Advances in Economic Analysis & Policy

Volume 4, *Issue* 2 2004 *Article* 6

THE POLLUTION HAVEN HYPOTHESIS

Trade Liberalization and Pollution Havens

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Trade Liberalization and Pollution Havens*

Josh Ederington, Arik Levinson, and Jenny Minier

Abstract

U.S. Presidential Executive Order 13141 commits the United States to a careful assessment and consideration of the environmental impacts of trade agreements. The most direct mechanism through which trade liberalization would affect environmental quality in the U.S. is through the composition of industries. Freer trade means greater specialization, increasing the concentration of polluting industries in some countries and decreasing it in others. We begin by documenting the substantial shift in U.S. manufacturing toward cleaner industries from 1972 to 1994. We then use annual industry-level data on imports to the U.S. to examine whether this compositional shift can be traced to the significant trade liberalization that occurred over the same time period, and we conclude that no such connection exists. A shift toward cleaner industries has also occurred among U.S. imports, and we find no evidence that pollution-intensive industries have been disproportionately affected by the tariff changes.

KEYWORDS: Pollution Haven, PACE, Environment

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In recent decades, while United States manufacturing output increased, total pollution from manufacturers declined. Much of the decline has been due to a large shift in the composition of the U.S. manufacturing sector away from polluting industries and toward cleaner industries. During the same period, U.S. tariffs on imported manufactured goods declined. These concurrent trends have led many to conclude that trade liberalization – "globalization" – has *caused* the shift in U.S. manufacturing to clean industries at the expense of environmental quality in developing countries. In this paper we seek empirical support for that claim, using data on tariffs, U.S. imports, pollution abatement costs, and industries' relative pollution intensities. While much research has been devoted to studying the effect of environmental regulations on trade, we know of no other direct empirical tests of whether trade liberalization has exacerbated the tendency for pollution-intensive industries to relocate to developing countries.

This concern, that trade liberalization leads to a transfer of polluting industries to developing countries, has been part of the impetus for widespread protests against the World Trade Organization. It has been the motivation for environmental addenda to trade agreements such as the North American Free Trade Agreement (NAFTA), and it is the subject of President Clinton's Executive Order 13141, "Environmental Review of Trade Agreements." EO13141 requires that the United States "factor environmental considerations into . . . its trade negotiating objectives," and that the U.S. Trade Representative and the Chair of the Council on Environmental Quality oversee analyses of the "environmental impacts of trade agreements."

Despite the intuitive appeal of the idea, trade liberalization will not necessarily lead to a shift toward cleaner goods production in U.S. manufacturing. Indeed, using country-level data, recent work by Antweiler, Copeland and Taylor (2001) and Copeland and Taylor (2003) has shown that increases in the volume of trade can result in increased pollution emissions in the U.S. From this they infer that trade liberalization could actually shift the composition of U.S. manufacturing toward *more* polluting industries. Our work differs from theirs in that we examine the compositional effect of tariff reductions directly using industry-level data, while Antweiler *et al.* and Copeland and Taylor infer the compositional effect indirectly from country-level correlations between pollution emissions and trade. As we show, our results support their inference.

Trade liberalization can affect the environment through several mechanisms, such as interjurisdictional competition to lower standards, transfer of pollution abatement technology, cross-border spillovers, or changes to the overall scale of economies. But it seems to us that the most direct effect of trade liberalization on the environment would be through the composition of industries. Trade liberalization leads to specialization, and countries that specialize in less pollution-intensive goods will have cleaner environments.

In this paper we assess the degree to which the reduction of U.S. tariffs on imported goods accounts for the changing composition of U.S. manufacturing toward cleaner industries. We do this in three ways. First, in section 1 of the paper, we examine the pollution content of U.S. manufactured goods, imports, and exports, in the spirit of

Kahn (2003), to see whether imports have replaced the pollution-intensive goods no longer produced in the U.S. Second, in section 2 we use a regression approach similar to Grossman and Krueger (1993) to see whether the tariff reductions of the past several decades have exacerbated the "pollution haven" effect. If this is the case, then broad-based tariff reductions could have caused the compositional shift observed in the data. Finally, in section 3 we investigate whether the compositional shift in U.S. industries could be due to asymmetric trade liberalization (i.e., larger U.S. tariff reductions in the more pollution-intensive industries). Specifically, we use our regression coefficients to predict the changes in the composition of U.S. industries that are due to past tariff reductions (as well as the changes that would be the result of setting current tariff levels to zero).

We find that that the tariff reductions over the past several decades cannot account for the change in the composition of U.S. manufacturing toward cleaner industries. First, imports from other countries do not appear to have replaced the domestic production of pollution-intensive goods in the U.S. Second, we find no evidence that pollution-intensive industries are disproportionately sensitive to tariff reductions. (In fact, just the opposite appears likely.) Finally, while it is true that tariff reductions have been greater for polluting industries, that difference explains only a small part of the overall shift in U.S. manufacturing.

1. The Pollution Content of U.S. Manufacturing

The various effects of trade on environmental quality can be divided into three components: how trade affects the overall *scale* of the economy; how trade affects the *techniques* of production, and how trade affects the *composition* of industries.[1] The various parties concerned about trade liberalization's effect on the environment appear to concentrate on the composition effect: specifically, the concern that trade liberalization will result in the creation of pollution havens (countries that specialize in polluting industries). Hence we investigate mainly the composition effect and not the technique effect. We begin by examining the degree to which the composition of U.S. manufacturing has shifted toward clean industries, and how much of that shift can be explained by changes in the composition of imports and exports.

In order to isolate this composition effect, we need a metric with which to label various industries as being relatively "clean" or "dirty." To that end, we rely on the World Bank's "Industrial Pollution Projection System" (IPPS).[2] The IPPS reports the amount of each of 14 pollutants, in pounds per million dollars of value added, that were generated from each of 459 four-digit SIC codes in 1987. These data are summarized in Table 1. They represent a snapshot of the production techniques as of 1987.

Figure 1a demonstrates the degree to which the U.S. industrial composition has shifted toward less-polluting industries. The bold line plots an index of total real

[1] See, for example, Copeland and Taylor (2003).
[2] See Hettige *et al.* (1994).

manufacturing output. The recessions of the mid-1970s, early 1980s, and early 1990s are apparent, and overall manufacturing grew by 57 percent between 1972 and 1996.

Table 1: Pounds of Pollution per Dollar Value Added 1987

Pollutant	Industries (1)	IPPS Coefficients [lbs/$] Mean (2)	Std. dev. (3)	Max (4)
Air pollution				
Particulates	448	1.64	8.79	147
CO	448	2.67	14.5	202
SO2	448	2.47	10.78	140
NOx	448	1.63	6.23	67
VOC	448	1.38	4.77	85
PM10	448	0.89	7.64	108
Water pollution				
BOD	321	0.0011	0.0066	0.068
TSS	321	0.0069	0.053	0.70
Toxics				
Air	434	1.31	5.31	77
Land	434	1.64	7.28	83
Water	434	0.204	2.208	43
Metals				
Air	317	0.020	0.091	1.24
Land	317	0.592	4.50	74
Water	317	0.0035	0.310	0.53

Source: World Bank Industrial Pollution Projection System (Hettige *et al.*, 1994).

