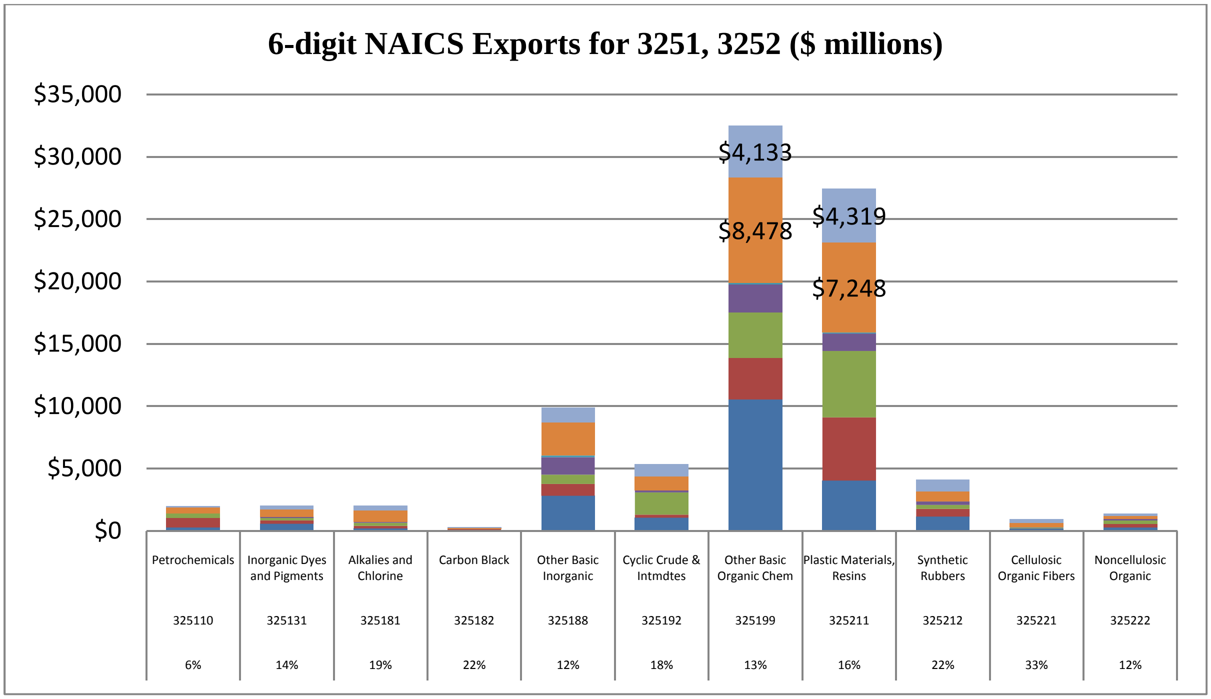
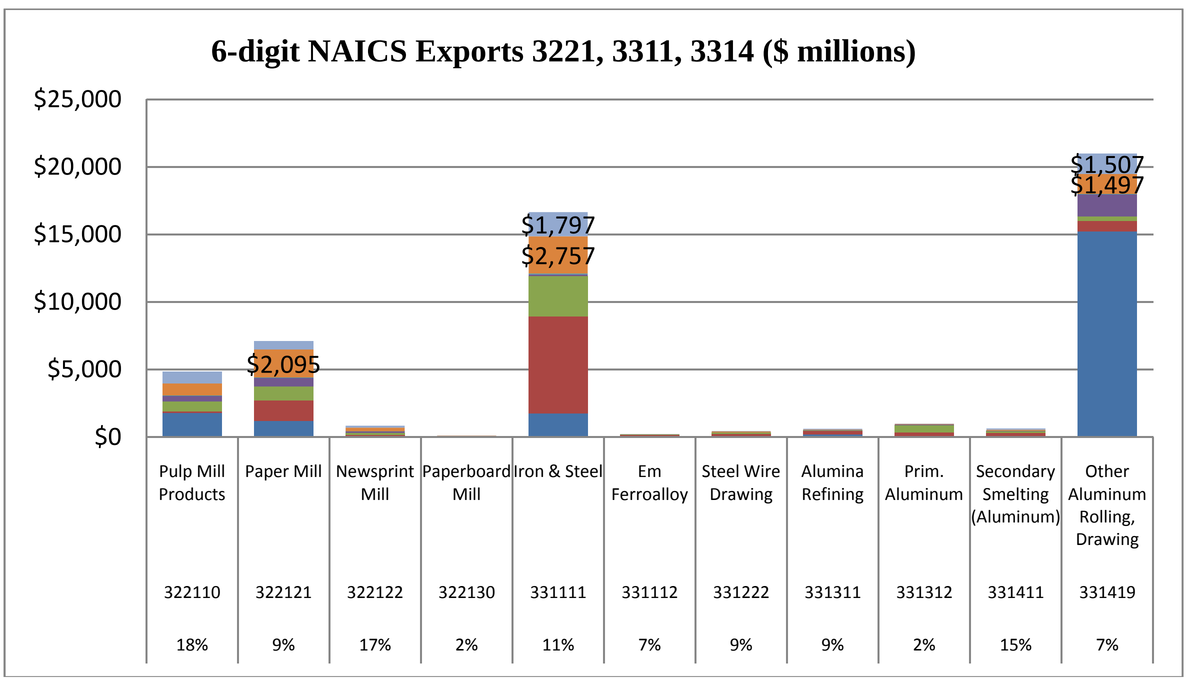


Figure F-4: 6-digit NAICS for 3221, 3311, and 3314



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