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International Trade and Air Pollution: The Economic Costs of Air Emissions from Waterborne Commerce Vessels in the United States

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Abstract

Although there is a burgeoning literature on the effects of international trade on the environment, relatively little work has been done on where trade most directly effects the environment: the transportation sector. This article shows how international trade is affecting criteria air pollution emissions in the United States' shipping sector. Recent work has shown that cargo ships have been long overlooked regarding their contribution to air pollution. Indeed, ship emissions have recently been deemed "the last unregulated source of traditional air pollutants." Air pollution from ships has a number of significant local, national, and global environmental effects. Building on past studies, we examine the economic costs of this increasing and unregulated form of environmental damage. We find that total emissions from ships are largely increasing due to the increase in foreign commerce (or international trade). We analyze the period 1993 to 2001 and find that the economic costs of SO_2 pollution during the period are estimated to be $1.1 billion or $126 million per year. For NO_x emissions the costs are $3.7 billion over the entire period or $412 million per year. Because foreign trade is driving the growth in U.S. shipping, we also estimate the effect of the Uruguay Round on emissions. Separating out the effects of global trade agreements reveals that the trade agreement-led emissions amount to $460 million for SO_2 between 1993 and 2001, or $51 million per year. For NO_x they are $1.2 billion for the whole period or $144 million per year. Without adequate policy responses, we predict that these trends and costs will continue to rise with trade flows into the future.

1. Introduction

Economists have begun to develop a broad theoretical framework for analyzing the trade and sustainable development relationship. Economic integration has direct and indirect effects on environment and development. The indirect effects are those those that economists have focused most on. Economic integration can also have indirect effects on sustainable development. Economists have outlined four mechanisms whereby trade and investment liberalization have indirect effects on environment and development: scale, composition, technique, and regulatory effects (Grossman and Krueger 1993). Scale effects occur when liberalization causes an expansion of economic activity. If the nature of that activity is unchanged but scale is growing, then pollution and resource depletion will increase along with output. Ever-increasing levels of carbon dioxide emissions due to the expansion of the world economy in the 1990s are often cited as examples of scale effects.

Composition effects occur when increased trade leads nations to specialize in the sectors where they enjoy a comparative advantage. When comparative advantage is derived from differences in regulatory stringency (i.e., the pollution-haven effect), then the composition effect of trade will exacerbate existing environmental and social problems in the countries with relatively lax regulations. If pollution intensive industries begin to concentrate in nations with standards that are relatively weak, it is feared that a "race to the bottom," in environmental standards may occur. Technique effects, or changes in resource extraction and production technologies, can potentially lead to a decline in pollution per unit of output. The liberalization of trade and investment may encourage the transfer of cleaner technologies to developing countries. In addition, it is said that trade-led economic growth may raise incomes to the point where newly affluent citizens begin to demand a cleaner environment.

The literature on these three effects has become quite large and it is beyond the scope of this paper (Gallagher 2002). There has been relatively less attention to the "direct" effects of trade on the environment. After all, trade in and of itself is the movement of goods and services across borders. Only a few studies have examined the extent to which increases in transportation due to trade have affected the environment. One study of the increasing levels of transportation due to the North American Free Trade Agreement (NAFTA) found that NAFTA trade has directly contributed to air pollution in the five key transportation corridors that link North American commerce. Such pollution is estimated to be 3 to 11 percent of all mobile source nitrous oxide emissions in those regions, and 5 to 16 percent of all particulate matter emissions (Consulting 2001)). A second direct effect is the introduction of alien-invasive species through trade. Again, the example of NAFTA is telling, where increased trade in alien-invasive species has been found to have "decreased biological diversity that cost North America millions of dollars." (NACEC, 2001).

This study builds on this emerging literature by examining the environmental effects of U.S. shipping in the United States. A number of recent studies have shed light on the fact that waterborne commerce (or shipping) is a significant contributor to air pollution in the

United States. It has been recently referred to as "the last unregulated source of traditional air pollutants."(Corbett 2003). Shipping accounts for 14 percent of nitrous oxide (NO_x) emissions from all global fossil fuels, and 16 percent of sulfur from all petroleum fuel (Corbett 2003). In the U.S. alone, shipping accounts for up to 4 percent of transportation-related NO_x emissions, and 8 percent of sulfur dioxide (SO_2) emissions (Corbett and Fishbeck 2000; EPA 2000). The environmental effects of shipping emissions are local, national and global in nature. Two of the busiest ports in the United States, California and Texas, are non-attainment areas for some of these pollutants. EPA estimates that marine diesel engines entering California and Texas account for 15 and 17 percent of the NO_x emissions on summer days in these regions (EPA 1999). Emissions of these gases can also contribute to global climate change.

