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Chapter 5

Effects of Domestic Environmental Policy on Patterns of International Trade

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Introduction

The potential for domestic environmental regulations to produce trade distortions has a strong element of a priori plausibility. Proposed environmental regulations are, in fact, often opposed vigorously on the grounds that they will impair the international competitiveness of domestic industries. This chapter provides an ex post assessment of the effect of environmental regulation on patterns of international trade using the well-known Heckscher-Ohlin-Vanek (HOV) model of international trade. Several empirical tests are undertaken, but no systematic evidence of deviations in world trade patterns is detected. The primary reason seems to be that the costs of pollution control have not loomed very large, even in heavily polluting industries. However, because the incremental costs of pollution abatement increase at an increasing rate, the prospects for more significant trade effects following the introduction of more stringent pollution controls cannot be ruled out.

The trade effect of environmental controls is one of several macroeconomic effects on the domestic and international economy that

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have been discussed in the United States and other industrialized countries since the late 1960's when many important pollution control programs were introduced. Other issues of concern include reductions in domestic productivity and increases in inflation.

A careful review of the literature indicates that these effects have been relatively modest. Although many researchers initially pointed toward the introduction of environmental regulations as the primary cause of the slowdown in U.S. productivity in the 1970's, studies show that they accounted for only about 8 to 30 percent of the slowdown (Denison, 1979; Crandall, 1981; Christainsen and Haveman, 1981). There is also little evidence that environmental regulations have had a large effect on inflation. Leontief and Ford (1972) and Pasurka (1984) find that environmental protection costs have had only small effects on prices. As Pasurka (1984, p. 389) observes, "it is unlikely that a significant amount of the inflation experienced by the United States in recent years was caused by the costs of meeting environmental regulations."

A survey of the literature similarly shows little reason for concern over the distorting effect of environmental regulations on trade. The adoption of costly environmental control measures will alter the international structure of relative costs with potential effects on patterns of specialization and world trade. These trade effects have been explored in some detail, making use of standard models of international trade (Asako, 1979; McGuire, 1982; Pethig, 1976). Environmental control costs encourage reduced specialization in the production of polluting outputs in countries with stringent environmental regulations. In contrast, countries that fail to undertake an environmental protection program should increase their comparative advantage in the production of items that damage the environment.

Some studies have made use of existing macroeconometric models to assess the likely magnitude of the trade effects of environmental controls (D'Arge, 1974; Robison, 1986; OECD, 1985). These studies use estimates of the costs of pollution control programs on an industry basis to get some sense of the effects of these programs on trade and payment flows. They generally find small, but measurable, effects.

Other studies, relying on ex post evaluations of the historical evidence, have not been able to confirm the predicted trade effects of environmental policy. One methodology for addressing this issue involves the study of trade and foreign-investment flows for several key industries and countries. These "location of industry" studies (Leonard, 1988; Pearson, 1987; Walter, 1985) have found little evidence that pollution-control measures have exerted a systematic effect on international trade and investment. Leonard (1988) observes that the differentials in the costs of complying with environmental regulations in industrialized and industrializing countries have not been sufficiently large to offset larger political and economic forces in shaping international comparative advantage.

Identification of Pollution-Intensive Commodities

A commodity's relative pollution intensity can be defined by the pollution-abatement costs incurred in its production. The direct pollution abatement costs are reported by the U.S. Department of Commerce (1975) and the Environmental Protection Agency (1984). In addition to the direct pollution abatement costs, we also need to consider the abatement costs embodied in intermediate goods purchases, which are the indirect pollution abatement costs. By multiplying direct pollution abatement costs by the total expenditures I-O (input-output) table, others have generated an estimate of total (direct and indirect) pollution abatement costs per dollar of industrial output.

