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WPS-0964

Policy Research

WORKING PAPERS

World Development Report

Office of the Vice President
Development Economics
The World Bank
August 1992
WPS 964

Background paper for World Development Report 1992

Toxic Releases by Manufacturing

World Patterns and Trade Policies

Robert E. B. Lucas

Would free trade result in greater and more rapid environmental degradation for developing countries? Less protection of their domestic industrial chemical industries would reduce the pollution-intensity of their manufacturing sector — but merely relocating firms that emit globally damaging toxins clearly misses the point.

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World Development Report

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This paper — a product of the Office of the Vice President, Development Economics — is one in a series of background papers prepared for the *World Development Report 1992*. The *Report*, on development and the environment, discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Copies of this and other *World Development Report* background papers are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact the *World Development Report* office, room T7-101, extension 31393 (August 1992, 25 pages).

Little evidence exists on the distribution across countries of toxic releases by manufacturing, or on how those patterns change through time.

A number of studies have asked whether environmental controls imposed in the industrialized economies are diverting investments in pollution-intensive activities offshore. These studies reach a broad negative conclusion: direct investment does not appear to be stimulated by such regulation, in part because the cost of emission controls is generally a tiny fraction of operating costs.

But direct investment reflects only part of what may be happening to world production patterns. Technology transfers may occur with no simultaneous direct investment, and production may readily shift toward a different global distribution without either direct investment or technology transfer.

Lucas presents the evidence on the world distribution of manufacturing production according to pollution density — using data from the World Bank Industrial Pollution Projections Team. He then examines the validity of the claim that free trade would result in greater and more rapid environmental degradation for developing countries. He finds that:

- The onus is on the higher-income countries to contain the emissions of their increasingly pollution-oriented mix of manufacturing industries.

- The global trend has been toward an increasingly emission-intensive pattern of production, in relation to both manufacturing and to GDP. This trend has been remarkably constant over three decades and shows no signs of slowing.

- The upward trend in emission-intensity of manufacturing production has been faster among lower-income nations. If pollution restraints on given industries are progressing more rapidly among the wealthier countries, this disparity would be even sharper than the Bank data suggest.

- Developing countries that produce coal, crude oil, or natural gas also have more pollution-intensive manufacturing sectors, based on the availability of those raw materials. It may be doubted that fostering such industries always reflects a comparative advantage. Petrochemical industries in the coal-oil-gas-producing countries are often substantially protected or subsidized.

- Among all developing countries, import protection stimulates a larger chemicals industry and thus more emission-intensive manufacturing. One might guess that less protection of local industrial chemical industries would decrease the pollution-intensity of the developing countries' industry. But merely relocating firms that emit globally damaging toxins clearly misses the point.

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Toxic Releases by Manufacturing: World Patterns and Trade Policies*

Robert E.B. Lucas
Boston University

Background Paper Prepared for the
World Development Report 1992

The World Development Report 1992, "Development and the Environment," discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Under current practices, the result could be appalling environmental conditions in both urban and rural areas. The World Development Report presents an alternative, albeit more difficult, path - one that, if taken, would allow future generations to witness improved environmental conditions accompanied by rapid economic development and the virtual eradication of widespread poverty. Choosing this path will require that both industrial and developing countries seize the current moment of opportunity to reform policies, institutions, and aid programs. A two-fold strategy is required.

- First, take advantage of the positive links between economic efficiency, income growth, and protection of the environment. This calls for accelerating programs for reducing poverty, removing distortions that encourage the economically inefficient and environmentally damaging use of natural resources, clarifying property rights, expanding programs for education (especially for girls), family planning services, sanitation and clean water, and agricultural extension, credit and research.
- Second, break the negative links between economic activity and the environment. Certain targeted measures, described in the Report, can bring dramatic improvements in environmental quality at modest cost in investment and economic efficiency. To implement them will require overcoming the power of vested interests, building strong institutions, improving knowledge, encouraging participatory decisionmaking, and building a partnership of cooperation between industrial and developing countries.

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Robert E.B. Lucas, David Wheeler, and Hemamala Hettige, "Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: 1960-1988"

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Other (unpublished) papers in the series are available direct from the World Development Report Office, room T7-101, extension 31393. For a complete list of titles, consult pages 182-3 of the World Development Report. The World Development Report was prepared by a team led by Andrew Steer; the background papers were edited by Will Wade-Gery.

Table of Contents

* A later version of this paper, prepared in conjunction with Hemamala Hettige (Industry/Energy Department, World Bank) and David Wheeler (Environment Department, World Bank), and entitled "Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: 1960-1988", is also available in the Policy Research Working Paper Series.

Introduction

Little evidence exists on the distribution across countries of toxic releases by manufacturing, or on how those patterns are changing through time. A number of studies have asked whether environmental controls imposed in the industrialized economies are diverting investments in pollution intensive activities off-shore.[1] In broad terms these studies reach a negative conclusion: direct investment does not appear to be stimulated by such regulation, in part because the cost of emission controls is generally a tiny fraction of operating costs. Yet direct investment reflects only a portion of what may be happening to world production patterns; technology transfers may occur with no simultaneous direct investment and production may readily shift toward a different global distribution without either direct investment or technology transfer.

Consequently, this paper has a two-fold purpose. The first is to present evidence on the world distribution of manufacturing production according to pollution intensity. This examination is made possible by the availability of a new data source compiled by the World Bank Industrial Pollution Projections Team. These data are described briefly in Section I and some results on estimated world patterns of toxic releases, and how these are changing through time, are presented in Section II.

The second is to examine the validity of the claim that free trade would result in greater and more rapid environmental degradation for developing countries. Section III considers some of the issues surrounding this idea and offers some empirical evidence from the manufacturing sector.

I. Data Sources and Limitations

The World Bank Industrial Pollution Projections Team has compiled intensities of toxic releases per dollar's worth of output in the USA, for every three digit -- and a selection of four digit -- industries on the International Standard Industrial Classification. There are two primary

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1. Dean (1991) offers a very useful survey of this material.

data sources for these intensity measures. First, a sample of 15,000 plants is drawn from the US Environmental Protection Agency Toxic Release Inventory; this latter reports air, water, underground and solid waste releases for 320 toxic substances. After matching these data with observations on the same 15,000 plants from the US Census of Manufacturing, the second primary source, emissions per unit of output are calculated.