The dotted lines in Figure 1a plot the predicted total emissions of sulfur (SO_2), suspended solids in water, and hazardous waste, three of the 14 pollutants tracked by the IPPS. The predicted pollution levels are calculated by multiplying each 4-digit manufacturing industry's real annual value added by the industry's IPPS coefficient, and then summing across industries to get total predicted pollution for each year. By holding the IPPS coefficients constant as of 1987, we are in effect freezing the technique of production, and only looking at changes in pollution due to changes in the scale and composition of manufacturing. If industrial growth were balanced, and every four-digit industry grew by the same 57 percent as did overall manufacturing, then predicted pollution would coincide perfectly with manufacturing growth, and grow 57 percent. The dotted pollution lines would overlie the bold manufacturing line. But because relatively pollution-intensive industries shrank, while clean industries grew, the total amount of predicted pollution grew by much less than 57 percent over this time period. Predicted sulfur grew 21 percent, suspended solids fell 15 percent, and hazardous waste grew 35 percent, all much less than the growth of overall manufacturing.[3]

Figure 1a. Trends in Manufacturing, Pollution, and Tariffs

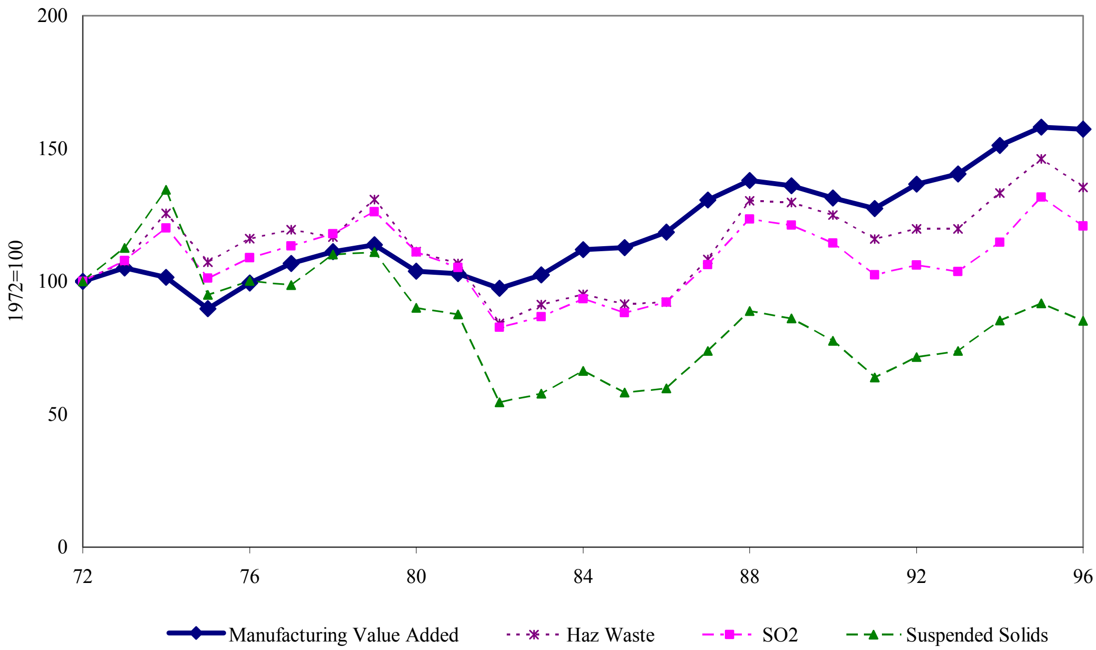


Table 2 summarizes the data behind Figure 1. The first column presents the growth in real U.S. manufacturing value added from 1972 to 1994 (51 percent), compared with the predicted growth in each of the 14 pollutants, where the predictions are based on the scale and composition of manufacturing, holding technique constant.[4]

Figure 1a and Table 2 demonstrate the degree to which the U.S. manufacturing sector shifted toward cleaner industries. During this same time period, U.S. tariffs fell: from 1974 to 1994, the average tariff on manufactured imports to the U.S. fell by over 50 percent, from over 8 percent to less than 4 percent. Given the steep drop in tariffs, combined with the dramatic shift toward cleaner industries, we understand how casual observers could conclude that the two trends are related. Indeed, this inference makes sense intuitively, since trade liberalization could lead to increased specialization, which in turn could result in the U.S. producing cleaner goods.

[3] Thirteen of the 14 pollutants tracked by the IPPS grew by less than manufacturing. The only exception was biological oxygen demand (BOD), which had predicted growth of 69 percent. Of this growth, 49 percent came from two industries: "chemical preparations n.e.c." (SIC 2899) and "paperboard mills" (SIC 2631). These industries grew by 68 and 54 percent, respectively, and had 57 and 32 times the mean IPPS coefficient for BOD.

[4] Table 2 uses data only up until 1994, which is the last year of the pollution abatement cost data we use later in the paper.

Table 2: Predicted Pollution Changes 1972-1994

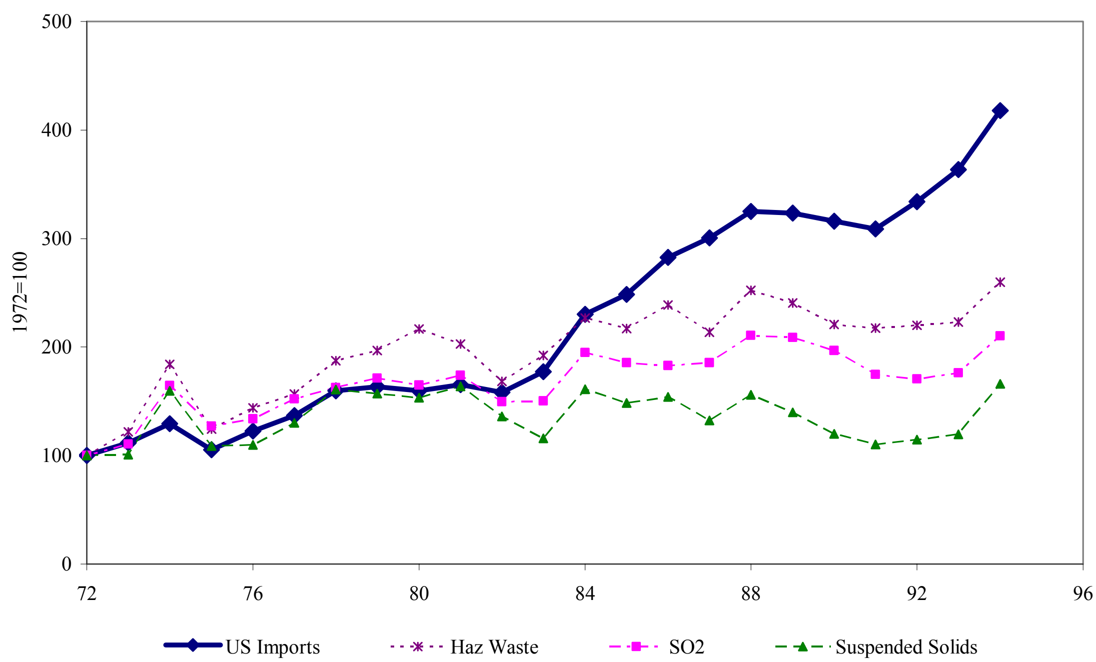
Pollutant	US Manufacturing (1)	Imports to the US (2)	Imports from non-OECD (3)	US Exports (4)
Particulates	13.3	103.6	109.4	169.4
CO	1.9	96.7	113.2	158.6
SO2	14.8	110.3	119.3	183.5
NO2	22.8	114.7	117.2	205.2
VOC	36.4	171.0	177.3	223.3
pm10	-6.3	51.3	66.0	124.0
BOD	71.5	95.9	95.3	120.7
TSS	-14.7	66.0	100.7	152.6
Air toxics	47.8	196.6	197.2	264.3
Water toxics	34.7	148.4	151.5	273.7
Solid waste toxics	33.2	159.8	162.7	242.1
Metals to air	-2.3	89.5	109.9	217.5
Metals to land	-1.0	81.5	91.6	207.8
Metals to water	19.8	111.2	135.9	234.9
Percent change in manufactured products	51.1	317.9	344.4	268.8