Commodities termed pollution-intensive are defined as the products of those industries whose abatement costs in the United States are equal to or greater than 1.85 percent of total costs. The cutoff of 1.85 percent results in a set of industries that are generally considered the most polluting (metals, chemicals, and paper industries) throughout the world.[1] There is also a considerable difference between the pollution-abatement costs in these industries and in those of the remaining group of industries.

In table 1, the input-output industries defined as pollution-intensive are matched to commodities according to three-digit Standard International Trade Classification (SITC) codes and aggregated into five commodity groups, including paper and pulp products (paper), mining of ores (mining), primary iron and steel (steel), primary nonferrous metals (nfmetals), and chemicals (chems).

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[1] This cutoff does not include the petroleum industry. Petroleum is excluded because the dynamics of this industry during early to mid-1970's were heavily influenced by extraordinary circumstances affecting the availability and processing of crude oil.

Table 1--Pollution-intensive input-output industries' pollution abatement costs as percentage of total costs

I-O industry	SITC	Description	Direct and indirect pollution abatement costs as percentage of total costs
Mining:			*Percent*
5	281	Iron ore, concentrates	2.03
6	283	Ores of nonferrous base metals	1.92
Primary nonferrous metals:			
38	681	Silver, platinum	2.05
38	682	Copper	2.05
38	683	Nickel	2.05
38	685	Lead	2.05
38	686	Zinc	2.05
38	687	Tin	2.05
38	689	Nonferrous base metals, n.e.s.	2.05
Paper and pulp:			
24	251	Pulp and waste paper	2.40
24	641	Paper and paperboard	2.40
24	642	Articles of paper	2.40
Primary iron and steel:			
37	671	Pig iron	2.38
37	672	Ingots	2.38
37	673	Iron and steel bars	2.38
37	674	Universals, plates	2.38
37	675	Hoops and strips	2.38
37	676	Railway material	2.38
37	677	Iron and steel wire	2.38
37	678	Tubes and fittings	2.38
37	679	Iron, steel castings	2.38
Chemicals:			
27	513	Inorganic elements	2.89
27	514	Other inorganic chemicals	2.89
28	581	Plastic materials	2.36

n.e.s. = Not elsewhere specified.
Source: Kalt (1985).

The Heckscher-Ohlin-Vanek Equations

The HOV equations are a multifactor, multicommodity extension of the Heckscher-Ohlin model of international trade. They have been used in three different ways. The factor content studies and cross-commodity regressions use measures of factor intensities and trade to infer factor endowments. The third methodology and the approach taken in this study regresses trade in a specific commodity across countries on country resource endowments. In that resource endowments are the explanatory variables, such regressions reveal the direct influence of resources on trade in a specific commodity. Because this study seeks to reveal information on the most pollution-intensive commodities across countries, the cross-country analysis is chosen as the most appropriate approach.

A set of 11 resource endowments for the year 1975 is used to explain net exports of the most polluting industries under the HOV model. These endowments are provided by Leamer (1984) and include the following:

1. CAPITAL (CAP). Accumulated and discounted gross domestic investment flows since 1948, assuming an average life of 15 years.

2. LABOR 1 (LAB1). Number of workers classified as professional or technical.

3. LABOR 2 (LAB2). Number of literate nonprofessional workers.

4. LABOR 3 (LAB3). Number of illiterate workers.

5. LAND 1 (LND1). Land area in tropical rainy climate zone.

6. LAND 2 (LND2). Land area in dry climate zone.

7. LAND 3 (LND3). Land are in humid mesothermal climate zone.

8. LAND 4 (LND4). Land area in humid microthermal climate.

9. COAL (COAL). Value of production of primary solid fuels (coal, lignite, and brown coal).

10. MINERALS (MINLS). Value of production of minerals: bauxite, copper, fluorspar, iron ore, lead, manganese, nickel, potash, pyrite, salt, tin, and zinc.