Obtaining estimates of the economic costs of these emissions in the U.S. will be of use to decision-makers attempting to prioritize the nation's policies with respect to waterborne emissions from ships in particular and air pollution in general. On the one hand, private shipping entities bear abatement costs to reduce these pollutants; on the other society at large bears costs by way of health, environment and other social damages. For some pollutants, pollution markets already exist for SO_2 and NO_x pollution in the U.S. Therefore, assigning monetary values that represent economic damages related to abatement costs by private shipping entities are relatively straightforward. However, estimating the environmental costs (and benefits) of economic activity for society can be most difficult because the environmental benefits do not often lend themselves to monetary valuation (Arrow 2000). To estimate these costs we consult Environmental Protection Agency (EPA) studies and the peer-reviewed economics literature.

This paper builds on the work of previous studies by delineating the relative contribution and intensity of domestic and foreign waterborne commerce in U.S. shipping emissions from 1993 to 2001. Furthermore, based on pre-existing market prices for SO_2 and NO_x pollution in the U.S., the paper estimates the economic damages related to increases in foreign and domestic shipping during this period and into the future. Because we learn that international trade is driving much of the increase in waterborne commerce and related emissions, we estimate the effect of the Uruguay Round trade talks on past emissions as well.

2. International Trade and Shipping Emissions: An Analysis

This paper utilizes previous estimates of SO_2 and NO_x pollution in U.S. waterborne commerce in 1997 to calculate the pollution-intensity of the U.S. shipping fleet, total emissions of that fleet from 1993 to 2001, and the economic costs of total emissions from 1993 to 2001 and beyond.

Estimates of SO_2 and NO_x pollution estimates come from landmark studies that appeared in the journals *Science* and *Environmental Science and Technology* (Corbett and Fishbeck 2000; Corbett 2000a). The authors created emissions factors to estimate levels of SO_2 and NO_x , particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO) in U.S. waterborne vessels.

Working with these data, to use these estimates for air pollution in U.S. ships in 1997 to create an index of pollution intensity for shipping in the U.S. The United States Department of Transportation Maritime Administration (USDTMA) provides statistics on the amount of cargo (measured in short tons but converted to metric tons) in domestic and foreign shipping trips from 1977 to 2001. Corbett and Fischbeck provide pollution estimates for domestic and foreign shipping for 1997. To create pollution intensities for SO_2 and NO_x we divided the amount of cargo in 1997 by the Corbett and Fischbeck pollution estimates in 1997. Table 1 exhibits the pollution intensities for SO_2 and NO_x in 1997. For each pollutant, according to our calculations, foreign commerce is less pollution intensive than domestic.

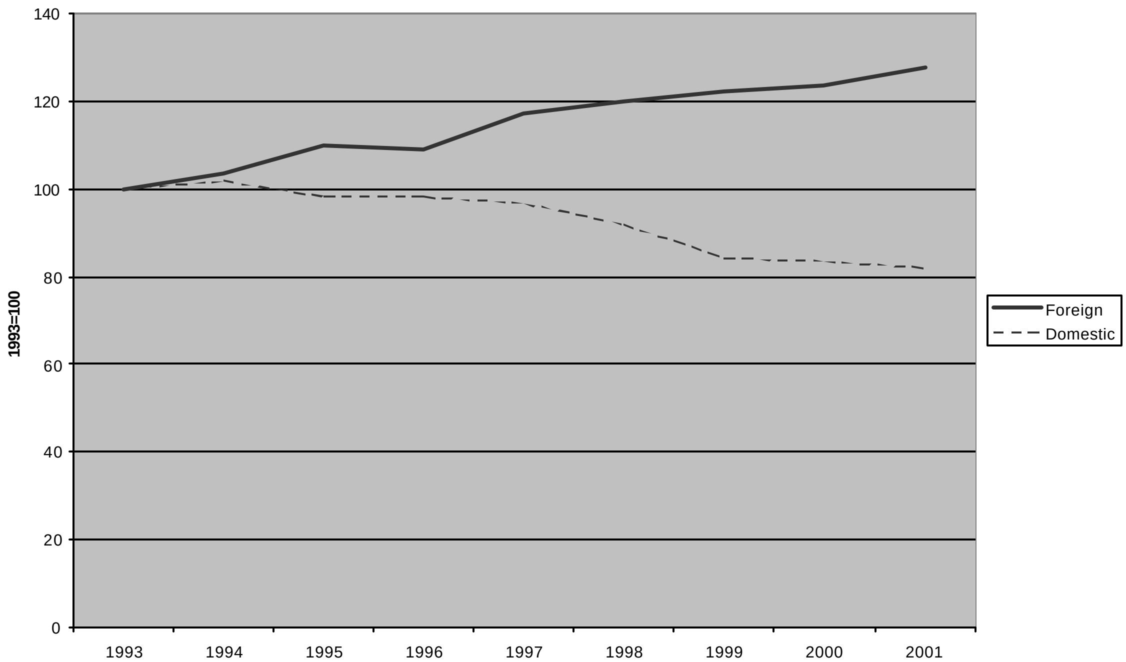
Table 1: Pollution Intensity of Waterborne Vessels in the U.S.