If it is true that the composition shift of U.S. manufacturing toward clean industries has been caused by tariff reductions, one might expect that the composition of imports will have shifted toward dirty industries. Figure 1b investigates the pollution composition of imports. The bold line in Figure 1b plots the real value of U.S. imports, which grew by 318 percent from 1972 to 1994. The dotted lines plot the predicted pollution content of those imports, calculated in the same way as in Figure 1a. We multiply the real value of each 4-digit industry's imports by its IPPS coefficient and then aggregate across industries. If the composition of imports remained the same, then the dotted lines would overlie the bold imports line (i.e., grow by 318 percent). The fact that the dotted lines lie below the imports line indicates that the composition of imports to the U.S. has also shifted toward clean industries.

The second column of Table 2 summarizes the data behind Figure 1b. Real imports grew 318 percent, while the predicted pollution composition of those imports grew by markedly less. Of the 14 pollutants tracked by the IPPS, none grew by even two-thirds as much as real imports. Figure 1b and Table 2 thus demonstrate that cleaner U.S. manufacturing composition is not offset by more polluting imports. Rather, the composition of imports has also become cleaner.

One potential counterargument to our observation that the composition of imports has become cleaner is that the concerns about tariff reductions exacerbating pollution havens is based largely on imports from developing countries, not from developed countries. To see whether the composition of imports from relatively poorer countries has become more pollution-intensive, in Figure 1c we conduct the same exercise for imports from non-OECD countries only. The bold line plots the real value of imports from non-OECD countries. The dotted lines again plot pollution predicted from the IPPS coefficients, multiplied by their respective 4-digit industries' imports, and aggregated across industries. Again, pollution predicted by the scale and composition effects, holding technique constant, grew by far less than overall imports, even from poorer countries. Table 2 summarizes these data in column (3). Real imports from non-OECD countries grew by 344 percent from 1972 to 1994, but the composition of those imports shifted toward cleaner industries. As a result, the pollution predicted from those imports grew by far less than 344 percent.

Figure 1b. Trends in Imports and Pollution



So far we have demonstrated that the industrial composition of U.S. imports has become less pollution-intensive, and that the missing polluting industries have not been replaced by imports. A remaining piece of the puzzle, then, is to ask what happened to the pollution composition of U.S. exports. If the composition of U.S. *consumption* has remained steady, and the composition of U.S. manufactures and imports have become cleaner, then the U.S. must be exporting the excess clean manufactured goods.

Figure 1d plots the growth in real U.S. exports, and the predicted pollution content of those exports, in the same manner as Figures 1a-1c. Here the predicted pollution lines also lie below the real exports line, but the shift is much less stark. Column (4) of Table 2 presents the data behind Figure 1d. Real manufacturing exports grew by 269 percent, and most of the predicted pollutants grew by slightly less. The composition of U.S. exports has shifted toward cleaner goods, but this shift is less dramatic than the shift that occurred in U.S. manufacturing or imports.

Figure 1c. Imports from Non-OECD and Pollution

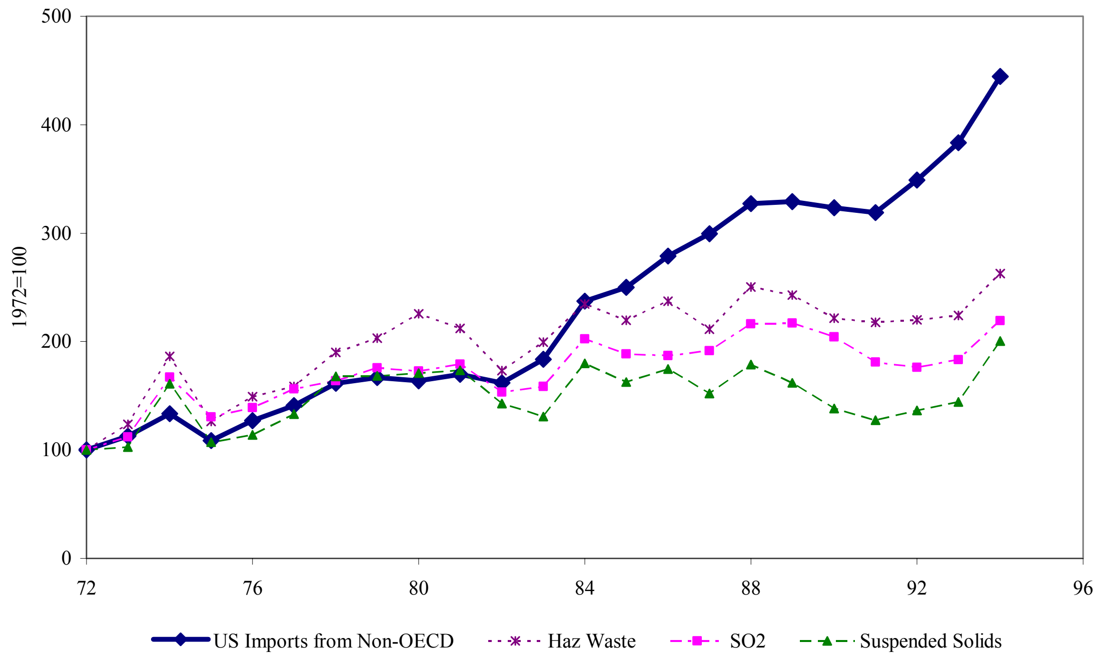
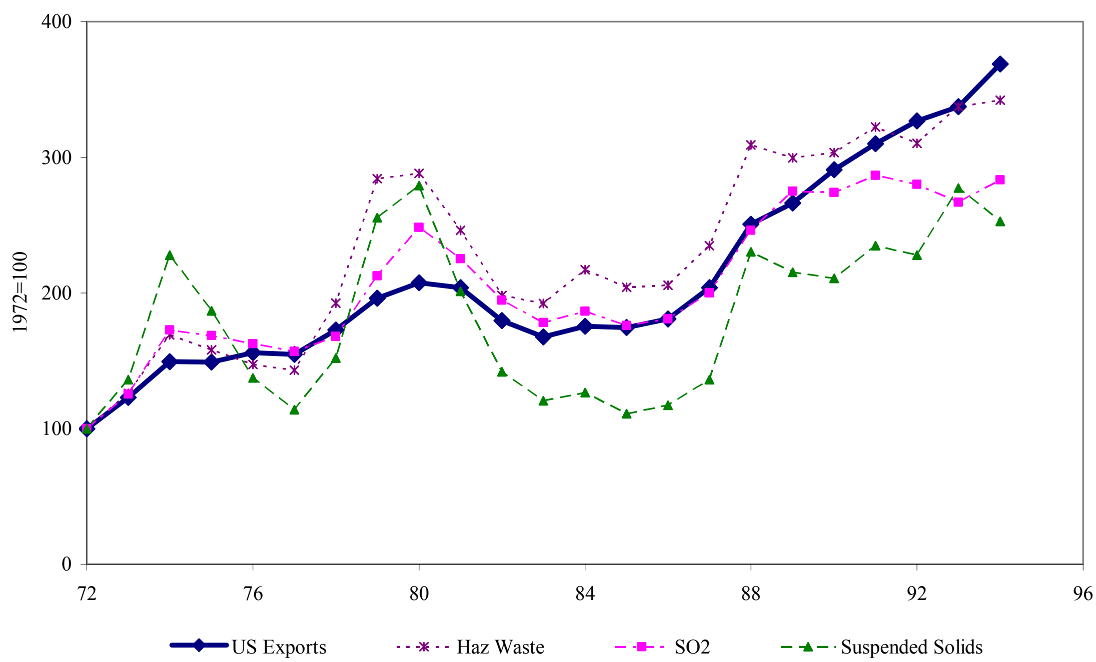