The present paper focuses upon three intensity measures generated from the above sources. The first is the number of pounds of all 320 toxic releases -- atmospheric, effluent or solid -- per dollar's worth of output. In Table 1, this measure is referred to as total emissions. Clearly though, some toxic wastes are of greater concern than others. The USEPA consequently assigns a risk index, ranging from 1 (low risk) through 4 (high risk), to each of the 320 toxic substances monitored, according to their threat to humans. The second intensity measure, compiled by the World Bank Industrial Pollution Projections Team, uses these risk factors as weights in a linear weighted sum of toxic releases per dollar's worth of output.

The implicit assumption in such a measure is that the USEPA risk scale is inherently linear; one pound of risk factor 4 emissions is presumed to be as damaging as four pounds of risk factor 1 releases. This assumption may not be accurate. Hence a third intensity measure assigns -- admittedly somewhat arbitrarily -- exponential weights to the USEPA's four risk factors (1, 10, 100 and 1000). In Table 1, the latter two measures are referred to as the linear and exponential intensities respectively.

Two features of these intensity measures are worth noting at the outset. First, the simple (unweighted) correlation of the three measures is very high across industries:

Correlation Coefficients
Industry Toxic Intensity

	Linear Weights	Exponential Weights
Total	0.995	0.944
Linear Weights		0.941

In other words, although the three measures offer different representations of toxic emission

Table 1 Toxic Release Intensities by Manufacturing Industries

Industry	ISIC Code	Total[2]	Weighted Risk Factor Linear	Exponential
Food Products	3110	781.6	1418.0	20776.7
Beverages	3130	205.1	387.1	4647.5
Tobacco	3140	489.0	977.9	5308.9
Other Textile Production	3210	3502.2	6289.7	51086.7
Spinning, Weaving	3211	3106.7	7400.0	154381.3
Wearing Apparel	3220	1744.8	3341.8	17515.8
Leather & Products	3230	15380.7	25762.0	268922.3
Footwear	3240	2277.7	3324.0	11695.0
Wood Products	3310	4399.4	9247.0	137294.6
Furniture, Fixtures	3320	5366.8	10056.8	61291.0
Other Paper Products	3410	8741.7	16897.6	98109.5
Pulp, Paper	3411	6225.9	11720.6	116899.8
Printing, Publishing	3420	7513.9	14931.6	109252.0
Other Industrial Chemicals	3510	52260.3	105302.7	966600.0
Basic Industrial Chemicals	3511	32254.6	54922.9	609770.9
Synthetic Resins	3513	14002.9	26436.7	544602.8
Other Chemical Products	3520	3563.8	6582.8	58049.0
Drugs and Medicines	3522	3966.7	7416.5	42819.7
Petroleum Refineries	3530	3757.9	7669.5	78634.6
Petroleum & Coal Products	3540	2544.1	4777.4	29444.3
Rubber Products	3550	2934.2	5385.5	26305.2
Plastic Products n.e.c.	3560	9335.0	17310.5	175559.9
Pottery, China, etc.	3610	3614.5	5479.4	29164.7
Glass & Products	3620	1481.2	2893.2	43583.8
Non-Metal Prods. n.e.c.	3690	3853.8	5920.2	44194.1
Iron and Steel	3710	7642.8	12931.9	349897.7
Non-Ferrous Metals	3720	9334.3	13234.7	151219.2
Metal Products	3810	4592.5	9103.6	166930.2
Other Machinery n.e.c.	3820	1596.2	2840.5	39165.8
Office & Computing Machinery	3825	303.3	452.4	3163.4
Other Electrical Machinery	3830	1797.3	3195.2	38967.4
Radio, Television, etc.	3832	1808.3	3137.4	29207.4
Transport Equipment	3840	1007.8	2085.8	28055.7
Shipbuilding, Repair	3841	2546.5	3743.2	17426.9
Motor Vehicles	3843	666.9	1188.4	15733.1
Professional goods	3850	887.6	1576.5	16127.0
Other Industries	3900	2706.8	4679.0	42682.7

2. lbs. per million 1987 US dollars.

intensities, their levels move quite closely together across the 37 industrial categories. As a result, most of the analysis in this study will focus upon total emissions rather than risk-weighted measures.

The second feature to note is that all three measures peak for Industrial Chemicals (ISIC codes 3510 and 3511). This feature helps explain the high correlation just noted; as discussed later, it is also significant in the context of protectionism (see Section III).

The international distribution of toxic emissions from manufacturing is examined here by applying the intensity measures from Table 1 to the mix of industrial outputs reported for various countries.[3] This, of course, involves certain assumptions, including the following:

- The application of observed US emission intensities to other countries assumes similar technologies and enforcement standards across countries. For instance, to the extent that lower income countries have more pollution-intensive techniques for given industries than does the US (whether because of the state of know-how, differing regulations, or greater difficulty in enforcement), the measures generated here understate toxic outputs from lower income nations. On the other hand, if emissions per unit of output are roughly similar across countries, then the measures provide a reasonable approximation.

- Closely related to the above is an issue arising from the level of disaggregation available in the industrial data. The application of US intensities to other countries assumes either that the pollution intensity of various products within an industry group are not too dissimilar or that the mix of products within each industry is essentially the same across countries.

- Emissions are assumed to relate to output by an industry rather than, for instance, to value added. It is not obvious that this is an unreasonable assumption; the limited availability of international data on value added prevented exploring sensitivity with respect to this assumption.

Despite these limitations, the evidence presented in this paper nonetheless conveys some useful preliminary insights about the implications for toxic emissions of the international patterns in manufacturing production.

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3. The source of data for manufacturing output is the United Nations Industrial Statistics Yearbook. These data are deflated using the GDP deflator for each country since specific deflators for each manufacturing sector are generally not available.