	SO_2	**NO_x**
Foreign Oceangoing	5.49 x $^{-5}$	1.06 x $^{-4}$
Domestic Oceangoing	2.01 x $^{-4}$	2.68 x $^{-4}$

Source: Author's calculations based on (Corbett and Fishbeck 2000; Colton 2003a).

We then calculate total emissions for foreign and domestic shipping from 1993 to 2001. Figure 1 shows trends in U.S. foreign and waterborne shipping during this period. The average cargo was 1,272 million metric tons annually from waterborne commerce (1,043 from foreign commerce, 229 for domestic). One of our initial findings is that foreign shipping (that is, cargo destined for ports outside the U.S.) is driving the increases in U.S. shipping over this period. Indeed, foreign commerce increased by 28 percent during the period while domestic cargo decreased by the same amount. The recent trends represent a real change. Between 1977 and 1987, domestic cargo was driving growth in U.S. shipping. During that period domestic commerce increased by 24 percent while foreign commerce decreased by 18 percent. These new trends reflect the fact that international trade in goods in services is accelerating. Since 1986 the U.S. has engaged in numerous negotiations for the liberalization of trade in goods and services, most notably the Uruguay Round (1986 to 1993) and the North American Free Trade Agreement (NAFTA). This analysis uses the fixed pollution coefficient from equation one, in other words it holds technology constant for 1997. Most ships for domestic or foreign commerce have a vintage of 15 to more than 25 years. Thus, using a coefficient for the eight-year period in this analysis is not as problematic as it would be for other analyses such as in manufacturing (Colton 2003b).

Figure 1: Domestic and Foreign Commerce in the U.S.



Source: author's calculations based on (Colton 2003a).

Finally, we calculate the economic costs of the total emissions. We do this for the private costs to firms as represented in current regulation and also for the costs to society at large. The first is done by multiplying total emissions in a given year by the price of pollution as set by the markets for tradeable permits for SO_2 and NO_x . As mentioned earlier, permits for SO_2 and NO_x pollution are traded for firms to be in compliance with national and regional air pollution regulations. Thus, these costs represent abatement costs by private firms equal to the amount of externalities required to be abated under current air regulations. The economic costs to society could come in the form of health care costs, damage to ecosystems due to acid rain, and the effects of global climate change. We use estimates from the peer reviewed economics literature to represent these social costs.

SO_2 is traded at the Chicago Board of Trade in accordance under Environmental Protection Agency regulations (EPA). Tradeable permit schemes are relatively new innovations in environmental economics whereby a market is created where firms can purchase and sell the right to emit certain quantities of pollution. The idea is that with an overall limit on the amount of pollution allowed, the purchase and sale of pollution permits will allow firms to allocate and innovate toward pollution reduction more efficiently, and be rewarded for their reductions (Tietenberg 1996). For SO_2, EPA provides information regarding the price of permits for a ton of SO_2 on the market from

1993 to the present. In addition, firms can purchase “advance bids” for years until 2010. Therefore, the costs of SO_2 pollution from ships is calculated from 1993 to 2010 by multiplying the price of a SO_2 permit in a given year by the amount of total pollution in shipping for that year. Table 2 exhibits the price per ton (converted to metric tons for this analysis) of SO_2 permits in the U.S. from 1993 to 2010.