Figure 1d. U.S. Exports and Pollution



Together, Figure 1 and Table 2 provide suggestive evidence that the shift in U.S. manufacturing toward cleaner industries has not been caused by trade liberalization, because the shift in U.S. production has not been matched by an offsetting shift in imports toward more polluting industries. But this evidence is only indirect. For more direct evidence we turn to a regression-based approach, and ask whether tariff reductions exacerbate the tendency for polluting industries to be imported in response to rising domestic pollution abatement costs.

2. A Regression Approach

The large and growing literature evaluating the relationship between environmental regulations and international trade has until recently found little or no effect of environmental regulations on trade, and sometimes even found counterintuitive results suggesting that strict environmental regulations increase exports and decrease imports. Through the late 1990s, most studies used cross-sections of data, making it difficult to control for unobserved heterogeneity across countries or industries, and to account for the endogeneity of environmental regulations.[5] Recent studies have reversed these findings by using panels of data, including industry or regional fixed-effects to account for heterogeneity, and instrumenting for pollution regulations to account for their endogeneity.[6]

This literature, however, has had little to say about how free trade agreements are likely to affect the environment, the focus here. As mentioned previously, U.S. tariffs on imports have fallen, and the composition of U.S. manufacturing has shifted toward cleaner goods in recent decades, leading many observers to infer a causality between these two trends. However, we know of no direct empirical tests of whether the trends are related.[7]

One problem is that both the economics literature and the public debate have blurred two alternative definitions of the "pollution haven effect." The first is what we call the direct effect: jurisdictions that impose strict environmental regulations may drive out polluting manufacturers and increase imports of polluting goods. This direct effect has been the focus of all of the empirical studies to date. These studies regress some measure of economic activity, (such as imports, M) on characteristics of industries or jurisdictions, whatever the relevant unit of observation, including the stringency of the prevailing pollution regulations:

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[5] Jaffe *et al.* (1996) summarized the earlier literature, and Brunnermeier and Levinson (2004) provides an update.

[6] See, for example, Ederington and Minier (2003) and Levinson and Taylor (2004).

[7] Antweiler *et al.* (2001) and Copeland and Taylor (2003) explore a slightly different question. They ask how *trade* (rather than *tariffs*) affects the environment. Our work investigates the compositional effect of tariff reductions directly (using industry level data), while Antweiler *et al.* and Copeland and Taylor infer the compositional impact indirectly (from country-level correlations between pollution-emissions and trade). Nevertheless, we both reach the same conclusion: trade liberalization has not resulted in a compositional shift in the U.S. toward cleaner industries.

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \mathbf{X}'_{it}\boldsymbol{\gamma} + d'_i\boldsymbol{\alpha} + v'_t\boldsymbol{\delta} + e_{it} \tag{1}$$

where P_{it} is a measure of pollution regulations, T_{it} is a measure of trade restrictions, $\mathbf{X}_{it}$ is a set of industry characteristics, and d_i and v_t are cross-section and time dummies. In this context, the direct effect of pollution regulations (P) on imports (M) is captured by the coefficient β_1 in equation (1). Estimation of a negative coefficient on β_1 is taken as evidence for the existence of a pollution haven effect (i.e., more stringent environmental standards result in more imports).

Whether such pollution haven effects exist has taken on great importance in current policy debates, as the existence of such effects is a potential problem in negotiating trade agreements. Specifically, anti-globalization protests (and Executive Order 13141), are concerned that international trade agreements, by lowering tariffs broadly, may enable polluting industries to avoid strict environmental laws by relocating overseas and thus assist in the creation of pollution havens. However, estimation of β_1 tells us nothing about how trade liberalization will influence the composition of industries and hence pollution patterns. Indeed, if equation (1) is correctly specified, then trade agreements and tariff liberalization will have no effect on the composition of industries unless the trade agreements are asymmetrically implemented and result in disproportionately greater tariff reductions in the more pollution-intensive industries.[8]

Many environmental activists, however, are concerned with what we call the indirect effect: the effect of trade liberalization on the direct (pollution-haven) effect. Implicit in this concern is the assumption that pollution-intensive industries are more sensitive to tariff reductions than other industries, and thus a broad-based U.S. tariff reduction will result in a compositional shift with relatively large increases in U.S. imports of pollution-intensive goods. Technically, if the direct effect is $\partial M/\partial P$, then the indirect effect is $\partial^2 M/(\partial P \partial T)$. Empirically, this indirect effect can be measured by adding an interactive term to equation (1) to get

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \beta_3 \overline{P}_i T_{it} + \mathbf{X}'_{it}\boldsymbol{\gamma} + d'_i\boldsymbol{\alpha} + v'_t\boldsymbol{\delta} + e_{it} \tag{2}$$

where β_3 captures the indirect effect of pollution regulations on the sensitivity of trade to tariffs.