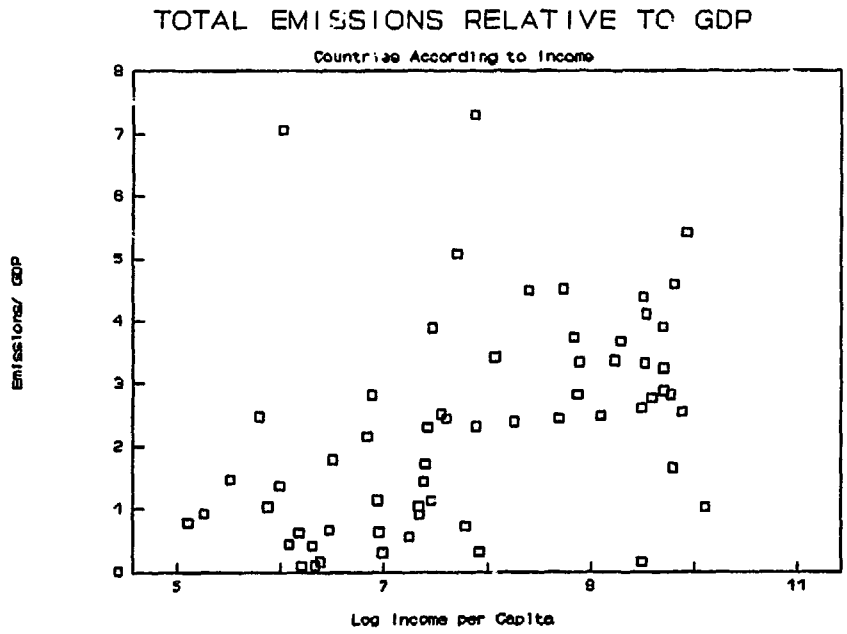
II. International Patterns in Toxic Emissions

This section of the paper presents a picture of the international distribution of toxic emissions from manufacturing, and of how this is changing over time.

1. Patterns across Countries

A cross-sectional view of 61 countries in 1980 is depicted in Figure 1.

FIGURE 1



The measure on the vertical axis is pounds of toxic emissions per 1000 US 1987$ of GDP in each country. Although there is a good deal of dispersion in this index of toxic emissions, a rough pattern may be seen: emissions first rise and then fall with income per capita. This is brought out quite clearly in a regression of this same index (EG) on both income per capita (Y)

and income per capita squared (Y2):[4]

EG = 1.368 + 0.349 Y - 0.0139 Y2	No. obs.	61
(4.37) (4.24) (3.43)	Adj-R^2	0.18
	F-Stat	7.75

According to this regression, the turning point is at an income of around 12,500 1987 US dollars in 1980. Thus, it is only in high income countries that rising incomes are accompanied by improving emissions per unit of GDP.

The inverted U-shape pattern observed in manufacturing emissions relative to GDP might have two separate causes: it might be first, a result of a pattern in the proportion of GDP derived from manufacturing, or second, a result of changing composition within manufacturing. To examine these possibilities, Figure 2 depicts the latter -- manufacturing emissions per unit of manufacturing output graphed against income per capita for various countries in 1980.

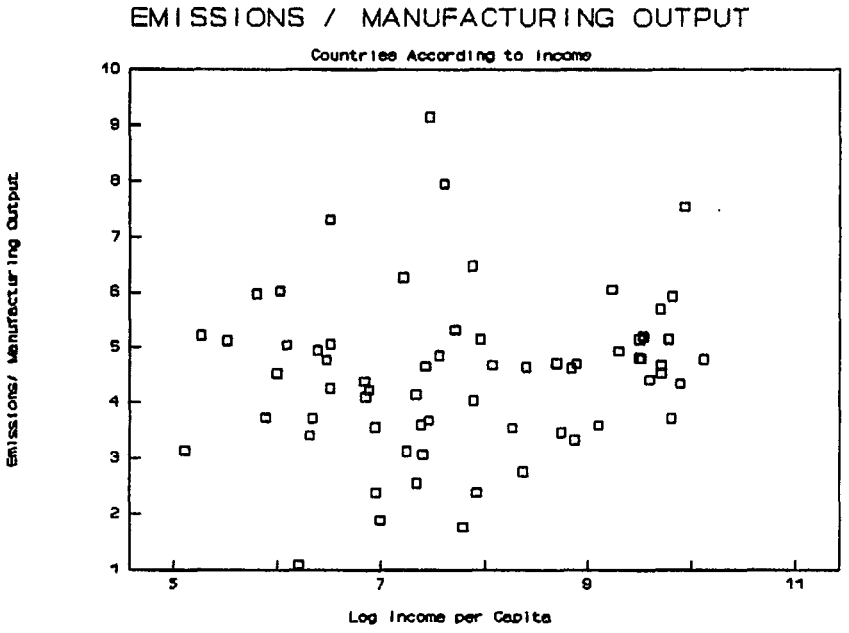
No obvious inverted U-shape is discernible in Figure 2. This is confirmed by the following regressions in which EM refers to lbs of emissions per 1000 1987 US dollars' worth of manufacturing output:

EM = 4.353 + 0.004 Y + 0.0021 Y2	No. obs.	66
(15.07) (0.06) (0.57)	Adj-R^2	0.01
	F-Stat	1.46
EM = 4.286 + 0.044 Y	No. obs.	66
(17.02) (1.96)	Adj-R^2	0.03
	F-Stat	2.77

Emissions relative to manufacturing output rise significantly with income levels across countries (albeit with a great deal of variation around this rising pattern) and there is no evidence that this rising pattern turns down. In other words, the inverted-U in manufacturing emissions relative to GDP appears to be largely a result of a decline in the value of manufacturing output

4. Income per capita is rescaled to 1000 1987 US $. Figures in parentheses are T-statistics for a zero null-hypothesis. Standard errors are computed using the heteroskedasticity robust method suggested by White (1980).

FIGURE 2



relative to GDP amongst the highest income nations.

2. Patterns across Time

How has the international pattern of toxic emissions from manufacturing shifted over time? To answer this question, annual observations on the logarithms of the two intensity measures already considered -- intensity relative to total GDP and intensity relative to manufacturing output -- are simply and separately regressed on time for each country.[5] The resultant estimated time trends for each country are graphed against the logarithm of income per capita in Figures 3A and 3B respectively.

5. The period of observation as well as the number of observations differ from country to country depending upon data availability. The mean number of observations available in the case of both indices is between 19 and 20. For all countries the potential range of observation considered is from 1960 through 1988.

