The Environmental Impacts of Trade Liberalization: A Quantitative Analysis for the United States Using TEAM

Jared Creason, Michael Fisher, Svetlana Semenova, and Susan F. Stone

A highly disaggregated emissions factor model is presented. The model generates changes in emissions and resource use by state and 6-digit NAICS sector. Removal of all U.S. import restrictions is examined. Results for agriculture show that composition effects explain highly varied regional patterns of emission changes. Scale effects are also important for expanding sectors. Quantitative assessments such as this may prove useful in conducting full environmental reviews of U.S. trade agreements consistent with Executive Order 13141 and the Free Trade Act of 2002.

Key Words: trade, emissions, input-output, residuals

Beginning with the North American Free Trade Agreement (NAFTA), continuing with Chile and, more recently, the Central American Free Trade Agreement (CAFTA), there has been growing concern in the United States over the possible environmental effects of increasing trade. This concern was explicitly addressed in Executive Order 13141 signed in 1999 and the 2002 Free Trade Act, both of which committed the United States to undertake formal environmental reviews for all future trade agreements. Since the Executive Order was signed, there have been six completed environmental reviews (for free trade agreements with Chile, Singapore, Jordan, Bahrain, Morocco, and Australia) and four interim reviews pending completion (for agreements with the Dominican Republic, CAFTA, Thailand, and Panama).

Most environmental analyses of large economy-wide events, such as trade liberalization, focus on global pollutants such as changes in carbon dioxide emissions or on policy concerns such as the sovereignty of domestic regulation and its consistency with internationally negotiated agreements.[1] The studies that have reported more sector-specific environmental effects, such as environmental effects of agricultural reform, still often have a national focus. For the most part, these studies have shown that, at the national level, trade does not have a detrimental effect on the environment. This paper attempts to go beyond existing studies by examining the regional effect of trade liberalization, both economic and environmental, to see if these results still hold. We do this by taking sector-specific economic changes from a trade liberalization scenario and applying them to a highly disaggregated environmental emissions model. This way we can determine whether, when examined at a more detailed level, the changes brought about by trade are indeed environmentally benign or whether, as some have suggested, environmental "hot spots" develop.

In 2000, the U.S. Environmental Protection Agency (EPA) commissioned Abt Associates to

Jared Creason and Susan F. Stone are economists at the National Center for Environmental Economics at the U.S. Environmental Protection Agency in Washington, D.C. Michael Fisher and Svetlana Semenova are economists at Abt Associates in Cambridge, Massachusetts.

This paper was presented at the International Trade and the Environment Workshop sponsored by the Northeastern Agricultural and Resource Economics Association and the U.S. Environmental Protection Agency, National Center for Environmental Economics, in Halifax, Nova Scotia, on June 23, 2004. The views expressed in this paper are the authors' and do not necessarily represent those of the U.S. Environmental Protection Agency. In addition, the paper has not been subjected to the Agency's peer and policy review process. No official Agency endorsement should be inferred.

[1] See, for example, Esty (2001) for a discussion of policy changes and Copeland and Taylor (2003) for an overview of economic impacts of trade on the environment.

Agricultural and Resource Economics Review 34/1 (April 2005) 90–103

build a trade and environmental assessment model, or TEAM (Abt Associates 2004). While the acronym refers to "trade" as the source of change, the model can be used to analyze environmental impacts from any economic change. TEAM follows the method pioneered by Ayres and Kneese (1969), Kneese, Ayres, and d'Arge (1970), and Leontief (1970). This literature takes the view that pollution emissions are a fundamental part of production processes, just like raw materials, and can thus be treated as an input in the input-output framework. This early work was an effort to bring economic analysis more in line with the fundamental law of conservation of mass by showing that pollution "externalities" were intrinsic to economic processes, not an exceptional case easily addressed through a partial equilibrium analysis of economic welfare (Ayres and Kneese 1969).

Background

The effects of trade on the environment have often been placed into three categories: scale, composition, and technique (Grossman and Krueger 1993). The scale effect predicts that an economic expansion due to an increase in trade will increase pollution because, all things equal, more output means more pollution. However, while trade may increase overall levels of pollution in a country, its effect is not uniform across all industries. Trade liberalization will likely cause some industries to expand and others to contract. Put simply, this compositional effect reduces pollution if the output from "dirty" industries falls while the output from "clean" industries expands. Finally, increases in output that are a result of technology (Grossman and Krueger's "technique" effects) are usually associated with decreases in pollution, as modern methods of production tend to be cleaner. However, technology can also have a negative impact on pollution. Capital-intensive industries are often associated with large pollution emissions, so that increases in capital-intensive industries will raise pollution levels. Which effect ultimately dominates is an empirical question.

Antweiler, Copeland, and Taylor (2001) investigate the relative contribution of each of these effects by modeling how openness to international trade affects sulfur dioxide (SO_2) concentrations. They conclude that freer trade is good for the environment. They find, overall, little change in SO_2 emissions from changes in the composition of national output. Estimates of trade-induced technology and scale effects imply a net reduction in pollution. The authors estimate that for every one percent increase in national income resulting from trade liberalization, there is a 0.8 to 0.9 percent reduction in concentrations of SO_2. They also find that income gains brought about by further trade or neutral technical progress tend to lower pollution, whereas income gains from capital accumulation raise pollution. They attribute this to the fact that capital accumulation tends to favor the production of pollution-intensive goods, whereas neutral technical progress does not.