11. OIL (OIL). Value of oil and gas production.

With the endowments from Leamer, the HOV model can be summarized by the following equations:

$$N_{it} = CST_{i0} + b_{i1}V_{1t} + b_{i2}V_{2t} + \dots + b_{i11}V_{11t} + \mu_{it} \quad (1)$$

where N_{it} are net exports of commodity i by country t, V_{kt} are endowments of resource k (k = 1...11) in country t, b_{ik} are the coefficients which indicate the total effect (production and consumption) of an increase in a resource on net trade of a specific commodity, μ_{it} is the disturbance term, and CST_{i0} is the equation's constant term. The constant term embodies one resource endowment or country characteristic which all countries are assumed to possess identically and which has a nonzero value.

If the environmental endowment, measured by the stringency of environmental regulation, has an effect on trade patterns, then the set of 11 endowments in equation (1) is incomplete.[2] In this case, estimation of the HOV trade equations implies a specification error involving an omitted variable. Several approaches are taken to test the effect of the environmental endowment on trade patterns under the HOV model when cross-country quantitative data on the environmental endowment are not available. In the first, a qualitative variable is included in equation (1) to represent the omitted variable. In the second, an omitted variable test is conducted. In the third, a fixed-effects test is undertaken.

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[2] Although pollution emissions are a joint product of the production process, they can also be interpreted as an input, or endowment, in the production function because they can be viewed as one of the various uses of the environment. Because use of the environment is typically a public good, the environmental endowment has no price attached to it and will be used freely by industries until pollution control measures are introduced. Thus, a country's environmental endowment can be measured by its stringency of pollution control measures.

Introducing "Environmental Endowments" in the HOV Model

To test the pollution-haven hypothesis under the first approach, I estimated the following equation under ordinary least squares (OLS):

$$N_{it} = CST_{i0} + b_{i1}V_{1t} + b_{i2}V_{2t} + \ldots + b_{i11}V_{11t} + b_{iE}D_{Et} + \mu_{it} \qquad (2)$$

where D_{Et} is a qualitative variable measuring the stringency of pollution control measures in country t based on a 1976 survey by the United Nations Conference on Trade and Development (UNCTAD) (Walter and Ugelow, 1979).

The degree of environmental stringency is measured on a scale from 1 (tolerant) to 7 (strict); the mean score for developed countries is 6.1, while for developing countries it is 3.1. There are observations for 23 countries: 13 industrialized and 10 developing countries (table 2).

Table 2--Index of the degree of stringency of environmental policy (7 = strict, 1 = tolerant)

Industrialized countries	Index	Less developed countries	Index
1 Austria	4	1 Chile	4
2 Australia	5	2 Colombia	5
3 Benelux	3	3 Cyprus	1
4 Denmark	5	4 Israel	4
5 Finland	6	5 Liberia	1
6 Germany	5	6 Malta	1
7 Japan	7	7 Nigeria	2
8 New Zealand	5	8 Panama	4
9 Netherlands	5	9 Singapore	6
10 Norway	6	10 Spain	4
11 Sweden	7		
12 UK	4		
13 USA	7		

Source: Walter and Ugelow (1979).

The OLS regression results are presented in table 3 (absolute value of the t ratio is shown in parentheses beside the estimated regression coefficient). In no instance is the t ratio found to be statistically significant on the measure for the stringency of environmental policy in the five regressions of net exports of polluting industries.

Aside from the Walter and Ugelow index, no cross-country data or synthetic measures of the stringency of environmental policies are available. However, to extend the analysis to a larger group of countries, I estimated equation (2) using a dummy variable (equal to one for industrialized countries with enforced environmental regulations, and zero for developing countries without enforced environmental regulations) for a group of 58 countries: 17 industrialized and 41 developing. The dummy variable was not statistically significant in any of the five equations.

Omitted Variable Test

A second approach to testing the effect of pollution control measures on trade patterns investigates the bias in the regression residuals when the variable representing countries' environmental endowments are not included in the HOV equations.