Note that we have interacted T_{it} with $\overline{P}_i$, the *average* pollution abatement costs for industry i across all time periods. This means that we are asking whether tariff changes have a larger effect on imports for industries whose average pollution abatement costs are larger. The independent effect of average pollution abatement costs on imports is captured by the industry dummies. We could, of course, have asked a

[8] The coefficient on tariffs, β_2, is constant across industries and is assumed to be independent of the pollution intensity of the industry. Thus, a symmetric tariff reduction on all manufacturing industries will have an equal effect on all industries, and thus no effect on the composition of manufacturing.

slightly different question, by interacting T_{it} with P_{it} , which would estimate the degree to which tariffs have a larger effect on imports for industries whose pollution abatement costs rose more. Or, we could have interacted $\overline{T_i}$ with P_{it} , which would estimate the degree to which increases in pollution abatement costs have a larger effect on industries with higher tariffs. We believe, however, that equation (2) best captures the concerns of Executive Order 13141 and the WTO protests.[9]

We estimate versions of equation (2) in which the dependent variable (M_{it}) is annual imports to the U.S., by four-digit manufacturing SIC code. We have two main motivations. First, we believe that this interactive effect (β_3) is an important test of the effect of trade agreements on the environment. One of the chief mechanisms by which trade will change environmental quality in various countries is by changing the distribution of industries. Countries that host increasingly polluting industries as a consequence of liberalized trade will become more polluted, while countries whose industrial compositions become less polluting will become cleaner. If a trade agreement lowers tariffs on polluting industries, and raises tariffs on clean industries, the environmental consequences will perhaps be obvious. More realistically, if a trade agreement lowers tariffs across the board, the environmental consequences will depend on whether the polluting industries or the clean industries are more responsive to the tariff reductions: in other words β_3 in equation (2).

The policy debate seems to presume that this indirect effect is negative for the U.S. – that lowering tariffs will increase imports more in those industries that have stricter pollution regulations. This inference assumes that the U.S. is at a comparative disadvantage in industries facing stringent environmental regulations and thus, a reduction in tariff barriers will result in a relatively greater import surge in these more regulated industries. We, however, see no particular reason for this to be true as comparative disadvantages can arise from many factors, not just environmental costs.[10] We test for the interaction anyway, because we believe it to be the underlying assumption of so much public debate.

The second important motivation for our empirical strategy is that if equation (2) is the correct specification, then equation (1) contains an important missing covariate that is clearly correlated with pollution abatement costs. The indirect pollution haven effect is thus not only important in its own right, as the focus of policy concerns, but it may also provide an additional explanation for why early attempts to measure the direct pollution haven effect have been biased downwards.

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[9] In section 2.3 below we discuss a sensitivity test, running a version of equation (2) interacting T_{it} with P_{it}, rather than with $\overline{P_i}$.

[10] A similar point is made by Copeland and Taylor (2003), in which they point out that increased trade could shift dirty industries to high-environmental standard (high-income) countries if such countries have a comparative advantage in dirty goods production (due, for example, to relative capital abundance, or labor costs necessary to compensate workers for poor conditions).

2.1 Data

Because only the United States has collected pollution abatement cost data for a significant period of time, researchers studying pollution havens and trade barriers have focused on U.S. imports and exports. This paper, like many before it, starts by following Grossman and Krueger (1993) and regressing manufacturing imports by industry on industry characteristics, as in equation (1). Data on imports to the U.S. come from the *NBER Trade Database*, documented in Feenstra *et al.* (2002). Our dependent variable (M_{it}) is imports divided by the value of shipments, taken from the *NBER Manufacturing Productivity Database* (Bartelsman *et al.*, 2000).[11]

The industry characteristics used include environmental costs, tariffs, capital intensity, and human capital intensity. Environmental costs come from the Pollution Abatement Costs and Expenditures (PACE) survey (U.S. Department of Commerce). We use the data from 1978 to 1994, the last year the PACE data were collected, and focus on pollution abatement operating costs.[12] The PACE data were not collected in 1987, and were not disaggregated by four-digit SIC code in 1979, so we exclude those two years. Our measure of an industry's environmental costs (P_{it}) is pollution abatement operating costs (U.S. Dept. of Commerce) divided by total materials costs (Bartelsman *et al.*, 2000).

Tariffs by four-digit SIC code are taken from Feenstra *et al.* (2002), where the tariff rate for each industry is duties paid divided by the customs value of imports. We converted the 1989-94 data to the 1972 SIC codes using the Bartelsman *et al.* concordance.

Finally, each industry is characterized by its capital intensity and human capital intensity. Like Grossman and Krueger we measure capital intensity as one minus payroll's share of value added:

(3) $$\text{capital intensity} = 1 - \frac{\text{payroll}}{\text{value added}}$$

Human capital intensity is then the total payroll less what would have been paid to workers had each earned the average wage of an 18-year-old worker with less than a high school education, all divided by the value added in the industry:

(4) $$\text{human capital intensity} = \frac{\text{payroll - (low-skill wage)} \times \text{(worker hours)}}{\text{value added}}$$

[11] It should be noted that we strictly follow Grossman and Krueger (1993) in using gross imports (not net imports) as our dependent variable. This is due to the fact that we are estimating the effect of unilateral trade liberalization by the U.S. on its imports (i.e., we do not have foreign tariff data to measure the corresponding effect of foreign tariff liberalization on U.S. exports).

[12] After 1987 the data switch from the 1972 SIC codes to the 1987 SIC codes. We used the concordance in the *NBER Manufacturing Productivity Database* to reallocate pollution costs to 1972 industry definitions.

Income data come from the *Current Population Survey*, May supplemental surveys.

Table 3 presents summary statistics of these data. There are 394 industries, and 15 years of data (1978-1994, less 1979 and 1987 when the PACE data are unavailable). Many 4-digit SIC codes are not reported in the 4-digit PACE data, partly to prevent disclosure of confidential business information. We have omitted these missing observations, resulting in a sample size of 4409.[13] The average U.S. manufacturing industry imported 17 percent of the value shipped by domestic producers, divided about evenly between OECD countries and the rest of the world. The average industry spent 1.1 percent of total materials costs on pollution abatement operating costs, ranging from zero to 18 percent. Tariffs averaged 4.0 percent, ranging from zero to over 40 percent. The question we ask is whether those industries whose tariffs dropped most saw larger increases in imports if their environmental costs were high.

Table 3: The Data

	Means (std. dev.) (1)	**Max (2)**
Dependent variable:	0.169	14.4
gross imports / value shipped	(0.414)	
From OECD countries	0.085	12.1
	(0.261)	
From non-OECD countries	0.084	7.1
	(0.231)	
Environmental cost	0.011	0.176
	(0.015)	
Tariff	0.040	0.41
	(0.040)	
Tariff × Average	0.000346	0.00675
environmental cost	(0.000608)	
Human capital	0.275	0.99
	(0.092)	
Physical capital	0.612	0.95
	(0.120)	
Observations	4,409	
Number of industries	394	

[13] We have run all of the specifications below with the missing environmental cost data treated as zeros, with no change in the substantive conclusions. Coefficients' magnitudes change, but not the pattern of signs nor statistical significances.