Tsigas, Gray, and Hertel (2002) argue that there are four mechanisms linking trade policy and the environment: (i) international mobility of industry, (ii) the changing composition of national output, (iii) the intensity of production, and (iv) changes in consumer demand for environmental goods. Thus, they apply the same basic rationale as Antweiler, Copeland, and Taylor (2001), with the added dimension of consumer behavior. Tsigas, Gray, and Hertel (2002) examine the environmental effects of Western Hemisphere trade liberalization and find that liberalization leads to an increase in pollution. This comes principally from an increase in output of grains, chemicals, and metal manufacturing sectors. However, they find that increases in pollution abatement expenditures offset the increase in emissions, leading to an overall improvement in environmental quality.

Frankel and Rose (2003) use the gravity model to estimate the effects of openness on several environmental measures, including particulate matter, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), deforestation, a measure of energy depletion, and access to clean water.[2] The results show that for three air measures, namely SO_2, NO_2, and particulate matter, openness reduces pollution. Openness is shown to have a beneficial effect on energy depletion and clean water access, although of borderline significance. Outcomes for CO_2 are the exception, showing an increase in emissions associated with openness.

Cooper, Johansson, and Peters (2003) look specifically at trade liberalization in agricultural markets. They use a series of models to capture a multilateral trade liberalization scenario where all

[2] Energy depletion is a measure used by the World Bank's World Development Indicators and relies on unit resource rents multiplied by physical quantities of fossil fuel energy extraction. See http://www.worldbank.org/ data/wdi2001/pdfs/tab3_15.pdf.

tariffs and domestic support programs in the agriculture sector are removed. They then examine how these world market changes affect U.S. production and subsequently how these changes in production impact environmental outcomes. Specifically, they examine changes in nitrogen, phosphorous, and pesticide loss to water; sheet, rill, and wind related soil erosion; and manure nutrient production. Unlike other studies cited here, they then examine how these impacts play out geographically within the United States.

The results of Cooper, Johansson, and Peters (2003) show small changes in U.S. output as a result of worldwide agricultural trade liberalization. The exceptions are corn (positive) and dairy (negative), which experience somewhat larger changes. These small changes lead to small overall changes in environmental outcomes. However, the authors note that there are important regional variations in their results. For example, the northern plains and the Northeast experience an increase in sheet and rill erosion, while other parts of the country see a reduction.

The work presented here picks up on the Cooper, Johansson, and Peters (2003) paper by focusing on the geographic diversity of environmental outcomes across the United States. It also extends Frankel and Rose's (2003) work by examining outcomes on a variety of emission types. By combining a detailed sectoral analysis of economic effects of trade liberalization with a geographically diverse environmental outcomes model, we attempt to examine how robust the results obtained in previous studies are, or whether there is a flaw in deductive reasoning that would imply that the lack of significant national level effects would necessarily preclude regional problems. Much of this relies on TEAM (Abt 2004), which is discussed next.

TEAM

The main contribution of the TEAM framework is in its scope and scale. The environmental effects are based on economic output changes derived from data at the 6-digit NAICS (North American Industry Classification System) level, covering 1,175 sectors, for every U.S. county. These are calculated for over 900 chemicals covering four broad emission/resource use categories: water (use and direct and indirect discharges), air (point source, mobile source, and area source), agriculture (land use and chemical use), and hazardous waste. TEAM estimates the environmental impacts of any economic event, defined as the absolute total change in domestic production for each 6-digit NAICS sector.[3] TEAM is designed to process economic changes as either *primary* or *total impacts*. When expressed as *primary* impacts, the economic event is defined as changes in economic activity expected to occur in the affected sectors only, and does not account for the indirect economic effects. To account for the total impacts—in both economic and environmental terms—of an economic event expressed as *primary* impacts, it is therefore necessary to convert these impacts to *total impacts* that account for linkages between sectors either as purchasers or suppliers of intermediate inputs to production. TEAM converts the primary impacts to total impacts using information from the most recent U.S. input-output benchmark account tables (U.S. Department of Commerce 2002). The outputs in this paper are generated using a general equilibrium model, so the handling of primary impacts is not discussed further here.

TEAM uses the estimated changes in economic activity in 1997 dollars to calculate the change in emissions/resource use by specific pollutant/resource economic sector and location (county). TEAM calculates the change in emissions/resource use based on emission factors for each of four pollutant emission or resource use categories. Each emission factor is defined as the value of baseline emissions/resource use—for a given pollutant/resource, and entity (or sector and county)—divided by the value of baseline economic activity measured as value of shipments in 1997 dollars. Emission coefficients are of the form

$$E_{ijk} = a_{ijk} \times N_{jk} ,$$

where $a_{i,j,k}$ is the quantity (generally mass) of pollutant i per dollar of commodity output j in region k; $N_{j,k}$ is the change in dollars of commodity j output in region k due to a policy change; and $E_{i,j,k}$ is the change in emission of pollutant i due to the impact of the policy change on the output of commodity j in region k.

[3] The event, however, may be specified in an economic sector framework other than NAICS, for a base year that differs from the TEAM 1997 base year, and as primary economic impacts to specific sectors rather than total impacts distributed among all linked sectors of the economy.

The TEAM framework uses the concept of the direct requirements coefficient as the basis for its emissions coefficient or emission factors. TEAM's emission factors differ from the more common concept of emission factors (based on environmental engineering analyses) by being defined in relation to the economic value of output—that is, quantity of pollutant emission or resource use per dollar value of output—instead of in relation to a physical unit of operation or production. This implies that the change in value of output is a real change and not one based solely on changes in price.[4]

The TEAM emission factors are derived from facility-level data when available. The data were collected from a variety of sources, including the EPA's National Emissions Inventory and National Toxics Inventory, Permit Compliance System, and Toxic Release Inventory; the U.S. Geological Survey's Aggregate Water-Use Data System; the U.S. Department of Agriculture's (USDA) Agricultural Chemicals Usage and Agricultural Census documents; and certain private sources of economic data, in particular, Dun & Bradstreet databases (Abt Associates 2004).