Table 3--Equations **(D.F. = 10)**

Variable name	Mining (R^2=0.99)	Paper (R^2=0.96)	Chems (R^2=0.93)	Steel (R^2=0.89)	NFMetals (R^2=0.92)
CAP	-192 (2.4)	177 (1.6)	583 (5.6)	1,537 (2.6)	-89 (1.0)
LAB1	735 (1.9)	-267 (5)	981 (1.9)	-1,434 (5)	-550 (1.2)
LAB2	-111 (3.2)	-25 (5)	-154 (3.5)	54 (2)	44 (1.1)
LAB3	-15 (0.6)	50 (1.5)	-49 (1.6)	84 (5)	69 (2.5)
LND1	385 (1.5)	278 (8)	521 (1.6)	237 (1)	-254 (9)
LND2	-104 (7)	-192 (1.0)	-31 (2)	503 (5)	-247 (1.5)
LND3	1295 (2.8)	100 (2)	-268 (5)	-2,898 (9)	-414 (8)
LND4	435 (9)	6,089 (9.2)	-2,003 (3.2)	-1,374 (4)	-589 (1.1)
COAL	-78 (6)	-110 (6)	-283 (1.6)	-83 (1)	88 (6)
MINLS	338 (1.6)	330 (1.4)	88 (4)	26 (1)	715 (3.7)
OIL	-30 (1.6)	-110 (4.3)	-20 (8)	-142 (1.0)	17 (8)
D	-10,314 (3)	2,454 (1)	-1,531 (1)	98,844 (4)	48,658 (1.3)
CST	-5,669 (1)	-168,370 (1.0)	-107,110 (7)	-697,020 (8)	-122,980 (9)

Consider first a simple HOV equation with one known and one unknown independent variable. Let x_{t2} represent a factor endowment for country t. Under the null hypothesis that the environmental factor (x_{t3}) has no effect on the pattern of trade, the equation specifying net exports (N_t) may be written as:

$$N_t = \beta_1 + \beta_2 x_{t2} + \bar{\mu}_t \tag{3}$$

The alternative to the null hypothesis is represented by the following equation:

$$N_t = \beta_1 + \beta_2 x_{t2} + \beta_3 x_{t3} + \mu_t \tag{4}$$

If equation (3) is correct, the least squares estimators of β_1 and β_2 using equation (3) will be unbiased and efficient for all sample sizes. If equation (4) is correct, the estimation of equation (3) will still generate an unbiased estimator or β_2 given the following assumption:

A1: The omitted variable is not correlated with any of the included independent variables.

If we except assumption A1, estimation of equation (3) when the omitted variable (x_{t3}) does not equal zero will not affect β_2. Its presence will, however, be embodied in the constant and disturbance term. Solving for $\bar{\mu}_t$, the following equation can be derived:

$$\bar{\mu}_t = \beta_3(x_{t3} - \bar{X}_3) + \mu_t \tag{5}$$

Under the null hypothesis that x_{t3} has no effect on the pattern of trade so that $\beta_3 = 0$, $\bar{\mu}_t$ is a consistent estimator of μ_t. Under the alternative case where pollution control measures have an effect on the pattern of trade, so that $\beta_3 \neq 0$, then (given assumption A1) $\bar{\mu}_t$ provides a consistent estimate of equation (5).

A methodology to test the effect of pollution control measures on the pattern of trade may now be presented. Under the alternative hypothesis that equation (4) is correctly specified and assuming it also has all the properties of the classical regression model, then the sign of μ_t is expected to be random. Therefore, the expected sign of $\bar{\mu}_t$ in equation (5) is the same as that of $\beta_3(x_{t3} - \bar{X}_3)$. β_3 is expected to be negative if pollution control measures reduce net exports of pollution-intensive commodities.