2.2 Empirics

Table 4 begins with a basic fixed-effect regression of import penetration, by industry, on industry characteristics from 1978 to 1994. It is a panel-data version of Grossman and Krueger (1993), as represented by equation (1). Industries whose environmental costs increased also saw their imports increase, and industries whose tariffs increased saw imports decrease.[14] Equally sensibly, higher capital intensity and human capital intensity are associated with lower imports. At the bottom of Table 4 we have calculated the elasticity of imports with respect to tariffs (-0.44) as a useful benchmark to compare with later specifications and samples. It suggests that a 10 percent increase in tariffs is associated with a 4 percent decline in imports.

Table 4: Baseline Regressions

Dependent variable: gross imports / value shipped	**Baseline (1)**	**With interaction (2)**
Environmental cost	1.45*	1.86*
	(0.28)	(0.29)
Tariff	-1.84*	-2.17*
	(0.14)	(0.16)
Tariff × Avg. env. cost		50.6*
		(12.4)
Human capital	-0.74*	-0.71*
	(0.22)	(0.22)
Physical capital	-0.44*	-0.42*
	(0.18)	(0.18)
Observations	4,409	4,409
Number of industries	394	394
R-squared	0.91	0.91
Elasticity of imports with respect to tariffs	-0.436	-0.382
Chi-sq. from Hausman test of fixed versus random effects	14.3	124.7

Notes to Table: The regressions are estimated with year and industry fixed effects, and cover the period 1978-94 (1979 and 1987 are omitted due to missing data). The dependent variable is gross imports divided by value shipped.
* statistical significance at the 5% level.

In column (2) of Table 4 we include an interaction term, as in equation (2). Our interpretation of public rhetoric, and EO13141, is that the coefficient (β_3) on this interactive term is expected to be negative. However, in practice the coefficient (50.6) is

[14] The fact that the coefficient on the environmental cost variable is positive and statistically significant is consistent with recent literature that uses time series data and fixed effects, and departs from previous efforts (such as Grossman and Krueger) that relied on a single cross section.

positive and statistically significant. Polluting industries appear to be *less* sensitive to tariff reductions rather than more sensitive, and trade liberalization does not exacerbate the pollution haven effect.[15]

If we take the point estimates from column (2) seriously, and calculate the elasticity of import penetration with respect to environmental costs at the average level of tariffs, that elasticity is -0.38. Though this number is not markedly different from the tariff elasticity when the interaction term is omitted (-0.44), the important point is that the interaction term is positive, so that as we consider industries with lower pollution abatement costs, this estimated elasticity shrinks in absolute value.

We conclude from Table 4 that in general, tariff reductions from 1978 to 1994 did not significantly increase imports more from polluting industries than from clean industries. In fact, the opposite is more likely to be true: if anything, trade liberalization has shifted U.S. industrial composition toward dirtier industries, by increasing imports of polluting goods by less than clean goods.

In previous work, we explored the possibility that environmental regulations have different effects on trade with developing countries than they do on trade with developed countries (Ederington *et al.*, 2005). It seems plausible that the same forces are at work here. Trade agreements may alter the pollution intensity of trade between the U.S. and developing countries, but not with other developed countries.[16]

To test whether trade agreements have increased imports in pollution-intensive industries from developing countries, in Table 5 we run versions of equations (1) and (2) separately for OECD and non-OECD countries. The coefficients are smaller than for the whole sample because the scale of the dependent variable is smaller: imports from OECD divided by U.S. value shipped. Hence comparisons can be made only by examining the relevant elasticities. In column (1) of Table 5, without the interaction term, the elasticity of imports with respect to tariffs (-0.15) is smaller for OECD countries than for all imports. Most importantly, as with the full sample, the interactive term in column (2) of Table 5 is still positive and statistically significant.

The real test, however, comes with imports from non-OECD countries, where the concern about pollution havens is strongest. Once again the interactive term between tariffs and pollution costs remains positive and statistically significant. The point estimate (31.7) implies that tariff reductions have had a *smaller* effect on imports from non-OECD countries in the more pollution-intensive industries. The interacted coefficient in column (4) has exactly the opposite sign to what we perceive to be the conventional wisdom. Rather than the U.S. manufacturing sector becoming cleaner at the expense of the manufacturing sector in developing countries, column (4) suggests

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[15] This result, that polluting industries are less sensitive to tariff reductions, is consistent with previous work (Ederington, Levinson and Minier, 2005), in which we show that polluting industries are less geographically footloose than clean industries. This would make them less sensitive to changes in tariffs as well as to changes in pollution regulations.

[16] Intuitively, if the U.S. is at a comparative disadvantage in dirty goods production (due to high regulatory standards) against developing countries but not other developed countries, then trade liberalization might only result in large increases in polluting imports from the developing world.

that the U.S. manufacturing sector has become more polluting as a consequence of tariff reductions.[17]

Table 5: Trading Partners' Environmental Standards

Dependent variable:	**OECD**		**Non-OECD**	
gross imports / value shipped	**(1)**	**(2)**	**(3)**	**(4)**
Environmental cost	1.03*	1.19*	0.33†	0.58*
	(0.14)	(0.15)	(0.20)	(0.21)
Tariff	-0.31*	-0.44*	-1.52*	-1.72*
	(0.07)	(0.08)	(0.10)	(0.12)
Tariff × Avg. env. cost		18.9*		31.7*
		(6.3)		(8.8)
Human capital	-0.24*	-0.23*	-0.51*	-0.49*
	(0.11)	(0.11)	(0.16)	(0.16)
Physical capital	-0.23*	-0.22*	-0.24*	-0.23*
	(0.09)	(0.09)	(0.13)	(0.13)
Observations	4,409	4,409	4,409	4,409
Number of industries	394	394	394	394
R-squared	0.94	0.94	0.85	0.85
Elasticity of imports with respect to tariffs	-0.146	-0.109	-0.723	-0.653

Notes to Table: The dependent variable in each regression is gross imports divided by value shipped to specified trading partners (OECD countries in columns 1 and 2, non-OECD in columns 3 and 4). All regressions include year and industry fixed effects.
* Statistical significance at the 5% level. † Statistical significance at the 10% level.

2.3 Democracy, Endogeneity, and Other Concerns

A number of readers have speculated that trade liberalization might have a larger effect on imports from dictatorships than from democracies. The intuition may not be explained by any formal trade theory, but rather by the notion that an oppressive government has a comparative advantage in that citizens with fewer civil liberties cannot vote for environmental policies and workplace safety laws that raise production costs. We have estimated a version of Table 4 separately for dictatorships and democracies, as defined by the Freedom House (2004) index of political rights, which is commonly used in empirical studies involving democracy. Freedom House assigns countries an index value from 1-7. The typical classification is that countries indexed 1-2 are "free," and those indexed 6-7 are "not free."