For air emissions and water discharges, the TEAM entity is based on *true* facilities, as identified in the National Emissions Inventory, Permit Compliance System, and/or Toxic Release Inventory facility data sets. Although TEAM is configured to analyze all emissions/resource use categories on the basis of true facility data, data are not currently available and/or present in TEAM to support true facility analysis for all the emission/resource use categories. TEAM analyzes the other categories (hazardous waste, agricultural chemicals, land use, and water use) on the basis of so-called *pseudo* facilities, which are defined based on the total value of economic activity and associated emissions/resource use in a given 6-digit NAICS sector by county (Abt Associates 2004).

TEAM accepts changes at the national level in economic activity by sector as shocks. These are distributed over all regions in proportion to the baseline distribution of economic activity. However, each TEAM entity's emission factors remain fixed at the baseline emission factor value (1997 for most pollutants and resources). This means that the change in emissions/resource use for each TEAM entity is a function of the same percentage change in national level economic activity for that entity's sector. For example, if national output of broad woven textile manufacturing declined 10 percent as a result of an economic shock, each county containing a broad woven textile mill would experience a reduction in output of 10 percent. Each facility's unique emissions coefficient structure would then be applied to the 10 percent reduction to determine the total change in environmental factors.

TEAM generates estimates of the change in emissions/resource use for all TEAM entities, where entities may be defined as *true* facilities (for air emissions and water discharges) or county-level *pseudo* facilities. For air and water pollution categories, in addition to calculating the change in emission/discharge for individual pollutants, TEAM calculates and reports *toxicity-normalized* aggregates for specific pollutant subsets in these pollutant categories. The toxicity-normalized estimates are calculated by use of toxic-weighting factors currently incorporated by the EPA in the "risk screening environmental indicators" model.[5]

TEAM organizes data for reporting in a wide range of formats, including aggregations by individual pollutant/resource category; toxicity-normalized emissions/resource use; by state or county; by industry; and various combinations of the above reporting formats. Changes in emissions/resource use may be reported both as absolute values and as changes relative to baseline values.

Estimates of the Economic Effects of Removal of Significant Import Restraints

This paper takes as its starting point the economic changes reported in the U.S. International Trade Commission's (ITC) 2002 report, *The Economic Effects of Significant U.S. Import Restraints* (ITC 2002). This report analyzes the effects of removing import restraints on U.S. manufacturing, agriculture, and services sectors. The restraints include tariffs, tariff-rate quotas, peak tariffs (that is, those with trade-weighted average ad valorem tariffs greater than 5 percent), and other significant restraints, including restriction on some services and cabotage.

[4] Thus, prices are assumed to be fixed, or experiencing very small changes.

[5] More information on this model can be found at http://www.epa.gov/opptintr/rsei/whats_rsei.html.

Table 1. Percent Changes in Selected Sectors

Sector	Employment	Output	Imports	Exports
Broadwoven fabric mills	-10.1	-17.2	26.4	-17.1
Yarn and thread mills	-10.5	-10.5	-3.8	-9.7
Luggage, etc.	-29.6	-29.7	21.9	-25.9
Knit fabric mills	-26.1	-26.1	5.6	-24.9
Butter	-1.6	-1.6	53.8	-0.6
Cane and beet sugar	-9.2	-9.3	107.5	-7.2
Cotton	-7.5	-7.6	-4.8	-2.9
Ceramic wall and floor tile	-11.1	-11.2	5.9	-10.5
Construction	0.1	0.0	-0.6	1.0
Durable manufactures	0.4	0.3	-0.4	0.5
Nondurable manufactures	0.2	0.1	-0.6	0.2
Wholesale and retail trade	0.1	0.0	0.0	0.3

Source: ITC (2002), Table 2-3.

The ITC uses a general equilibrium model, reporting outcomes for 73 sectors, based on an aggregation of a 497-sector U.S. model database.[6] The economic outcomes, or changes in output, for each of the 73 sectors are then disaggregated using a concordance to match the NAICS framework on which TEAM is based. Table 1 provides some summary statistics from the ITC report.

Generally speaking, Table 1 shows that the textile sectors are hardest hit in terms of output, employment, and exports from a removal of import restraints. In terms of employment, luggage falls about 30 percent, knit fabric mills drop 26 percent, and fabric, yarn, and thread mills decline by over 10 percent. The largest increase in imports affects the domestic sugar industry.

Environmental Effects

Overall, national average emission estimates fall as a result of the trade liberalization modeled. As shown in Table 2, on average, U.S. county air emissions from mobile sources and point sources decline, with large variation in outcomes. Values range from a decline of 97 percent to an increase of 13 to 15 percent.[7]

Similarly, agricultural land use changes range from a 5 percent increase to a 12 percent decline, with the average change of 0.8 percent. However, agricultural chemical use more generally falls, as liberalization forces crop substitution away from crops requiring high chemical inputs (for example, from cotton to oilseeds). Overall, the table illustrates the fact that while changes in these emissions/resource uses are relatively small, the variation is wide. This raises the questions, How do these results hold up in the specifics? To what extent does any region/sector/pollutant/resource fare worse than their national average? Is the variation enough to be of concern to policymakers?

Table 3 shows the top three sectors nationwide with the largest change in pollution emissions, by type of pollutant. Compositional effects within the agriculture sector are reflected in the increases in corn, wheat, nursery, and tree products, and the decrease in cotton. Most pollutants/resources showing large absolute changes are in sectors experiencing large changes due to trade liberalization, that is, in the textiles or agriculture sectors.