COUNTRY TRENDS IN EMISSION INTENSITIES

FIGURE 3.A

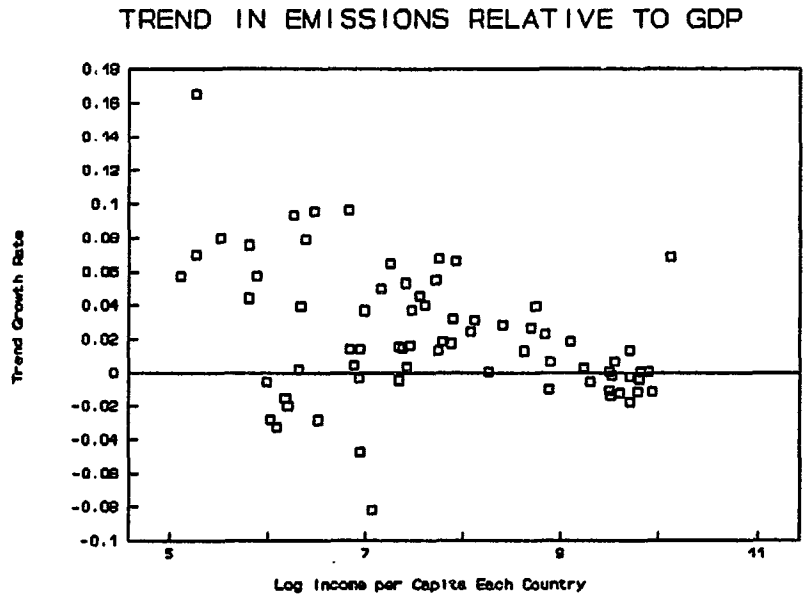
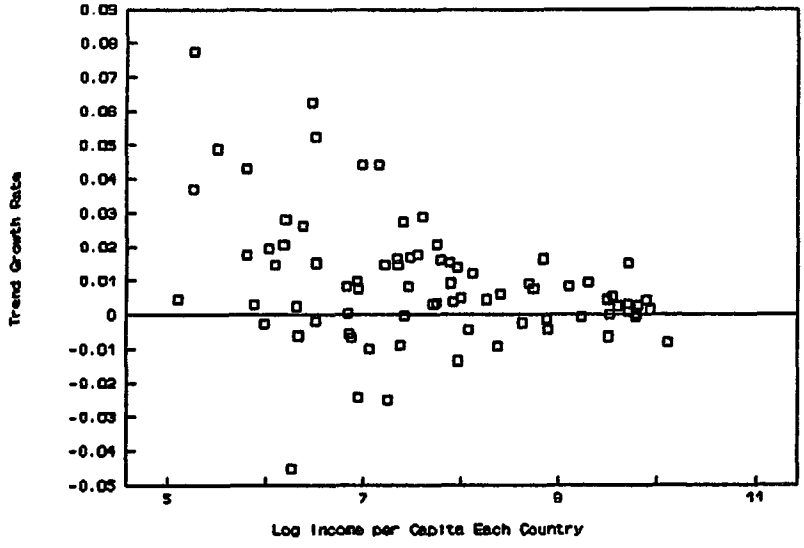


FIGURE 3.B



For the majority of countries both trend growth rates are positive -- emission intensities have broadly risen over the last three decades in most countries. But it is also apparent from both portions of Figure 3 that emission intensities have risen more rapidly in the lower income nations. The significance of this pattern is confirmed in the regressions reported in Table 2.

Table 2 Toxic Release Intensity Trends Regressed Upon Income Per Capita

	Emissions Relative To			
	GDP		Manufacturing Output	
Intercept	0.151 (5.09)	0.023 (5.14)	0.068 (5.17)	0.009 (4.31)
Log(Income per Capita)	-0.015 (4.02)		-0.007 (4.45)	
1/Income per Capita	14.01 (3.43)		6.199 (2.50)	
No. Obs.	51	51	59	59
Adj-R^2	0.32	0.35	0.32	0.26
F-Stat.	28.9	27.38	27.40	20.97

T-statistics in parentheses.

In particular, Table 2 expresses the trend in emissions, relative to either manufacturing output or GDP as a whole, first as a linear function of the natural logarithm of a country's income per capita then as asymptotically approaching zero as income per capita rises. Each of these four regressions demonstrates a significant negative association between the trend in emission intensities and income per capita across countries.

III. International Trade and Emissions Patterns

Why has the intensity of toxic emissions relative to production risen more quickly in lower income countries? Why does the emission intensity of production rise (at least initially) with income levels? This section sketches a number of hypotheses, then offers some related

evidence.

1. Possible Hypotheses

(i) Private Comparative Advantage

In the absence of binding controls on the generation of environmental bads -- including failure of private contractual arrangements to contain damaging effects -- negative externalities will result in over-production and over-consumption of environmentally harmful commodities. Free trade in such an unregulated context results in a distribution of production across countries based on comparative private cost advantages without regard to environmental costs: the capacity or willingness of nations to withstand or accept environmental damage does not enter the trade calculus. The result is a distribution of production and consumption that is determined without regard for local or global environmental consequences. Residents of some countries may be comparatively lucky, if the resultant production near their domicile happens to generate less locally damaging effects, and if their fellow consumers pick products which are less harmful.

As nations develop the range of commodities in which they have a private comparative cost advantage, trade obviously shifts. Shifts result from accumulating capital available per worker, from improvements in the state of know-how and worker skills, or from enhanced identification of -- or ability to exploit -- natural resources. The more rapid expansion in toxic-emission intensive production in lower income countries could consequently reflect simple shifts in world private cost advantages over time -- shifts which coincidentally result in greater emissions being located in developing countries. Rising manufacturing emission intensity with income may simply be a reflection of a shift toward comparative advantage in manufacturing generally, and of more capital intensive (smoke-stack) industries, which also happen to be pollution intensive, in particular.

(ii) Environmental Regulation

The standards required by environmental regulations vary substantially across countries -- this, however, is not without some justification.