To determine the sign of $(x_{t3} - \bar{X}_3)$, consider the distribution of the stringency of environmental regulations, x_{t3}, over the world. Industrialized, high-income countries have environmental endowments greater than the population mean $\bar{X}_3$, and less-developed countries have environmental endowments less than the population mean. Thus, the pattern of sign of $\hat{\mu}_t$ under the alternative hypothesis depends on the distribution of x_{t3} over countries. Because the distribution suggested above, the proportion of error terms that are positive for developing countries is expected to be significantly greater than the proportion of error terms that are positive for industrialized countries.

Let T_n represent the true proportion of errors for countries in group n (where n=1 corresponds to industrialized countries and n=2 corresponds to developing countries). The null hypothesis (H_0) states that the proportion of errors that are positive is the same for both industrialized and developing countries. The alternative hypothesis (H_1) states that the proportion of such errors is greater for developing countries than for industrialized countries.

$$H_0: T_2 = T_1$$
$$H_1: T_2 > T_1$$

A nonparametric statistical procedure was chosen to conduct the statistical test because it requires few assumptions regarding the distribution of the error terms. Under the null hypothesis, the test statistic may be given as (see Yamane, 1967):

$$A = \frac{R_2 - R_1}{[T \times (1-T)[(1/IxJ_2) + (1/IxJ_1)]]^{1/2}}$$

where $R_n = S_n/(IxJ_n)$ represents the proportion of estimated errors that are positive, "I" equals the total number of commodity groups (=5), J_n equals the total number of countries in country group n, and S_n equals the number of estimated error terms for countries in group n that are positive.

T is an estimate of the true proportion under the null hypothesis. The best estimate of the true population proportion is constructed by combining the observations for both industrialized and developing countries as follows:

$T = (S_1 + S_2)/(Ix(J_1 + J_2))$

To perform the omitted variable test, I arranged a set of 58 countries in three groups (table 4). Group one consists of industrialized, high-income countries. Environmental regulatory costs in this group are predicted to generate a comparative disadvantage in the production of polluting commodities. Group two is composed of upper-income developing countries and semi-industrialized nations without a stringent

Table 4--Country observations, 1975

Country (group 1)	GDP per capita[1]	Country (group 2)	GDP per capita[1]	Country (group 3)	GDP per capita[1]
	1975 *dollars*		1975 *dollars*		1975 *dollars*
Australia	5,919	Argentina	3,159	Afghanistan	380
Austria	4,994	Brazil	1,978	Burma	312
Benelux	5,569	Chile	1,834	Colombia	1,596
Canada	6,788	Costa Rica	1,835	Dominican Republic	1,443
Denmark	5,969	Cyprus	1,811	Ecuador	1,300
Finland	5,192	Greece	3,360	Egypt	929
France	5,864	Hong Kong	2,559	El Salvador	1,005
Germany	5,758	Ireland	3,067	Ghana	952
Iceland	5,201	Israel	4,154	Honduras	871
Japan	4,904	Italy	3,870	India	472
Netherlands	5,321	Malta	2,154	Indonesia	536
New Zealand	4,769	Mexico	2,276	Jamaica	1,763
Norway	5,419	Panama	2,026	Korea	1,530
Sweden	6,749	Peru	1,860	Liberia	830
Switzerland	6,082	Portugal	2,397	Libya	6,680
United Kingdom	4,601	Singapore	2,875	Malaysia	1,532
United States	7,132	Spain	4,032	Mauritius	1,260
Average	5,661	Turkey	1,738	Nigeria	1,179
		Yugoslavia	1,960[1]	Paraguay	1,186
		Average	2,567	Philippines	912
				Sri Lanka	661
				Thailand	930
				Average	1,002[2]

[1] 1977 GNP per capita, from World Bank, 1979 *World Development Report.*
[2] Excluding Libya.
Source: Heston and Summers (1984).

environmental program in 1975. Group three is composed of middle to low-income developing countries, also without stringent environmental programs.

A summary of the results when equation (1) is estimated using this set of 58 countries is shown in table 5. One cannot reject the null hypothesis that $T_2 = T_1$ in the comparison of industrialized countries with any combination of the developing country groups. These results reenforce the earlier finding that used a qualitative variable to represent the environmental endowment and which also found no effect of pollution control measures on HOV trade patterns.