Tables 4a–4d show the top five sectors for each of the emission/resource use categories. The sectors are ranked by total change rather than percentage change. The tables allow a comparison of environmental impacts across sectors and states and illustrate some of the key data and methods underlying TEAM. One thing to keep in mind when looking at the sector-specific results is that we applied a concordance that assigns the same output change for all six-digit NAICS sectors within each sector as defined by the U.S. International Trade Commission. This limitation is inherent when two models are linked using a concordance process. Thus, to the extent that the

[6] Details of the U.S. International Trade Commission model can be found in Appendix D of the report (ITC 2002).

[7] Area source emissions are not reported. This discussion is based on county-level data, and area emissions are available only at the state level.

Table 2. Percent Changes in Emission Categories—United States

Emission Type	Mean	Standard Deviation	Minimum	Maximum
Mobile source air	-0.400	3.823	-96.80	15.00
Point source air	-0.169	2.566	-96.81	12.76
Agricultural chemical	-1.144	1.845	-7.42	0.69
Agricultural land use	0.803	2.750	-12.09	5.10
Water use	-0.334	3.190	-96.81	12.76
Indirect water discharge	0.005	1.436	-19.95	5.98
Direct water discharge	-0.237	1.895	-19.95	2.79
Hazardous waste	0.075	1.395	-96.80	15.00

Source: Authors' estimates using TEAM.

Table 3. Top Three Sectors in Largest Absolute Change in Pollution Emissions (values in parentheses)

Pollution Emissions	1	2	3
Water use (millions of gallons)	Cotton (-161,979)	Nursery and tree products (15,637)	Sugar beets (-83,585)
Land use (acres)	Nursery and tree products (3,325,485)	Cotton farming (-952,731)	Corn farming (488,037)
Agricultural chemicals (pounds)	Corn farming (2,433,076)	Cotton farming (-1,283,034)	Wheat farming (863,614)
Hazardous waste (pounds)	Photographic film, paper (329,698,441)	Petroleum refineries (269,987,738)	Noncellulosic organic fiber manufacturing (-262,444,998)
Direct water discharges (tons)	Other pressed and blown glass (42,878,815)	Beet sugar manufacturing (-11,205,362)	Cellulosic organic fiber manufacturing (-5,566,056)
Indirect water discharges (tons)	Pulp mills (229,274)	Plastic material and resin manufacturing (-116,207)	Leather and hide tanning (-110,918)
Point source air (tons)	Iron and Steel[a] (12,372,106)	Noncellulosic organic fiber manufacturing (-11,146,697)	Cellulosic organic fiber manufacturing (-10,281,933)
Mobile source air (tons)	Cotton farming (-5,110,599)	Couriers (3,914,009)	Nursery and tree products (3,024,089)

Source: Authors' estimates using TEAM.

[a] The "iron and steel" category is actually an artifact of the concordance. The ITC report describes a general expansion in the durable goods manufacturing sector as a result of reduction in significant import restraints. Iron and steel are not reported as a separate sector in the ITC report and are included with durable goods. Thus, this sector shows an increase, albeit small, in output in the TEAM modeling run.

change in sugar cane production, for example, differs from changes in overall sugar output, the economic changes applied to sugar cane may be over- or understated. Similarly, TEAM applies the same percentage change in economic activity across all producers in the United States. Thus, variation in regional output changes will not be captured. To the extent that there are known differences in production effects within a broader sector classification or region, follow-up analysis of individual results is warranted.

The top portion of Table 4a shows the increases and decreases with respect to land use. This category of resource use is defined only for agriculture sectors and relies on USDA estimates. Because land use is directly related to production in the model, this table is unique in that it reflects production estimates. Note that there are only four agriculture sectors declining in this scenario. Most of the impacts occur within a relatively small number of states.

The bottom portion of Table 4a shows changes in agricultural chemical use. The largest change in agricultural chemical use is in corn farming, even

Table 4a. Emission Changes from Removing Import Restraints (land use and agricultural chemicals)

Emission Type	Land Use (in acres)		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Nursery and tree production	3,325,485	5.10	PA (44), CA (30)
Corn farming	488,038	0.70	IA (20), IL (19), NE (15), MN (11), IN (10)
Soy farming	392,251	0.60	IA (19), IL (19), MN (12), IN (10)
Wheat farming	299,338	0.51	ND (23), KS (20), MT (12), OK (10)
Oilseed (except soy) farming	92,187	0.60	IA (17), IL (15), ND (14)
Top five declining sectors (ranked by total change):			
Cotton farming	-952,731	-7.42	TX (43), GA (11)
Sugar beet farming	-174,436	-12.09	MN (32), ND (17), ID (14), MI (12)
Sugar cane farming	-106,586	-12.09	FL (50), LA (47), HI (3)
Tobacco farming	-1,411	-0.17	NC (39), KY (31), TN (7)
(end of declining sectors)			
Emission Type	**Agricultural Chemicals (pounds applied)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Corn farming	2,433,076	0.70	MI (65), IL (9)
Wheat farming	863,614	0.51	OH (52), ND (20), OK (8)
Soybean farming	821,691	0.60	NC (69), OH (5)
Potato farming	84,144	0.53	ND (45), OR (28), ID (10)
Other vegetable farming	18,600	0.53	FL (46), CA (20), MI (17)
Top five declining sectors (ranked by total change):			
Cotton farming	-1,283,035	-7.42	SC (21), TN (20), MS (16), LA (13)
Dairy cattle and milk production	-7	-0.11	TX (16), NE (15), OK (12), WA, PA (10)
(end of declining sectors)			

Source: Authors' estimates using TEAM.

[a] County totals within each state. States shown are where significant results are stated.