Table 2: Price of SO_2 Permits in the U.S.

Year	Price	
1993	$	141.52
1994	$	144.24
1995	$	119.75
1996	$	92.53
1997	$	100.12
1998	$	106.11
1999	$	187.82
2000	$	118.56
2001	$	158.73
2002	$	116.12

Source:(EPA 2003)

NO_x emissions are now traded in nine states: Connecticut, Massachusetts, Maine, Maryland, Maryland, New Jersey, New York, Pennsylvania, Texas and Rhode Island. At the margin, NO_x pollution abatement is more costly than for SO_2 . Whereas SO_2 can be abated by fuel switching, NO_x abatement often entails the replacement of core combustion technologies. For this reason, NO_x permits are much more costly. NO_x markets are not as available and data for permits was only available for 2003. In 2003, permits ranged from $1,700 per ton in New York and Pennsylvania, to $9,500 per ton in Connecticut. The wide range of estimates is due to the fact that these markets are still in the developing stages (NATSOURCE 2003). Because data is available for only one year, our NO_x analysis cannot be as precise as our estimates for SO_2.

Table 3: Emissions and Economic Costs of SO_2 Pollution from Ships in the United States, 1993 to 2001

	Emissions (tons)			Economic Costs (dollars)		
	Foreign	***Domestic***	***Sum***	***Foreign***	***Domestic***	***Sum***
1993	49,874	49,604	99,478	$7,058,395	$7,020,100	$14,078,495
1994	51,632	50,516	102,148	$7,447,671	$7,286,629	$14,734,300
1995	54,818	48,692	103,510	$6,564,475	$5,830,892	$12,395,367
1996	54,379	48,692	103,071	$5,031,887	$4,505,689	$9,537,576
1997	58,608	47,963	106,571	$5,867,750	$4,801,945	$10,669,696
1998	59,816	45,592	105,408	$6,346,887	$4,837,569	$11,184,456
1999	61,025	41,762	102,787	$11,461,537	$7,843,656	$19,305,193
2000	61,684	41,397	103,081	$7,313,372	$4,908,152	$12,221,523
2001	63,771	40,668	104,439	$10,122,583	$6,455,327	$16,577,909
annual	**57,290**	**46,098**	**103,388**	**$7,468,284**	**$5,943,329**	**$13,411,613**
Totals	**515,608**	**414,885**	**930,493**	**$67,214,557**	**$53,489,958**	**$120,704,515**

Source: author's calculations from (Corbett and Fishbeck 2000; EPA 2003; Colton 2003c)

Table 3 exhibits the results of the second and third series of analyses: total emissions and the pollution costs as represented by tradeable permit markets. Because we are using a fixed emissions coefficient, emissions are rising at a rate proportional to domestic and foreign cargo. In 1993 emissions were 99,478 metric tons and 104,439 in 2001. Corresponding to trends in foreign and domestic shipping commerce, whereas emissions where close to equal for domestic and foreign shipping, they have decreased by 28 percent in the domestic fleet and increased by the same amount in foreign cargo. The economic costs of SO_2 pollution total to $120 million for the entire period, or $13 million on an annual basis. The bulk of the cost is from foreign commerce, where the annual costs average to be $7.4 million with a total of $67.2 over the entire period.

Because SO_2 permits for future years can be purchased in the market, we provide estimates for the future costs of SO_2 as well. Assuming that foreign commerce would grow at the 1993 to 2001 rate we multiplied future cargo by our emission intensities to get total emissions. We then multiplied total emissions by the price of SO_2 in the future. In present value terms, SO_2 will continue to cost the U.S. $10 million per year ($7 million for foreign commerce), and $93 million from 2001 to 2010.