Fixed Effects Empirical Test

A reasonable explanation for the empirical results above may be that the magnitude of environmental expenditures incurred by the industrialized countries in the late 1960's and early 1970's was not sufficiently large to cause a noticeable effect on trade patterns between countries with and without environmental protection programs. The cross-section HOV model may not be sufficiently precise to identify these small changes in factor abundances and comparative advantage. Thus, the effect of domestic environmental policy on trade may be getting lost in the "noise." By examining the change in trade patterns before and after the introduction of environmental measures in the industrialized countries,

Table 5--Positive residuals

Country group	Paper	Steel	Chems	NFMetals	Mining	[1]S_n	[2]J_n	[3]R_n	[4]A
1	7	9	5	8	11	40	17	0.47	--
2	5	10	9	5	6	35	19	.37	-1.32
3	10	18	15	5	11	59	22	.54	.96
2 + 3	15	28	24	10	17	94	41	.45	-.15

--=Not applicable

[1]S_n is the number of errors for group n that are positive.

[2]J_n is the number of countries in group n.

[3]$R_n = S_n/(IxJ_n)$.

[4]"A" is the test statistic comparing group 1 countries against groups of developing countries. An absolute value of 1.65 for the test statistic in the normal distribution corresponds to a probability of 95 percent.

one might be able to detect the hypothesized shifts in trade patterns in response to environmental policies that do not show up in the equations using data from a specific point in time. Such a methodology would also be effective in capturing the effect of environmental policy even if there was a significant lag in the impact of pollution controls on international competitiveness.

Although endowment data are available only for 1975, most resource endowments change little over time. At least for the most polluting industries, one might argue that the most important endowment change during 1970-84 was the increase in environmental regulations. Consider then a HOV model where the change in net exports over 1970-84 is linearly related to the change in factor endowments over the same period. Under a "fixed-effects" specification, assume that, except for the environmental endowment, the change in factor endowments equals zero. In this case, one is left with the following equation:

$$\Delta N_{it} = E_t + \mu_{it} \tag{6}$$

where ΔN_{it} are 1984 minus 1970 net exports of commodity i by country t. E_t is the Walter and Ugelow (1979) measure of the degree of the stringency of environmental policy in 23 countries in 1977. Because these countries generally did not have enforced environmental programs in place by 1970, the level of environmental policy given by this index is a reasonable proxy for the change in environmental policy. Finally, μ_{it} are the random error terms.

Results of the OLS estimation of this model are shown in table 6. If environmental policies reduce countries' international comparative advantage in the most pollution-intensive commodities, then the sign on the environmental endowment coefficient should be negative and significant. Only in the chemicals group does the significance of the coefficient approach a conventionally accepted level of confidence. The

Table 6--Equations (D.F. = 22)

Variable name	Mining (R^2=0.03)	Paper (R^2=0.0+)	Chems (R^2=0.05)	Steel R^2=0.0+)	NFMetals (R^2=0.04)
E	-54155 (1.1)	-2298 (0.1)	78007 (1,9)	49437 (0.4)	-65593 (1.1)

sign, however, is positive, and once again does not support the hypothesized effect of pollution control measures on trade patterns.

Alternative Structural Forms

Another possibility for the above results may be that the commodity groups studied flagrantly violate the assumptions of the HOV model. For example, the HOV model assumes identical homothetic tastes, meaning that individuals facing identical commodity prices will consume commodities in the same proportions. In this cross-section study, with countries at widely different levels of development, this assumption may not be reasonable. To allow for nonhomothetic preferences, consumption across countries is assumed to be a linear function of population and national income. In this case, per capita net exports (n_{it}) become a linear function of per capita resource endowments (v_{kt}) as given by the following equation:

$$n_{it} = b^{*}_{i0} + \left(\sum_{k=1}^{K} b_{ik}v_{kt}\right) \tag{7}$$

where $b^{*}_{i0} = -c_{i0}$, and c_{i0} is a parameter that relates consumption of commodity i in country t to country t's population. As before, b_{ik} indicates the total effect of an increase in a resource on net trade of a specific commodity.