(a) One reason different nations will wish to impose different standards results from the inequality in world incomes. The desire for a cleaner environment is presumably a

normal good, in the sense that demands for tighter standards rise with income. Lower income countries would then be less concerned to avoid local environmental damage, as indeed were the advanced nations at an earlier stage in their growth.

(b) A second reason to anticipate some difference in imposed standards stems from variations in capacity to withstand environmental damage. More sparsely populated areas may conceivably be less concerned to avoid specific kinds of pollution. Being able to locate industries with emissions harmful to humans far from densely populated areas, presumably has its attractions. On the other hand, certain sparsely populated regions exhibit particularly fragile eco-systems with a diminishing capacity to withstand toxic releases.

(c) A third reason for different standards relates to variations in enforcement capacities. Such differences may rationalize differences in legislated norms and help in understanding gaps in enforced standards.

In principle, regulating environmental damage and taxing emissions can be used to internalize the external costs stemming from pollution in its various forms. To be effective, these instruments must alter production costs and hence comparative cost advantage in trade. If the externalities inherent in environmental damage are appropriately contained, then trade will take place according to the social comparative advantage of nations, an advantage defined by a balance of environmental and other costs. But since both private costs and environmental costs differ from country to country, there is unlikely to be an even spatial distribution of toxic emissions in an optimally regulated world. Indeed, it is probable that rising incomes may first give rise to worse emission levels, as cost advantage shifts toward smoke-stack pollution intensive industries, to be overtaken at higher income levels by electoral demands for a cleaner environment and perhaps enhanced capacity for enforcement.

(iii) The Effects of Protectionism

Factor costs, know-how, natural resource base, capacity and willingness to withstand environmental damage, and ability to enforce regulations, all help define the social comparative advantage of nations with respect to environmental bads. But the world trading system is by no means entirely molded according to social comparative advantage. Protectionism is rampant in developing and better off economies alike. Whether the vagaries of this system are such as to shift pollution-intensive activities towards lower income economies, perhaps irrespective of

social comparative advantage, is an open question of some importance.

2. Towards Testing

Is the more rapid rise in emission intensities in lower income countries a result of more rapid economic growth or does it reflect some other trend? Are there identifiable breaks in this trend and do these coincide with changing standards in richer nations? Is there any indication that more pollution-intensive activities are relocating to countries more capable of withstanding the resultant damage? What characterizes those countries which exhibit particularly high emission intensities? And what role does protectionism appear to play in this process?

Clearly some eco-systems are far more fragile than others, but it is difficult to quantify this meaningfully. Consequently, rather than trying to address the broader question of whether pollution intensive activities are relocating to more fragile environs, we begin by asking a much simpler question: are emission intensive activities concentrated in less populous countries (where there may be less potential for damage to humans near emitting plants)?

The evidence (see Figure 4) indicates that countries with higher population densities have no lower levels of emissions, relative to either GDP or manufacturing output. An important clue to the identity of countries which do have abnormally high emission intensities, derives from our earlier observation on the dominant role of the industrial chemicals industries in generating toxic emissions. Which countries tend to have particularly large industrial chemical industries and hence high emissions? The possession of coal, oil or gas deposits proves a key to understanding the spatial distribution of Industrial Chemicals manufactures. This is reflected in Figure 5, which shows the average toxic emissions from manufacturing relative to GDP (top graph), and relative to manufacturing output (bottom graph), for both producers and non-producers of coal, oil and gas.[6] Although the mere possession and extraction of these raw chemical inputs does not guarantee a country a comparative advantage in the down-stream production of industrial chemicals, the graphs make clear that countries producing coal, oil and gas also

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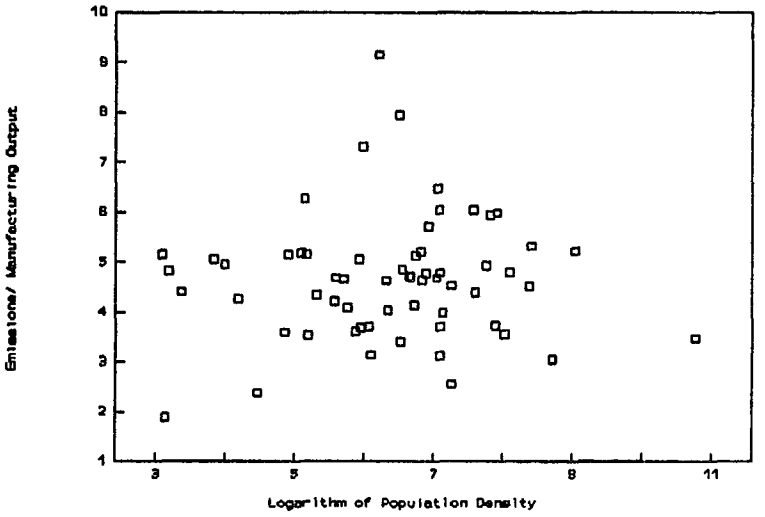
6. Data on coal, oil and gas production are from the United Nations Energy Statistics Yearbook.