Note: The fact that sugar cane and sugar beets face the same percentage decline in land use is an artifact of the ITC's sector scheme.

though its land use increase (488,038 acres) is much smaller than that of nursery and tree production (3,325,485 acres), the leading crop in land use changes. This is because of the higher chemical application rates in corn farming. Also, there are differences in the geographic distribution of impacts. Land use in corn farming expands in Iowa, Illinois, Nebraska, Minnesota, and Indiana; these states are among the leading states in baseline corn production. However, agricultural chemical use expands most in Michigan. This is derived from the underlying USDA data showing high levels of potash fertilizer use in that state. Similarly, USDA data indicates high levels of fertilizer use, especially potash, in what would probably be considered "marginal" producing areas for specific crops, such as wheat in Ohio and soybeans in North Carolina.

The top portion of Table 4b reports changes in water use, which is again dominated by agriculture sectors. The emphasis here is on irrigated crops. For example, corn farming is the fourth largest increasing sector, with the top states being Nebraska, Colorado, Kansas, and Texas, where corn is an irrigated crop. Similarly, the largest reduction in water use in the sugar cane sector is

Table 4b. Emission Changes from Removing Import Restraints (water use and hazardous waste)

Emission Type	**Water Use (in million gallons)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Nursery and tree production	105,637	5.10	CA (58)
Finfish farming and fish hatcheries	42,268	12.76	ID (41), MS (29), AR (16)
Oilseed (ex soy) farming	35,195	0.60	MT (19), CO (16), ID (12), WY (11)
Corn farming	28,125	0.70	NE (42), CO, KS (15), TX (11)
Floriculture production	26,193	5.05	CO, CA (20), TX (14), WY (13), ID (12), FL (11)
Top five declining sectors (ranked by total change):			
Cotton farming	-161,979	-7.42	CA (45), TX (32)
Sugar beet farming	-83,586	-12.09	ID (33), CA (21), WY (15), MT (11)
Sugar cane farming	-22,335	-12.09	FL (88), TX (10), LA (2)
Broadwoven fabric mills	-4,353	-9.92	NC (23), GA (18), SC (16), TN (15), AL (14), VA (11)
Women, girls outerwear mfg.	-2,345	-14.16	MS (23), CA (16), AL, WV (10)
Emission Type	**Hazardous Waste (pounds)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Photographic film and chemical mfg.	329,698,441	0.64	NY (99)
Petroleum refineries	269,987,739	0.11	PA (26), TX (24), CA, LA (14)
Photographic and photocopy mfg.	209,393,595	0.62	NY (99)
Paperboard mills	135,627,465	0.29	LA (99)
Semiconductor and related device mfg.	104,438,049	0.22	AZ (34), NM (27), CA (18)
Top five declining sectors (ranked by total change):			
Noncellulosic organic fiber mfg.	-262,448,000	-6.64	VA (61), MA (23)
All other basic organic chemical mfg.	-200,781,365	-0.23	TX (41), LA (24), WV (14)
All other basic inorganic chemical mfg.	-189,202,646	-0.18	TN (67), TX (13)
Pesticide and other agricultural chemical mfg.	-154,538,016	-0.83	WV (86)
Plastics material and resin mfg.	-80,744,047	-0.26	TX (31), PA (20), AL, LA (15), NJ (10)

Source: Authors' estimates using TEAM.

[a] County totals within each state. States shown are where significant results are stated.

in Florida, because it receives pumped (and measured) water transfers from the Everglades, instead of in Louisiana, which does not rely to the same extent on irrigation.

The bottom portion of Table 4b shows changes in hazardous waste. The list is made up mostly of known sources of hazardous waste such as photographic film, semiconductors, chemicals, plastics,

Table 4c. Emission Changes from Removing Import Restraints (direct and indirect water discharge)

Emission Type	Direct Water Discharge (tons)		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Other pressed, blown glass mfg.	43,878,815	0.49	KY (100)
Pulp mills	5,403,994	0.62	NC (36), FL (18), AR (12)
Paper (except newsprint mills)	2,264,668	0.31	AL (53), WI (11)
Iron and steel mills	1,121,948	0.39	WV (46), IN (18), OH (15)
Phosphatic fertilizer mfg.	779,052	0.51	LA (81), FL (16)
Top five declining sectors (ranked by total change):			
Beet sugar mfg.	-11,205,363	-12.32	MN (99)
Cellulosic organic fiber mfg.	-5,566,057	-7.94	AL (93)
Broadwoven fabric finishing mills	-1,112,206	-9.29	SC (39), NC (28), AL (14), RI (11)
Noncellulosic organic fiber mfg.	-1,074,641	-6.64	LA (64), AL, VA (15)
Other hosiery and sock mills	-727,604	-13.02	MS (97)
Emission Type	**Indirect Water Discharge (tons)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Pulp mills	229,274	0.62	OR (24), TX (20), FL (19), MN (16), MI (11)
Electronic capacitor mfg.	45,219	1.00	AL (78), SC (19)
Electroplating, plating, polishing	34,329	0.34	IL (19), OH (16), WI (15), MN (12)
Medicinal and botanical mfg.	28,273	0.23	NY (47), NJ (43)
Rolled steel shape mfg.	20,641	0.99	MI (72), PA (22)
Top five declining sectors (ranked by total change):			
Plastics material and resin mfg.	116,207	0.26	TX (48), FL (19), MN (16), MI (11), PA (10)
Leather and hide tanning and finishing	110,919	12.05	MN (25), MO (21), TX (14), WI (13), ME (10)
Broadwoven fabric finishing mills	62,807	9.29	SC (43), NC (26), RI (19)
Other textile and fabric finishing	56,994	7.41	SC (69), NC (20)
Broadwoven fabric mills	45,733	-9.92	GA (44), VA (24), AL (12), SC (10)

Source: Authors' estimates using TEAM.

[a] County totals within each state. States shown are where significant results are stated.

and resins. Changes in emissions of hazardous waste can most likely be attributed to scale effects, as small overall sector increases translate into large changes in hazardous waste emissions.