Appendix Table A contains a version of the basic specifications. Column (1) uses only imports from "non-dictatorships," with Freedom House indices from 1 to 5. The results are essentially the same as for the full specifications in Table 4. Column (2)

[17] This result is actually consistent with those of Antweiler et al., (2001) and Copeland and Taylor (2003) who, using a different technique, estimate that trade integration has shifted dirty-goods industries to high-standard (high-income) countries. (See fn. 7.)

uses only imports from "dictatorships," with Freedom House indices of 6 or 7. Here the direct effects of environmental costs are small and insignificant, but the direct effect of tariffs and the indirect effect of tariffs on high-environmental-cost industries are about the same as for the full sample. In other words, separating out the dictatorships does not change the substantive conclusion that trade liberalization does not increase imports of polluting industries any more than clean industries.

Another concern raised by many analysts of the pollution haven literature, ourselves included, is that regressions of trade flows on pollution costs suffer from endogeneity problems. It may be that countries use environmental policy as a strategic substitute for tariffs (Ederington and Minier, 2003). Or, it could be that the proxy for regulatory stringency, expenditures on pollution abatement, is a function of trade, if trade changes the composition of sub-industries within each 4-digit SIC code (Levinson and Taylor, 2004).

While these issues are not the focus of this paper, in column (3) of Appendix Table A we have tried employing the instruments from Levinson and Taylor (2004). That paper constructs an instrument based on the geographic dispersion of industries throughout the U.S. The idea is that industries concentrated in states whose environmental standards increased most will have experienced the highest run-up in environmental costs. So long as the geographic dispersion of industries throughout the U.S. is unrelated to import penetration, the geographic dispersion will be a good instrument for an industry's environmental regulatory costs. (See Levinson and Taylor for details.) The current paper represents a slightly different application: four-digit industries rather than three-digit industries, the dependent variable is gross rather than net imports, the regulatory proxy is pollution abatement cost over the cost of materials rather than value added, and the data run from 1974-1994, rather than just 1977-1986. Nevertheless, column (3) of Appendix Table A estimates a version in which P_{it} is instrumented using the Levinson and Taylor instruments. The environmental cost coefficient (2.86) is larger than in Table 4, but is statistically insignificant in this case. (We have fewer years of data and industries.) The interaction term, which is the focus of this paper, is smaller (13.7), and statistically insignificant, but still positive. So the basic finding from Table 4 survives. Industries whose environmental compliance costs are largest are not more responsive to tariff reductions.

Because of the concerns about endogeneity, we do not want to interpret the results in Tables 4 and 5 causally. Rather, the estimates in Tables 4 and 5 are conditional correlations that tell us that imports have increased more in industries whose tariffs have fallen the most, but that this conditional correlation is not larger for industries that are more pollution-intensive. Trade liberalization does not seem to be associated with increased imports from relatively pollution-intensive industries.

Finally, some commentators have argued that the correct version of equation (2) would interact tariffs T_{it} with current pollution costs (P_{it}), rather than with average pollution costs ($\overline{P_i}$). In column (4) of Appendix Table A we estimate that alternative model. All of the resulting coefficients are statistically indistinguishable from those in equation (2) except for the coefficient on P_{it} alone. This is because most of the variation in P_{it} is across industries rather than within industries over time, the cross-industry variation is soaked up by industry fixed effects, and including the interaction $P_{it}T_{it}$ means there are *two* right-hand-side variables trying to capture the effect of time-series variation in pollution costs.

In short, the basic result holds for a variety of alternative specifications (separating imports from dictatorships, instrumenting for pollution costs, and including a time-varying interactive term). Imports of pollution-intensive goods do not appear to be more sensitive to tariff reductions than imports of clean goods.

3. Predicted Pollution Changes

Tables 4 and 5 examine whether pollution-intensive industries are more responsive to broad-based tariff reductions than clean industries, and find just the opposite. Thus our estimates imply that symmetric tariff reductions in the U.S. would have actually shifted the composition of U.S. manufacturing toward dirtier industries. There is, however, an alternative mechanism through which the trade agreements could make U.S. manufacturing cleaner. It might be that trade agreements, either past or future, are skewed toward pollution-intensive industries. If tariffs fell *more* for polluting industries than for clean industries from 1978 to 1994, then trade liberalization might be said to have caused a shift of polluting industries overseas, even if the interactive coefficient β_3 in equation (2) is zero. Alternatively, if current tariffs are higher for polluting industries than for clean industries, then future trade agreements that lower all tariffs to zero might be expected to shift polluting industries overseas.

The first thing to note is that on average, industries whose tariffs fell further had higher pollution abatement costs than industries whose tariffs rose, or fell by less. Specifically, the raw correlation between the change in tariffs from 1978 to 1994 and average pollution costs is -0.19, which is statistically significantly different from zero. While this correlation is not strong, it lends plausibility to the claim that tariff reductions might have caused the shift in U.S. manufacturing composition, because the reductions were skewed toward polluting industries. That said, those industries that experienced the very largest tariff reductions are not among the most polluting industries.[18]

To explore the magnitudes of the correlations between environmental costs and tariff reductions, in Table 6 we predict the declines in U.S. pollution resulting from U.S. tariff reductions from 1978 to 1994 using the coefficients of Table 4. In column (1) of Table 6 we list the estimated change in the emissions of the 14 pollutants modeled by the World Bank's Industrial Pollution Projection System (IPPS) due to scale effects and compositional shift in U.S. industries. These are the same data used to generate Figure 1, but for the shorter time period for which pollution abatement cost data are available.

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[18] The five industries that have experienced the largest tariff reductions are SIC 2252 "Hosiery, not elsewhere classified," SIC 2322 "Mens' & boys' underwear & nightwear," SIC 2075 "Some fat/oil not cottonseed," SIC 2342 "Bras, girdles, and allied garments," and SIC 2341 "Womens' & childrens' outerwear."

To generate the numbers in column (1), we used the IPPS coefficients to predict the amount of pollution generated in each industry in 1978 and then aggregated across all industries. We did the same for 1994 and then reported the percentage change between 1978 and 1994. The numbers differ because industries with varying pollution intensities for different pollutants grew by different amounts during the period.

As in Figure 1, while the real value of manufacturing output increased by 36 percent from 1978 to 1994, the predicted pollution either rose by much less, or declined outright. This is because the manufacturing industries have shifted toward those that produce less pollution. In other words, while manufacturing output increased, predicted airborne particulate emissions declined by 6.4 percent because those four-digit industries that produce the most particulates declined over the period, while those that produced the least increased their output.