Table 4: Emissions and Economic Costs of NO_x Pollution from Ships in the United States, 1993 to 2001						
	Emissions (tons)			Economic Costs (dollars)		
	Foreign	*Domestic*	*Sum*	*Foreign*	*Domestic*	*Sum*
1993	96,672	66,101	162,773	$127,165,940	$86,952,248	$214,118,187
1994	100,079	67,316	167,395	$131,647,559	$88,550,634	$220,198,193
1995	106,254	64,886	171,140	$139,770,493	$85,353,861	$225,124,354
1996	105,402	64,886	170,288	$138,650,088	$85,353,861	$224,003,949
1997	113,600	63,914	177,514	$149,433,984	$84,075,151	$233,509,135
1998	115,942	60,755	176,697	$152,515,097	$79,919,345	$232,434,442
1999	118,285	55,651	173,936	$155,596,210	$73,206,120	$228,802,330
2000	119,562	55,165	174,728	$157,276,817	$72,566,765	$229,843,583
2001	123,608	54,193	177,801	$162,598,740	$71,288,056	$233,886,796
annual	**111,045**	**61,430**	**172,475**	**$146,072,770**	**$80,807,338**	**$226,880,108**
Total	**999,403**	**552,869**	**1,552,272**	**$1,314,654,928**	**$727,266,041**	**$2,041,920,968**

Source: author's calculations from (Corbett and Fishbeck 2000; EPA 2003; NATSOURCE 2003; Colton 2003c)

Table 4 shows these trends for NO_x. Referring to Table 1, shipping is more NO_x intensive than it is for SO_2. For that reason, total NO_x emissions are larger. In addition, NO_x is more expensive to abate because it entails fundamental changes in combustion technology. Thus, the permits are more expensive and the economic costs much larger. Between 1993 and 2001, the economic costs of NO_x emissions were $2 billion, or $226 million on an annual basis. For both SO_2 and NO_x emissions increased at the rate of growth in cargo shipments for domestic and foreign. Thus, total emissions are increasing largely due to the increase in foreign commerce.

The costs represented by tradeable permits fail to represent the full social costs to society for these emissions. Such costs, referred to as "externalities," occur when the actions of private market transactions affect the welfare of individuals, communities, and societies not involved in the market transaction. For the pollutants considered in this study, the economic costs to society could come in the form of health care costs, damage to ecosystems due to acid rain, and the effects of global climate change.

Numerous studies have attempted to calculate the external costs of SO_2 and NO_x emissions from ships that reach shore. We reviewed EPA studies and the peer reviewed economics literature to derive estimates of the damage costs to society for these pollutants. These pollutants can cause respiratory difficulty for people with asthma. Longer-term exposures to high levels can cause respiratory illness and aggravate heart disease. SO_2 can also cause acid rain, which damages forests and croplands, changes soil composition, and makes many waterways unsuitable for fishing(EPA 2003). For SO_2, the cost estimates range from $1,009 to $3,000 per ton, depending on the geographical area (Burtraw 1997; Burtraw 1999; (USDOI) 2001). We extrapolate conservatively from these studies and for our estimates use the lower bound of them at $1,096 per ton for SO_2. For NO_x the range of damage estimates is from $1,009 to $12,000 per ton (Kruputnik 2000).

Again, staying on the side of conservatism, we chose $1,009. The results of these calculations appear in Table 5.

Table 5: External Costs of Shipping Emissions in the United States, 1993 to 2001

	Economic Costs SO2(dollars)			Economic Costs NOx (dollars)		
	Foreign	***Domestic***	***Sum***	***Foreign***	***Domestic***	***Sum***
1993	$54,662,424	$54,365,851	$109,028,275	$107,209,015	$66,696,176	$173,905,191
1994	$56,588,853	$55,365,223	$111,954,076	$110,987,306	$67,922,209	$178,909,515
1995	$60,080,505	$53,366,479	$113,446,984	$117,835,459	$65,470,143	$183,305,603
1996	$59,598,898	$53,366,479	$112,965,377	$116,890,887	$65,470,143	$182,361,030
1997	$64,234,368	$52,566,981	$116,801,349	$125,982,400	$64,489,317	$190,471,717
1998	$65,558,788	$49,968,613	$115,527,401	$128,579,975	$61,301,632	$189,881,608
1999	$66,883,208	$45,771,249	$112,654,457	$131,177,551	$56,152,295	$187,329,846
2000	$67,605,619	$45,371,501	$112,977,119	$132,594,410	$55,661,882	$188,256,292
2001	$69,893,253	$44,572,003	$114,465,256	$137,081,131	$54,681,056	$191,762,187
annual	$62,789,546	$50,523,820	$113,313,366	$123,148,682	$61,982,762	$185,131,443
Total	$565,105,916	$454,714,378	$1,019,820,294	$1,108,338,134	$557,844,854	$1,666,182,988

Source: Author's calculations based on (Burtraw 1999; Corbett and Fishbeck 2000; (USDOI) 2001).