FIGURE 4.B

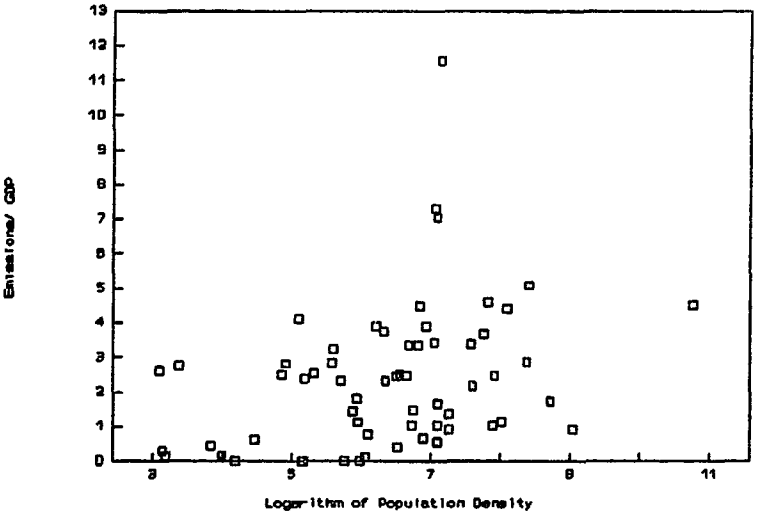
EMISSIONS/ MANUFACTURING OUTPUT



EMISSION INTENSITY
COMPARED TO POPULATION DENSITY

FIGURE 4.A

EMISSIONS/ GDP



MEAN MANUFACTURING EMISSION INTENSITIES BY PRODUCTION OF COAL, OIL AND GAS

FIGURE 5.A

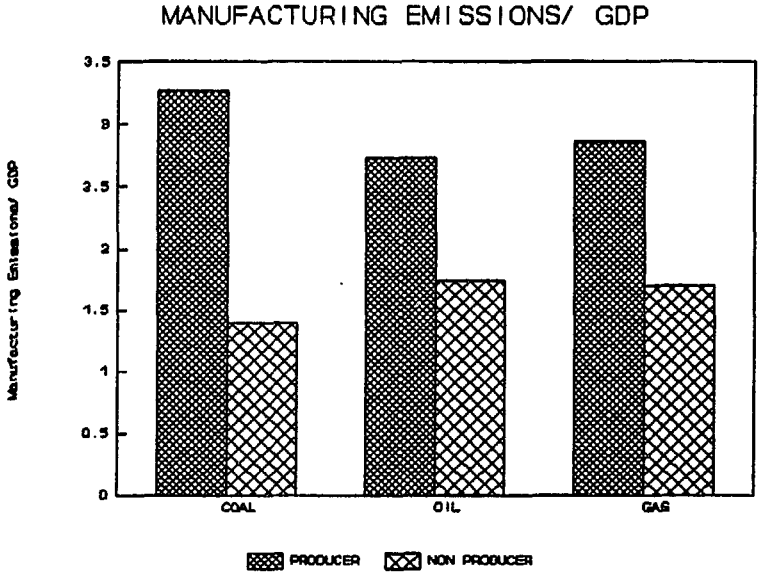
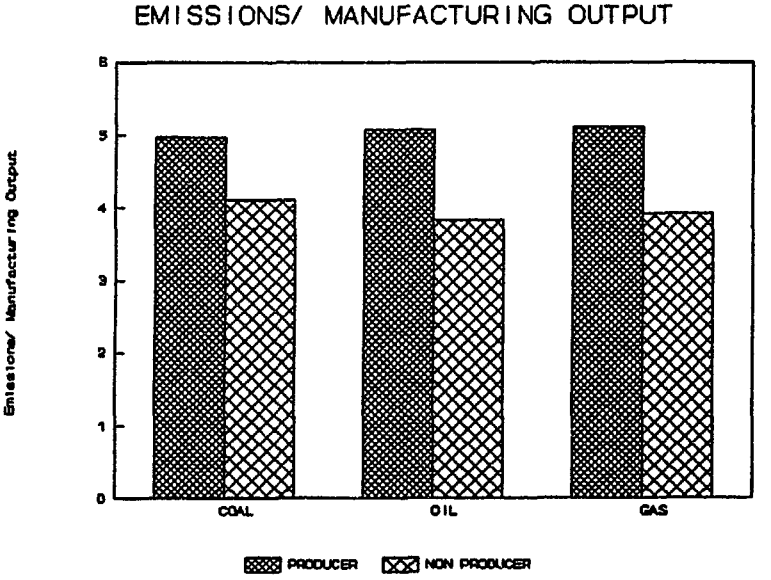


FIGURE 5.B



possess relatively large industrial chemical industries and are consequently estimated to have high toxic emission rates. Note, however, that the differences in Figure 5.A are proportionally greater than in 5.B. In other words, only a part of the high manufacturing emission rates estimated for coal, oil and gas producers is due to the composition of their manufacturing; the remainder reflects a more important role for manufacturing as a proportion of GDP within coal-oil-gas producer nations.

Another element likely to promote high levels of toxic emissions is the degree of protection offered to the most pollution-intensive activities. Ideally one would like to examine, for the various countries over time, a measure of the effective protection granted to differing industries in relation to the intensity of their pollution.[7] However, no compilation of effective rates of protection is readily available, even for a cross-section of countries at any one point in time.

As noted in connection with Table 1, industrial chemicals are the industry with the highest toxic emissions relative to output. Figure 6 plots, for each developing country, total manufacturing emissions -- relative to both GDP and manufacturing output -- against the logarithm of total tariff and para-tariff rates on chemicals.[8]

No obvious pattern emerges from the upper panel of Figure 6. However, a positive association may be discerned in the case of emissions relative to manufacturing output. (This association is weakened by the three countries with the highest intensities, each of which is an oil producer -- a point to which we shall return shortly). The significance of this positive association is confirmed and amplified by several regressions reported in Table 3.

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7. It is well recognized, however, that even effective rates of protection have substantial limitations for inference with respect to resource allocation.

8. These measures are extracted from UNCTAD (1987). Unweighted average tariffs are adopted rather than trade weighted, since the latter give zero weight to highly protected items effectively excluded from trade. This UNCTAD publication covers only the developing countries. Note that the tariffs refer to the average for all chemicals rather than to industrial chemicals specifically.