Table 6: Predicted Pollution Changes

Pollutant	Percent change in pollution 1978-1994 (1)	Percent change relative to real manufacturing growth (2)	Predicted percent change in pollution 1978-1994 (3)	Percent change from 1994 if tariffs set to zero. (4)
Air pollution				
Particulates	-6.4	-31.1	-3.0	-1.6
CO	-19.3	-40.6	-1.2	-1.0
SO2	-12.7	-35.8	-1.6	-1.5
NOx	-5.8	-30.7	-2.3	-2.2
VOC	+4.5	-23.1	-3.0	-3.0
PM10	-17.5	-39.3	-2.0	-1.3
Water pollution				
BOD	+26.9	-6.6	-1.1	-3.8
TSS	-29.2	-47.9	-1.4	-1.6
Toxics				
Air	+12.8	-17.0	-3.2	-2.3
Land	-3.5	-29.0	-1.4	-2.5
Water	-4.4	-29.7	-1.1	-1.4
Metals				
Air	-21.4	-42.2	-1.7	-1.4
Land	-20.9	-41.8	-1.4	-1.0
Water	-10.5	-34.1	-1.1	-0.9

Source: authors' calculations from World Bank Industrial Pollution Projection System, the NBER Manufacturing Industry Productivity Database (Bartelsman *et al.,* 2000), NBER Tariff Data (Feenstra *et al.*, 2002).

To represent the pollution changes in column (1) of Table 6 comparably with the predictions from the regression coefficients, in column (2) we report the predicted change relative to the change in real manufacturing growth. For example, the decline in particulates of 6.4 percent represents a 31 percent decline relative to the 36 percent growth in manufacturing. ([1-0.064]/[1.36]-1 = -0.31) This amounts to examining the composition effect alone, eliminating both the scale and technique effects.

In column (3) we use what we know about the changes in tariffs over this time period to ask whether the fact that tariff reductions were steeper in more polluting industries could have caused this shift in U.S. manufacturing toward cleaner industries, presumably at the expense of other countries' environmental quality. We used the tariff coefficients from column (2) of Table 4, along with the actual industry-level tariffs and environmental costs, to predict the changes in imports (as a share of value shipped) that resulted from U.S. tariff reductions. We then multiplied this result by the actual value shipped in each industry, to get the predicted change in imports. We then assumed as a benchmark that changes in imports are offset dollar-for-dollar with domestic production, so we can multiply the import change by the IPPS coefficients to get predicted changes in pollution emanating from each industry.[19] Finally, we aggregated these pollution changes across all industries, and divided this Figure total by the total estimated pollution as of 1978, to get the predicted percentage changes reported in column (3).

As column (3) shows, predicted pollution declined only slightly due to the varying declines in industry-specific tariffs. Given the degree to which tariffs declined over this time period, the predicted effect of this on imports, and the predicted pollution associated with each industry, imports are sufficient to replace between 1 and 3 percent of pollution generated by U.S. manufacturing. This change is small relative to the overall shift in U.S. manufacturing toward cleaner industries demonstrated in column (2). Though tariff reductions have been steeper in more pollution-intensive industries, that can explain only a small part of the shift of U.S. manufacturing toward cleaner industries.

There is, however, one last interpretation of the environmental opposition to trade liberalization that we can examine with these data. Observers could be concerned that *current* tariff levels offer more protection to polluting industries than to clean industries, and that *future* trade agreements that lower all U.S. tariffs to zero could cause U.S. polluting industries to relocate overseas more than relatively clean industries. In column (3) of Table 5 we predict the change in U.S. manufacturing pollution that would result from a drop in tariffs from their 1994 levels down to zero. For each four-digit SIC code we calculate the level of the 1994 tariffs (from Feenstra *et al.*, 2002). We then use the tariff and interactive coefficients from Table 4 to predict the change in imports that would result from reducing these 1994 tariffs to zero. We then assume as a benchmark that those imports replace U.S. production, and use the IPPS pollution coefficients to generate the resulting change in each of the 14 pollutants. As column (4) shows, this results in very small changes in pollution relative to actual changes over the 1978 to 1994 period. Once again, we find little basis for the fear that tariff reductions themselves will generate large shifts in the composition of U.S. manufacturers away from polluting industries.

[19] Note that this exaggerates the pollution changes, because the IPPS coefficients are calculated per dollar of *value added*, and we multiply by *value shipped*.

4. Conclusions

The "trade and environment" debate has captured public interest, from the street protests outside WTO meetings to President Clinton's executive order requiring that trade agreements be accompanied by environmental impact statements. The general consensus seems to be that tariff barriers protect U.S. manufacturers that would otherwise move overseas to avoid increasingly strict U.S. environmental standards, and that trade agreements, by lowering these tariffs, will disproportionately affect the most polluting industries.

This story is, on the surface, consistent with recent U.S. experience that has seen the U.S. manufacturing sector shift toward cleaner industries. As we show in this paper, while manufacturing's real value added grew by 51 percent from 1972 to 1994, that growth occurred mostly among the least polluting industries, causing the estimated emissions of most of the 14 pollutants tracked by the World Bank's IPPS to rise by much less than 51 percent, or even to decline. This shift has occurred simultaneously with a general reduction in U.S. tariff barriers due primarily to the success of GATT negotiations.

We show, however, that these two trends appear unrelated. We find no evidence that domestic production of pollution-intensive goods in the U.S. is being replaced by imports from overseas. In addition, we find that symmetric tariff reductions in the U.S. have most likely induced a compositional change toward dirtier industries (not cleaner) among U.S. manufacturing. Finally, while polluting industries have experienced larger tariff reductions than other industries in the U.S., these differences in tariff reductions do not appear to be of sufficient magnitude to explain more than a small fraction of the shift in U.S. manufacturing toward cleaner industries.

Appendix

Appendix Table A: Extensions

Dependent variable: gross imports / value shipped	**Imports from non-dictatorships (1)**	**Imports from dictatorships (2)**	**2SLS version 1977-1987 (3)**	**With $P_{it} \times T_{it}$ interaction (4)**
Environmental cost	1.60*	0.08	2.86	0.19
	(0.23)	(0.15)	(3.67)	(0.34)
Tariff	-0.97*	-1.15*	-0.55	-2.15*
	(0.13)	(0.08)	(0.42	(0.15)
Tariff × Avg. env. cost	24.02*	25.7*	13.7	
	(9.78)	(6.3)	(32.3)	
Tariff ×Annual env. cost				54.1*
				(8.2)
Human capital	-0.56*	-0.15	-0.84*	-0.76*
	(0.18)	(0.11)	(0.34)	(0.22)
Physical capital	-0.36*	-0.10	-0.48†	-0.46*
	(0.14)	(0.09)	(0.27)	(0.18)
Observations	4,409	4,393	1731	4,409
Number of industries	394	393	307	394

Notes to Table: The regressions are estimated with year and industry fixed effects, and cover the period 1978-94 (1979 and 1987 are omitted due to missing data). The dependent variable is gross imports divided by value shipped. "Dictatorships" are defined as counties with Freedom House (2004) indices of 6 or 7 on a scale from 1 to 7. Column (4) uses instrumental variables as in Levinson and Taylor (2004).
* statistical significance at the 5% level. †Statistical significance at the 10% level.

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