Table 4c shows changes in direct water discharges (top panel) and indirect water discharges (bottom panel). Direct water dischargers discharge waste directly to rivers and streams, while indirect dischargers discharge waste to a treatment facility. These categories are regulated by the EPA, and thus the actual outcomes of the reported changes are subject to permit limits. For example, the top increasing sector for direct water discharge is "other pressed and blown glass," and all of the emissions change is located in the state of Kentucky. Not shown in the table is the estimate that the increase is mostly in total suspended solids. Any actual discharge of total suspended solids from glass plants in Kentucky is subject to the EPA permit process. Thus, the actual total change

Table 4d. Emission Changes from Removing Import Restraints (point and mobile source air)

Emission Type	**Point Source Air (tons)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Iron and steel	12,373,107	0.39	OH (46), PA (19), IN (14)
Coal-generated electric power	9,215,411	0.03	OH (18), IN (12), PA (11), KY (10)
Primary aluminum production	6,160,823	0.58	WA (24), TX (19), MO (12), OH (11)
Crude petroleum and natural gas	5,710,545	0.53	TX (24), LA (15), ND (11), CO (10)
Paper (except newsprint) mills	4,822,865	0.31	WI (19), AL (15), AR (12), OH (10)
Top five declining sectors (ranked by total change):			
Noncellulosic organic fiber mfg.	-11,146,297	-6.64	TN (48), NC (17), SC (13), DE (9)
Cellulosic organic fiber mfg.	-10,281,934	-7.94	AL (28), TN (23), VA (22), SC (17), NJ (10)
Sugar cane mills	-9,138,140	-11.90	FL (68), HI (17), LA (8)
Beet sugar mfg.	-4,944,098	-12.32	MN (64), ID (11)
Broadwoven fabric finishing mills	-4,721,911	-9.29	SC (38), NC (37)
Emission Type	**Mobile Source Air (tons)**		
Sector	Total Change	Percent Change	State (% of total)[a]
Top five increasing sectors (ranked by total change):			
Couriers	3,914,010	0.188	CA (24), NY (10), PA (10)
Nursery and tree production	3,024,089	5.10	CA (21), VA (16)
General freight trucking	2,253,705	0.07	AL, OH, WI, TN, MI (11), FL, IN, PA, AR (9)
Animal (except poultry) slaughter	1,627,731	0.21	CA (22), TX (14), OH (11)
Commercial air, rail, and water transportation	1,162,793	0.37	CA (33), IL (19), FL (9), TX (9)
Top five declining sectors (ranked by total change):			
Cotton farming	-5,110,600	-7.42	MS (28), AL (16), TX (14), LA (11), GA (9)
Sugar beet farming	-2,612,024	-12.09	ID (19), ND, MN, WA (13), MT (12), MI (10)
Broadwoven fabric finishing mills	-1,873,938	-9.29	SC (32), NC (28), GA (13)
Sugar cane farming	-1,750,354	-12.09	LA (69), FL (28), TX (3)
Broadwoven fabric mills	-1,683,849	-9.92	VA (25), SC (25), GA (16), NC (15)

Source: Authors' estimates using TEAM.

[a] County totals within each state. States shown are where significant results are stated.

will likely be somewhat less than shown in the table.

It is possible to see differences between production changes and emission changes. For example, Table 4a shows that 32 percent of the overall reduction in sugar beet production is in Minnesota, but Table 4c shows that 99 percent of the reduction in direct water discharges from beet sugar manufacturing is also in that state.

Table 4d is the air emissions table, including point source (top panel) and mobile source (bottom panel) changes. The iron and steel expansion is an artifact of the model, owing to the aggregation scheme used by the U.S. International Trade Commission that includes iron and steel in durable goods manufacturing. The iron and steel industry is protected by import restrictions, and lowering those import restrictions unilaterally should most likely cause a decline in output and emissions, not an increase.

Table 5: Top Five States in Largest Absolute Change in Pollution Emissions

Rank	Water Use	Land Use	Agricultural Chemicals	Hazardous Waste	Direct Water Discharge	Indirect Water Discharge	Mobile SourceAir	Point Source Air
1	TX ⇓	PA ⇑	MI ⇑	NY ⇑	KY ⇑	SC ⇓	LA ⇓	OH ⇑
2	CO ⇑	CA ⇑	OH ⇑	PA ⇑	MN ⇓	NC ⇓	SC ⇓	NC ⇓
3	CA ⇑	TX ⇓	NC ⇑	WV ⇓	AL ⇓	OR ⇑	NC ⇓	FL ⇓
4	ID ⇑	IA ⇑	SC ⇓	TN ⇓	FL ⇑	TX ⇓	MS ⇓	TN ⇓
5	NE ⇑	IL ⇑	IL ⇑	CA ⇑	MI ⇑	MI ⇑	AL ⇓	PA ⇑

Source: Authors' estimates using TEAM.

While overall and on average point source air emissions decrease (Table 2), the Midwest and Northeast see increased emissions generally. These emissions are also subject to EPA regulations. For example, the top panel of Table 4d shows that coal-generated electric power point source air emissions, especially in Ohio, Indiana, Pennsylvania, and Kentucky, are increasing. It is doubtful that all of this expansion could occur under permit limits.

The bottom panel of Table 4d shows changes in mobile source emissions. There is no household sector in TEAM so we focus on commercial vehicular traffic. Couriers are the leading increasing sector, mostly in major metropolitan states like New York and California. In the agriculture sector, nursery and tree production expands, while cotton, sugar beets, and sugar cane decline.[8]

Table 5 presents the states experiencing the largest changes in emissions/resource use due to the trade liberalization. The arrows indicate the direction of change (increase or decrease). Mobile source air emissions is the only pollutant category where the top five absolute-value changes are all declines. Table 4d shows that this is because of the combined effects of the contraction in cotton farming and textiles.