EMISSION INTENSITIES IN RELATION TO TARIFFS ON CHEMICALS

FIGURE 6.A

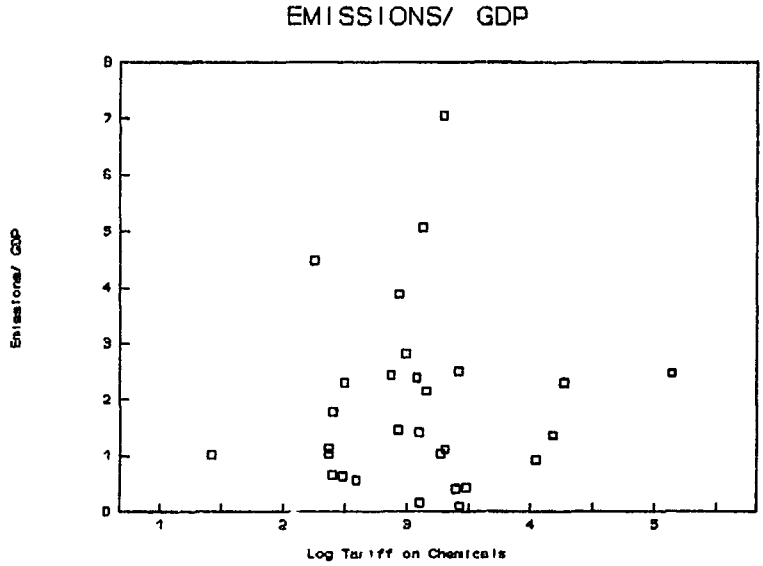

FIGURE 6.B

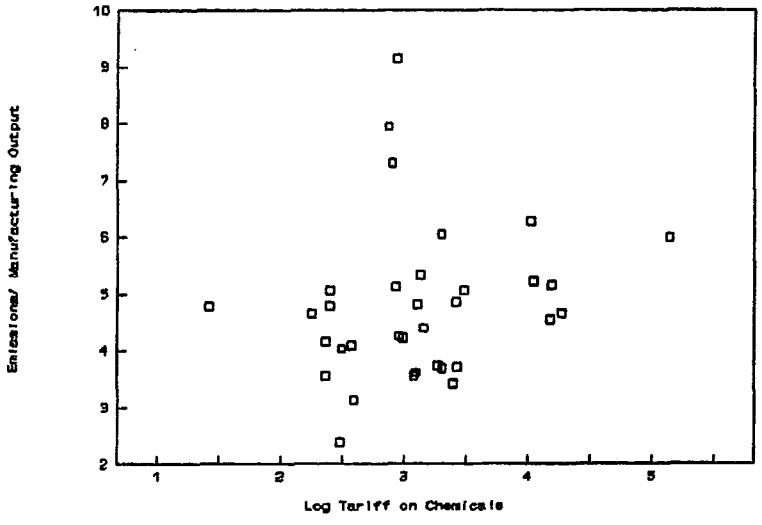

Table 3 Log(Toxic Releases/ Manufacturing Output) Regressed Upon Measures of Import Protection

Intercept	1.442	1.317	1.414	1.272	1.269	1.302	1.311	1.340
	(25.1)	(19.1)	(23.6)	(18.6)	(8.37)	(6.17)	(9.05)	(6.66)
Tariff on Chemicals	0.002		0.002					
	(3.35)		(2.34)					
Tariff Chemicals/ Tariff on Manufactures		0.295		0.276				
	(2.70)		(2.43)					
Log Tariff on Chemicals					0.084	0.113	0.054	0.080
					(2.06)	(1.44)	(1.29)	(0.93)
Log Tariff on Manufactures						-0.036		-0.031
						(0.34)		(0.31)
Quotas on Chemicals			0.002	0.002			0.002	0.002
			(1.58)	(2.15)			(1.88)	(1.86)
No. Obs.	36	36	36	36	34	34	34	34
Adj R2	0.05	0.04	0.06	0.08	0.02	-0.01	0.03	0,01
F-Stat.	2.87	2.57	2.04	2.04	1.72	0.86	1.67	1.10

T-statistics in parentheses.

The regressions in Table 3 indicate a significant positive association between the level of tariffs on chemical imports (or its logarithm) and the intensity of estimated toxic emissions relative to manufacturing output. But does a high tariff on chemicals tend to pull resources into this sector if there is also high protection elsewhere? A second set of specifications in Table 3 looks at the role of tariffs on chemicals relative to average tariffs on all manufactured goods; again this finds a positive association. Finally the regressions in Table 3 include a measure of the incidence of non-tariff trade barriers on chemicals, with a similar -- though perhaps statistically weaker -- result for the separate role of non-tariff trade barriers.[9] Overall there is therefore some evidence to suggest that developing countries with greater protection offered to their chemical sectors, suffer on average from a structure of manufacturing production biased toward higher toxic emissions. But there is also a great deal of noise in this average pattern,

9. The non-tariff trade barrier data are again taken from UNCTAD (1987). The measure is the percentage of chemical commodity codes subjected to a license, quota or prohibition.

toxic emissions (though it is difficult to distinguish the separate effects of the two instruments). In the second set of regressions in Table 4, an interaction is introduced between the coal-oil-gas production dummy and the import protection measures. There is a tendency for the import protection measures on chemicals to encourage toxic emissions both among coal-oil-gas producers and the remaining nations; the import measures have a slightly more substantial effect on the non-producers.

As a final step in reviewing this evidence, the available data on the various countries over time is pooled to estimate a fixed effects model including a dummy variable for each country in the sample.

In the first three regressions in Table 5, the dependent variable is the logarithm of total manufacturing toxic emissions relative to manufacturing output, while in the last two, the dependent variable is the logarithm of emissions relative to GDP. The former set of regressions include 80 dummy variables for the countries in the sample and consequently no intercept is reported, while the last two include 73 country dummies, owing to a more limited sample.

A positive time trend in emission intensities has already been noted from the simple univariate analyses earlier in this paper. However, a positive association with income per capita has also been noted. Is the time trend therefore a result of rising incomes? The results in Table 5 suggest not. Both a positive association with income per capita and a positive time trend are found. Indeed a separate time trend is estimated for the periods 1960-73, 1974-79, and 1980-88. Despite major global changes, remarkably little change in time trend is observed over these episodes. In particular, there is no tendency for the rate of emission intensity growth to slow down; if anything, there is a very slight speeding up in the growth of emission intensities.

The rising emission intensity relative to manufacturing output shows no sign of turning down at higher incomes. In fact, if income per capita squared is included, as in the second equation in Table 5, a positive relationship is found. This is not the case for emission intensity relative to total GDP where, as in the univariate analyses, a significant negative quadratic term is estimated.

Table 5 Pooled Annual Data Across Countries: Fixed Effects Regressions
Dependent Variables: Logarithm (Toxic Emissions/ Manufacturing Output or GDP)

	Toxic Emissions Relative To:				
	Manufacturing Output			GDP	
Time trend	9.206 (12.15)	9.901 (12.21)		27.396 (17.94)	
Trend: 1960-73			4.598 (3.04)		17.895 (6.03)
1974-79			4.629 (3.07)		17.982 (6.08)
1980-88			4.637 (3.09)		17.973 (6.10)
Income per capita	0.886 (4.06)	0.666 (2.82)	0.870 (3.99)	2.483 (5.76)	2.310 (5.38)
Income squared		0.001 (2.39)		-0.001 (2.66)	-0.001 (2.50)
Income * Trend	-0.450 (4.11)	-0.350 (2.98)	-0.442 (4.03)	-1.260 (5.89)	-1.173 (5.51)
No. country dummies	80	80	80	73	73
No. observations	1517	1517	1517	1395	1395
R squared	0.79	0.79	0.80	0.93	0.93

T-statistics in parentheses.