The second relaxation of HOV assumptions allows for scale economies in the production process. All of the pollution-intensive commodity groups are associated with relatively large-scale production processes. In particular, Hufbauer (1970) has found that the production of paper products is subject to large economics of scale and the production of nonferrous metals subject to diseconomies of scale. To allow for scale economies, I use a model that Murrell (1990) derives and that follows Krugman and Helpman (1986) closely. I assumed that each good can be produced in an infinite number of varieties and each variety exhibits economies of scale, at least at low levels of output. In this case, the exports of good i by country t, x_{it}, are specified as follows:

$$x_{it} = \sum_{k=1}^{K} b^{*}_{ik}v_{kt}(1 - G_t/G_W) \tag{8}$$

where G_t is the national income of country t and G_W is total world income. Equation (8) cannot be derived from the Heckscher-Ohlin theory, and the asterisks on the coefficients of the equation are a reminder that these coefficients are not equivalent to b_{ik} in the previous HOV models.

The HOV model was tested under these two alternative specifications. Again, the tests did not support the hypothesis under review.

The HOV model also assumes that commodities move internationally at zero cost of transportation, and that there are no other impediments to trade. However, transportation costs and tariffs are important elements in these industries and may significantly affect an individual country's composition of trade. This finding would not present a problem for the tests undertaken above if these trade impediments are not distributed across countries in the same pattern as environmental controls. In the absence of empirical evidence (trade impediments are very difficult to measure for large sets of countries), there is no reason to believe that their distribution would be closely correlated with the stringency of countries' environmental controls.

Interpretation of the Empirical Results

The empirical results that I found support other similar efforts which find that environmental management has had relatively little effect on productivity, inflation, and trade. From an environmental perspective, this finding is comforting, for it means that there is little force to the argument that we need to relax environmental policies to preserve international competitiveness. The primary reason seems to be that the costs of pollution control have not, in fact, loomed very large even in heavily polluting industries. Existing estimates suggest that control costs have run on the order of only 1 to 2-1/2 percent of total costs in most pollution-intensive industries (Kalt, 1985). The HOV model is probably not sufficiently precise to capture these small increments to costs; their effect on international trade is likely to be swamped by the much larger effects of changing differentials in labor costs and swings in exchange rates, for example. Moreover, nearly all the industrialized countries have introduced environmental measures--and at roughly the same time--so that such measures have not been the source of significant cost differentials among major competitors (Kopp and others, 1990). Nor has there been a discernible movement in investment in these industries to the developing countries because major political and economic uncertainties have tended to play much greater roles in location decisions than have the modest savings from less stringent environmental controls (Leonard, 1988).