Returning to Table 5, water use, land use, and agricultural chemicals all show an *increase* in use in four of the top five states, the exception being Texas for water use and land use and South Carolina for agricultural chemicals. This reflects the changes in agricultural output as a result of the liberalization. Indirect water discharges *decline* in three of the top five states, the exceptions being Oregon and Michigan. The increase in Oregon is a result of the increase in output in pulp mills. Pulp mills and rolled steel are driving the results in Michigan. The decline in South Carolina for indirect water discharges stems from a decline in the textile finishing industry. Finally, the increase in point source air emissions in Ohio and Pennsylvania stems from an increase in the iron and steel sector. As noted above, this is an anomaly due to the way the data is reported.

The maps in Figures 1 through 5 illustrate several of the points made above, by focusing on impacts on the sugar sector. As shown in Table 1, the removal of tariffs causes a large reduction in domestically produced sugar. TEAM takes these changes and separates impacts on beet sugar and cane sugar, applying the same percentage decline in output to both segments. Figure 1 shows that Minnesota, as the leading producer of sugar beets, faces the largest declines. Figure 2 shows that, furthermore, the changes are confined to a small region of the state, the Red River valley. Similarly, in other states, the regions affected are contiguous blocks of counties. Generalizing impacts at the state level would overlook a great deal of important information, such as local impacts on water and employment.

Figure 3 and Figure 4 show similar detail for changes in sugar cane production. Texas, Louisiana, Florida, and Hawaii (not shown) are top producers. Yet the regions within each state that actually bear the impacts are much smaller. For example, sugar production in Texas is confined to just three counties in the southernmost tip.

Figure 5 shows the changes in water use in sugar cane production. Comparing Figure 5 to Figure 3, we see that Louisiana and Florida have the largest change in production, yet Louisiana has the smallest absolute change in water use.

[8] As discussed in the text, the results for the two TEAM sectors, sugar beet and sugar cane, are derived from changes in the ITC's single overall "sugar" sector. Our analysis applied the same output change to both sectors, across all producing regions. To the extent that changes in beet and cane production are not proportional, these results could be misleading. This illustrates the need for additional sector-specific analysis to inform concordances and interpret TEAM output.

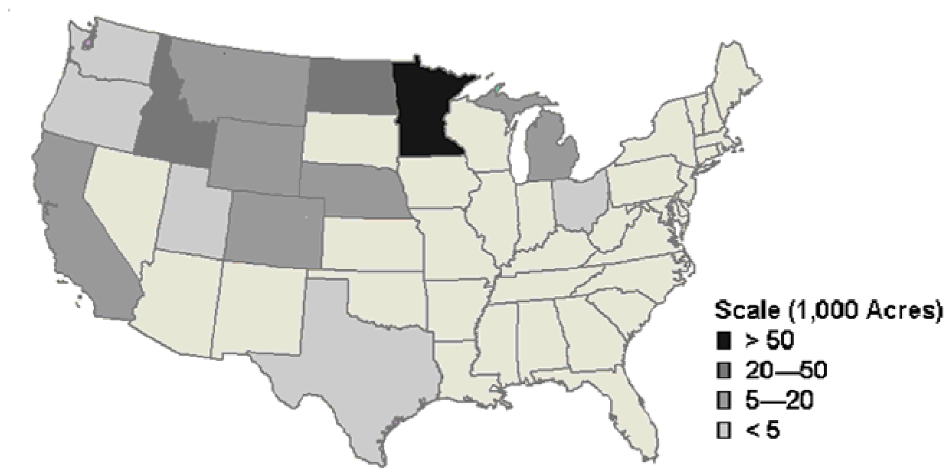

Figure 1. Reductions in Sugar Beet Farming by State

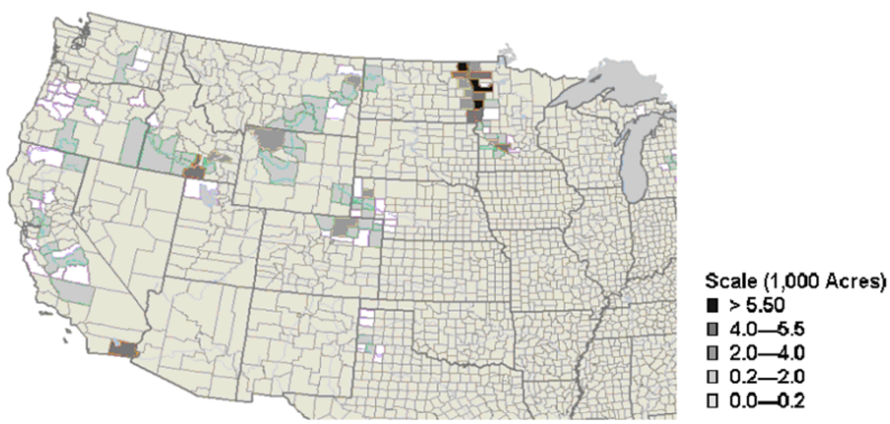

Figure 2. Reductions in Sugar Beet Farming by County

Most of the cane production in Louisiana is in the Mississippi River delta and is not irrigated, whereas the sugar cane in Florida and Texas is irrigated, explaining the small changes in water use in Louisiana.

Summary and Conclusions

This paper has examined the environmental impacts of economic changes given by the U.S. International Trade Commission's analysis of the economic impact of significant import restraints (ITC 2002). At a national level our results are consistent with those of researchers such as Grossman and Krueger (1993) and Antweiler, Copeland, and Taylor (2001), in that there is little change in emissions. Composition, technique, and scale effects imply a net reduction in pollution.