As shown in Table 5, using the lowest estimates the social costs of these pollutants for shipping can be quite high. The annual costs of SO_2 pollution are $113 million, and $1 billion for the entire period, for NO_x they are $185 million per annum and $1.6 billion over the entire period. Table 6 exhibits these costs juxtaposed with the tradeable permit costs from Tables 3 and 4. Table 6 exhibits estimates of the "full costs" of SO_2 and NO_x emissions from ships in the United States. The total costs for SO_2 pollution during the whole period are $1.1 billion or $126 million per year. For NO_x emissions the costs are $3.7 billion over the entire period or $412 million per year.

Table 6: Combined Economic Costs of Air Pollution from US Ships

	SO_2			NO_x		
	Permit	***Social***	***Total***	***Permit***	***Social***	***Total***
1993	$14,078,495	$109,028,275	$123,106,769	$214,118,187	$173,905,191	$388,023,378
1994	$14,734,300	$111,954,076	$126,688,376	$220,198,193	$178,909,515	$399,107,708
1995	$12,395,367	$113,446,984	$125,842,351	$225,124,354	$183,305,603	$408,429,956
1996	$9,537,576	$112,965,377	$122,502,953	$224,003,949	$182,361,030	$406,364,979
1997	$10,669,696	$116,801,349	$127,471,045	$233,509,135	$190,471,717	$423,980,852
1998	$11,184,456	$115,527,401	$126,711,857	$232,434,442	$189,881,608	$422,316,050
1999	$19,305,193	$112,654,457	$131,959,650	$228,802,330	$187,329,846	$416,132,176
2000	$12,221,523	$112,977,119	$125,198,643	$229,843,583	$188,256,292	$418,099,875
2001	$16,577,909	$114,465,256	$131,043,165	$233,886,796	$191,762,187	$425,648,982
annual	$13,411,613	$113,313,366	$126,724,979	$226,880,108	$185,131,443	$412,011,551
Total	$120,704,515	$1,019,820,294	$1,140,524,809	$2,041,920,968	$1,666,182,988	$3,708,103,957

Source: Author's calculations based on previous text

Because foreign commerce is driving trends in shipping, we also determine the effect of recent trade agreements on foreign commerce. The most recent round of the General Agreement on Tariffs and Trade (GATT), referred to the Uruguay Round, was competed in 1993. Three previous studies estimate the effect of the Uruguay Round on U.S. exports, and provide a range from 2.9 to 48 percent. In other words, holding all other determinants of export growth constant, the Uruguay round can account for 2.9 to 48 percent of the changes in exports(Haaland 1994; Francois, McDonald et al. 1996). We took the midpoint of the second two (the third found an estimate of 39 percent), or 43.5 percent. These two studies were the most comprehensive, providing estimates for trade changes in manufacturing and services. To calculate the Uruguay Round portion of foreign commerce (assuming that foreign shipping commerce increases in proportion to U.S. exports), we multiplied our economic cost estimates by .435. Separating out the effects of global trade agreements reveals that the trade agreement-led emissions amount to $460 million for SO_2 between 1993 and 2001, or $51 million per year. For NO_x they are $1.2 billion for the whole period or $144 million per year.

Conclusion

This study is far from the last word on the environmental effects of international trade and shipping in the U.S., but it is a useful start. Building on previous studies we analyzed total emissions and the economic costs of shipping emissions in the United States from 1993 to 2001. We found that total emissions from ships are largely increasing due to the increase in foreign commerce. The economic costs of SO_2 pollution during the whole period are estimated to be $1.1 billion or $126 million per year. For NO_x emissions the costs are $3.7 billion over the entire period or $412 million per year. Because foreign trade is driving the growth in U.S. shipping, we also estimate the effect of the Uruguay Round on emissions. Separating out the effects of global trade agreements reveals that the trade agreement-led emissions amount to $272 million for SO_2 between 1993 and 2001, or $30 million per year. For NO_x they are $745 million for the whole period or $82 million per year. Without adequate policy responses, we predict that these trends and costs will continue into the future. These estimates are very significant in that they will accrue locally. Remember that many of the areas ports where these damages will occur are already environmental hot spots. Future research would benefit from a more localized approach focusing on specific ports.

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