The Potential for Effects

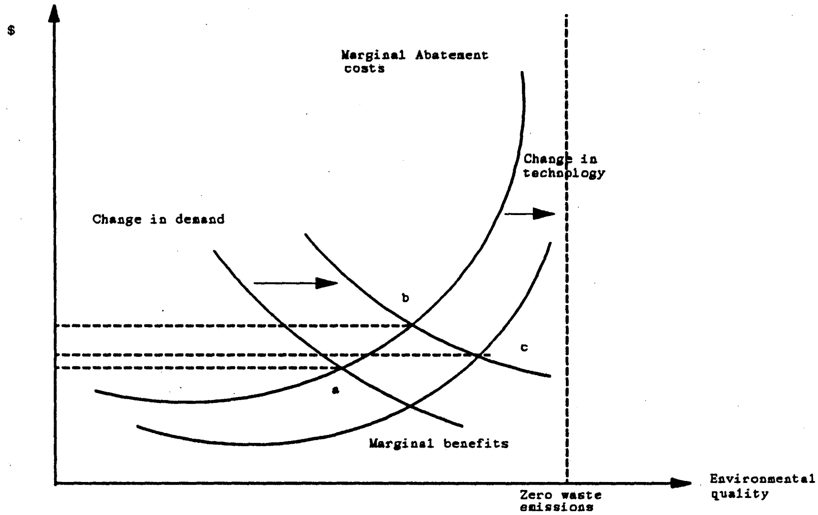
The incremental costs of pollution abatement have been relatively small in the past, but what about the future? The marginal costs of pollution abatement increase slowly at first, but increasingly greater levels of environmental quality can be achieved only at increasingly greater costs. The small effects so far on productivity, inflation, and trade seem to suggest that, for the present, we find ourselves on the relatively flat portion of the marginal abatement cost curve where additional increments in environmental quality are achieved at little extra cost. However, there is some evidence that there are fewer opportunities for inexpensive increments to the level of environmental quality than there have been in the past.

Oates and others (1989) have estimated marginal abatement cost curves for controlling a common air pollutant (total suspended particulates) in Baltimore under the command and control approach and an incentive-based case. In both cases, the marginal abatement cost curves are fairly flat over a low range of environmental quality levels, but eventually begin to rise steeply as emissions are increasingly reduced to achieve greater levels of environmental quality. Further, the intersection of marginal benefits and marginal costs of pollution abatement is located at the base of the steep portion of the marginal cost curve, implying that further shifts in the demand for environmental quality would entail large increases in control costs. One could speculate that more stringent environmental legislation (such as the recent revision of the Clean Air Act) might push industry to a new point on the marginal cost curve that would require significantly greater emissions control costs on the margin. This outcome is represented by the movement from point "a" to point "b" in figure 1.[3]

[3] It has been estimated that the recent amendments to the Clean Air Act will increase clean air spending by about $30 to $35 billion a year by the year 2005. Annual environmental compliance expenditures are now on the order of $90 billion a year.

Figure 1

Increase in demand for environmental quality with technological change in pollution abatement



One might also speculate that in the same way that the "limits to growth" arguments of the 1970's were flawed, so are predictions of economic catastrophe following the introduction of tougher environmental legislation. The limits to growth literature predicted a collapse of the world system based on the following implicit assumptions: an iron law of resource use in which industrial production uses up resources in a fixed manner, no technical progress, and no substitution of inputs in production (Forrester and Meadows 1972). Because of these unrealistic assumptions, the gloomy limits to growth modeling exercises were never taken seriously by economists.

I also believe that the possibilities for alternative production techniques, input substitutions, and technological change must be taken into consideration when we assess future effects of environmental management. These economic responses could allow a movement from point "b" to point "c" in figure 1. There is, in fact, evidence that considerable changes in the techniques of production took place as a result of the early clean air legislation. Environmental legislation induced a spurt of investment in pollution abatement equipment and plant modifications in the early and mid-1970's (table 7). Particularly in the pulp and paper industry, major plant modifications were introduced that led to significantly less polluting production practices. Following these modifications, pollution abatement capital costs fell dramatically. These same adaptations and technological advancements will probably continue to be important considerations in determining the location and shape of industries' marginal abatement cost curves, and the effect of environmental policy on the macroeconomy.

Table 7--Pollution-abatement expenditures as a percentage of total new plant and capital expenditures

Industry	1973	1975	1977	1979	1981	1983
				Percent		
Mineral processing	14.7	14.2	12.1	10.0	17.5	6.3
Chemicals	10.1	10.7	11.2	6.3	6.0	4.7
Pulp and paper	15.6	16.0	10.6	8.2	7.4	6.3
All manufacturing	4.5	8.7	6.4	5.0	4.2	3.7

Source: *Survey of Current Business* (Feb. 1986) "Plant and Equipment Expenditures by Business for Pollution Abatement," 66(2): 39-45.

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