We then use EPA and other data to "drill down" into sectoral and regional estimates of pollution changes. The results have such variability as to question seriously the value of estimates made at the national level. Many of the southern U.S. states seem to be getting emission/resource reductions from reductions in textiles, cotton, and

Figure 3. Reductions in Sugar Cane Farming by State

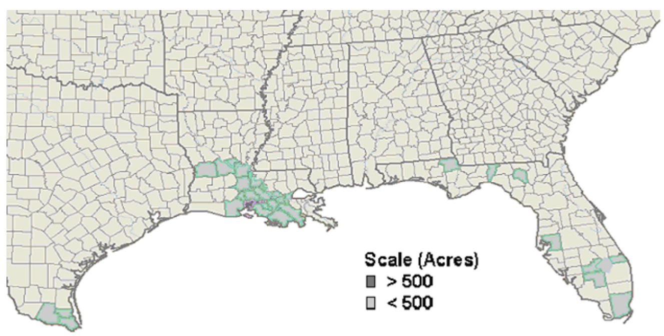

Figure 4. Reductions in Sugar Cane Farming by County

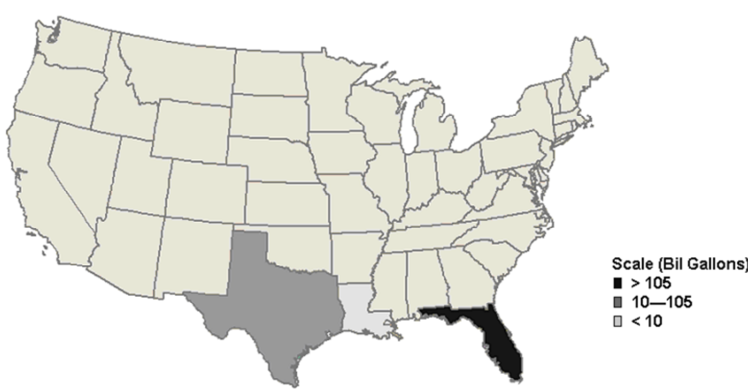

Figure 5. Reductions in Water Use in Sugar Cane Farming by State

sugar, while northeastern states and the Midwest are facing emissions growth due to expansions in durable goods manufacturing.

What emerges is a complex story that goes beyond the broad macro results usually presented in trade and environment empirical work. Some sectors experience large declines in air emissions, water use, and hazardous waste, but other sectors see relatively large increases in these same pollutants/resources.

Overall, the U.S. economy expands as a result of the trade liberalization, and overall emissions decline. If scale effects had dominated, we would have expected to see an overall increase in emissions as a result of trade liberalization, which we did not. Given the nature of the modeling exercise, technique effects cannot be reliably accounted for; therefore, it would appear that the composition effects dominate here.

The compositional effects can be seen by examining both the larger changes in the agriculture sector output and the corresponding fall in land and chemical use as well as movement within the sector (such as declining cotton and dairy outputs and emissions and increases in tree and nursery production). The effect can be seen throughout the textile sector as well. Textile industries tend to have large water discharges. Both direct and indirect water discharge show large declines due to decreases in output from these industries. The decline of these so-called "dirty" industries in the composition of the nation's output most likely explains the overall improvement in environmental outcomes.

References

Abt Associates. 2004. "Trade and Environment Assessment Model: Model Description." Prepared for the National Center for Environmental Economics, U.S. Environmental Protection Agency, Contract 68-W-02-040 (April).

Antweiler, W., B.R. Copeland, and M.S. Taylor. 2001. "Is Free Trade Good for the Environment?" *American Economic Review* 91(4): 877–908.

Ayres, R.U., and A.V. Kneese. 1969. "Production, Consumption and Externalities." *American Economic Review* 59(3): 282–297.

Cooper, J., R. Johansson, and M. Peters. 2003. "Some Domestic Environmental Effects of U.S. Agricultural Adjustments Under Liberalized Trade: A Preliminary Analysis." Paper presented at the conference entitled "Agricultural Policy Reform and the WTO: Where Are We Headed?," Capri, Italy (June).

Copeland, B.R., and M.S. Taylor. 2003. "Trade, Growth and the Environment." NBER Working Paper No. 9823, National Bureau of Economic Research, Cambridge, MA.

Esty, D.C. 2001. "Bridging the Trade-Environment Divide." *Journal of Economic Perspective* 15(3): 113–130.

Frankel, J., and A.K. Rose. 2003. "Is Trade Good or Bad for the Environment? Sorting Out the Causality." Harvard University Faculty Research Working Paper No. RWP03-038, Harvard University (September).

Grossman, G., and A. Krueger. 1993. "Environmental Impacts of a North American Free Trade Agreement." In P.M. Garber, ed., *The US-Mexico Free Trade Agreement*. Cambridge, MA: MIT Press.

ITC [see U.S. International Trade Commission].

Kneese, A.V., R.U. Ayres, and R.C. d'Arge. 1970. "Economics and the Environment: A Materials Balance Approach." Resources for the Future, Washington, D.C.

Leontief, W.W. 1970. "Environmental Repercussions and the Economic Structure: An Input-Output Approach." *The Review of Economics and Statistics* 52(3): 262–271.

Tsigas, M.E., D. Gray, and T.W. Hertel. 2002. "How to Assess the Environmental Impacts of Trade Liberalization." Paper presented at the 5th Annual Conference on Global Economic Analysis entitled "Sustainable Development and the General Equilibrium Approach," Taipei (June).

U.S. Department of Commerce. 2002. "Benchmark Input-Output Accounts of the United States, 1997." Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C. (December).

U.S. International Trade Commission (ITC). 2002. *The Economic Effect of Significant U.S. Import Restraints* (3rd update). U.S. International Trade Commission, Washington, D.C.