From the separate country time trend estimates depicted in Figure 3, a pattern of more rapid rise in emission intensities among lower income countries is seen. In the regressions in Table 5, the statistical significance of this pattern is confirmed; a negative coefficient is estimated on the interaction between time trend and income per capita, for both measures of intensity.

A fixed effects model cannot be estimated so as to include our protection measures for developing countries, since at this juncture only one observation on protection is available for each country -- these effects are then fully absorbed in the individual country dummies. The

Table 6 Pooled Annual Data Across Developing Countries: Fixed Effects Regressions
Dependent Variable: Logarithm (Toxic Emissions/ Manufacturing Output)

Intercept		-14.646	-14.747
		(4.76)	(4.93)
Time trend	8.859	8.109	8.126
	(7.58)	(5.20)	(5.37)
Income per capita	0.432	0.124	-0.047
	(0.65)	(0.15)	(0.06)
Income * Trend	-0.215	0.061	0.024
	(0.63)	(0.15)	(0.06)
Tariff on chemicals		0.002	0.001
		(5.22)	(3.23)
Quota on chemicals		0.001	0.001
		(1.77)	(1.27)
Coal-oil-gas producer			0.146
			(6.88)
No. country dummies	43	0	0
No. observations	770	770	770
R squared	0.61	0.08	0.14

T-statistics in parentheses.

same is true for any simple representation of whether each country is a coal, oil or gas producer. Table 6 therefore reports estimates of pooled cross-country time series regressions, including these LDC data, but omitting the country dummies. For reference, a fixed effects regression with country dummies for the 43 developing countries in the sample is reported first.

A positive time trend in emission intensity is again estimated for developing countries. However, within the range of incomes over which the developing countries are defined, the profile of emissions against income is flat. Nor is there evidence to suggest that the lowest income developing countries have experienced any more rapid increase in emission intensity than

the somewhat better off developing countries.

As with the univariate analyses, the final columns in Table 6 confirm that the coal-oil-gas producing nations do indeed exhibit a significantly greater estimated rate of emissions per unit of manufacturing output. Moreover, the coefficients on the rate of import duty on chemicals and on the percentage of chemical imports subjected to non-tariff barriers, again prove positive (although, in the case of non-tariff barriers, only weakly so in statistical terms). The positive association between protecting one's chemical industry and toxic emissions is not merely a result of patterns in income per capita across developing countries.

IV. Summing-up and Some Reflections

This simple analysis of manufacturing toxic emission intensities, through time and across countries, based upon fixed coefficients of emissions, has revealed a number of interesting patterns:

- The estimated rate of manufacturing toxic emissions relative to overall GDP, initially rises with income per capita, but eventually turns down, although not until quite high income levels are achieved. However, this inverted U-pattern is driven entirely by an initial rise, then fall, in manufacturing output relative to total GDP. The composition of manufacturing becomes increasingly toxic intensive at higher incomes (though the profile is quite flat within the low income countries), and shows no sign of turning down at higher incomes. Of course, this pattern may be mitigated to some extent if the higher income countries possess or enforce technologies which are less emission intensive within given industry groups -- this cannot be detected with our data. But the onus is on the higher income countries to contain the emissions of their increasingly pollution-oriented mix of manufacturing industries.

- The global trend has been toward a pattern of production which is increasingly emission intensive, both in relation to manufacturing itself and more generally in relation to GDP. Moreover, this trend has been remarkably constant across the last three decades, and in particular there is no sign of a slowing in the trend toward more pollution intensive manufacturing activities.

- The upward trend in emission-intensity of manufacturing production has been faster among lower income nations. If pollution restraints on given industries are progressing more rapidly among the wealthier countries, then this disparity would be even sharper than our data suggest.

• Among developing countries, those which are producers of coal, crude oil or natural gas also possess manufacturing sectors which are more pollution intensive. This is because these countries have developed industrial chemical production based on their raw materials. It may be doubted that the fostering of such industries always reflects a comparative advantage: the major advantage in local, downstream, very capital-intensive processing of raw materials, really stems from contexts in which transport costs for crude materials are very high, but for processed products are not. In fact, petro-chemical industries in the coal-oil-gas producing countries are often the result of substantial protection or effective subsidies.

• Among developing countries -- whether producers of coal, oil, gas or none of these -- import protection stimulates a larger industrial chemicals industry and results in greater emission intensity of manufacturing. The effects of a general trade liberalization cannot, of course, be discerned from this. But at least the results suggest that less protection offered to the local industrial chemical industries would improve the pollution intensity of the typical LDC's industry.

At a minimum, the evidence indicates that the emission intensity of LDC manufacturing has been growing significantly more rapidly than the intensity within industrialized nations. In this sense, there has been a tendency to shift production of the pollution intensive activities off-shore. Is this a bad thing?

If relocation of industries removed them from close proximity to people, the potential for human damage would clearly be diminished. But there is no evidence to suggest that the pollution intensive activities are settled in less densely populated countries.

Even if those developing countries whose manufacturing is rapidly becoming more emission intensive, are not better placed to absorb these emissions physically, because of removal from people or perhaps less fragile ecosystems, it <u>may</u> nonetheless be in their interest to accept relocation of these industries. The jobs, income and foreign exchange generated could be worth the environmental cost to the countries in question -- given their present level of income. But the most pollution intensive manufacturing industries are very capital intensive and hence generate very few jobs; they are commonly heavily protected in the developing countries and probably not efficient sources of foreign exchange.

Moreover, even if the acceptance of such industries is in the interests of certain individual countries, there is the more complex question of global consequences. Our data do not distinguish between globally and locally damaging emissions; the mere relocation of industries

which emit globally damaging toxins clearly misses the point.

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