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INPUT-BASED POLLUTION ESTIMATES FOR ENVIRONMENTAL ASSESSMENT IN DEVELOPING COUNTRIES

by

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RÉSUMÉ

Dans les pays en développement, la mise en oeuvre de la réglementation sur l'environnement et l'estimation des coûts sont loin d’être évidentes. Outre l’idée fausse et très répandue de liens négatifs entre la croissance économique et l'environnement, il existe de nombreuses autres barrières à l’évaluation de l'état de l'environnement et à l'application de mesures de protection et d'amélioration. Parmi ces barrières, on peut citer la faiblesse du cadre institutionnel et de la discipline, le coût élevé des contrôles et de la gestion administrative des programmes individuels et le peu d'information sur ces ressources technologiques locales.

Les contraintes institutionnelles peuvent entraver l'application des politiques considérées comme les meilleures, comme le contrôle et la réglementation directs de la pollution. Même des systèmes fondés sur les lois du marché, comme les permis de polluer négociables, nécessitent évaluation et contrôle au départ, démarches trop coûteuses et complexes pour être financées localement. Pourtant, des données détaillées sur la pollution existent pour les pays Membres de l'OCDE et ce document s'efforce de les rendre plus utilisables pour les analystes spécialistes de l'environnement dans les pays où les prélèvements sur place n'ont pas été possibles.

Les résultats économétriques rassemblés ici permettent également d'évaluer l'état de l'environnement et d'établir un schéma de réglementation plus facilement applicable dans les pays en développement. En transférant les procédures de contrôle et de réglementation de l’ensemble des producteurs industriels sur les échanges d’un petit nombre de biens intermédiaires, nos conclusions montrent que dans la majorité des cas, les causes de pollution industrielles pourraient être mises sous contrôle.

SUMMARY

The practice of environmental regulation and assessment in developing countries faces many special challenges. Apart from popular misconceptions about negative links between environmentalism and economic growth, there are numerous practical limitations to appraising environmental conditions and implementing policies that conserve or improve them. These include weak institutional capacity or discipline, high monitoring and administrative costs for individual programs, and limited local engineering information.

Institutional constraints mean that first-best policies like direct pollution monitoring and regulation may not be feasible. Even market-based systems like tradable pollution permits usually require initial assessment and monitoring which is too costly or complex to be supported locally. Detailed data on pollution do exist for OECD countries, however, and this paper attempts to render this information more usable to environmental analysts in countries where direct sampling has not been possible. The econometric results reported here are also designed for an environmental assessment and regulation scheme which would be more easily implemented in developing countries. By shifting monitoring and regulation from all industrial producers to trade in a small number of intermediate commodities, our results indicate that the vast majority of causes of industrial pollution could be brought under supervision.

PREFACE

This Technical Paper, part of the Development Centre's research program on "Sustainable Development: Environment, Resource Use, Technology, and Trade," analyses the use of input monitoring for pollution measurement and abatement policy in developing countries.

As increasing numbers of developing countries move down the path toward industrialization, more concern is being awakened about the threat of toxic pollution to environmental integrity and public health. At the present time, however, many of these countries lack sufficient institutional capacity for effective environmental assessment and regulation. Necessary conditions for success, including engineering expertise, monitoring infrastructure, and sufficient incentives and discipline in public employment, are in many cases only partially present. Overcoming such constraints takes human and financial resources and, above all, time. Meanwhile, environmental policies must still be implemented, and the authors of this paper recommend an interim approach which reduces domestic resource requirements.

Instead of focusing on pollution output at individual industrial sources, the authors advocate moving back up the production process. Factories producing pollution can be numerous and very dispersed geographically. The evidence reported here indicates that only a few commodities are responsible for determining pollution levels when they are consumed as intermediates. Trade in these intermediates can be more centralized which makes their monitoring and regulating easier. The authors' econometric estimates indicate that over 90 per cent of the variation in output of most toxic pollution can be explained by consumption of less than a dozen intermediate commodities. The authors also explain how these estimates, based on United States data, can be transferred to developing countries for environmental assessment, reducing the need for domestic engineering capacity.

With more extensive empirical work of this kind, it is hoped that more of the benefits of OECD-country investments in environmental assessment can be transferred to developing countries. Thus, the latter may better be able to confer upon their people a better material and qualitative standard of living.

Jean Bonvin
President, Development Centre
September, 1994

I. INTRODUCTION

Environmental policies toward final demand often focus on inputs such as fuel and energy. These policies are usually targeted to promote conservation and efficient resource use by directly taxing inputs and/or subsidizing processes (e.g. tax deductions for solar technology, home insulation, etc.) directly. By contrast, policies toward industry have historically emphasized control of effluent outputs. These most often take the form of effluent taxes, permits, and cleanup regulation which is intended to influence process and input choice only indirectly. The two main justifications usually advanced for this end-of-pipe approach are market-friendliness and the inherent complexity of production processes.

The incentive properties of effluent tax and permit systems are now fairly well understood, yet implementation of such schemes can sometimes entail extensive monitoring and supervisory infrastructure[1]. In developing countries in particular, it is often quite difficult and costly for central governments to monitor effluent levels in industry efficiently, particularly resource-intensive industries which may be geographically dispersed. In these cases, taxation of inputs which contribute most significantly to environmental degradation, particularly if those inputs are imported or distributed from centralized sources, can help achieve abatement objectives with significantly less administrative infrastructure. This approach may be second-best from an abatement-incentive and resource cost perspective, but the opportunity cost of administrative capacity in developing countries can be quite high. In such cases, some inefficiency in policy design may justify substantial savings in supervisory costs[2].

For economists and policy makers who want to evaluate the potential of input taxation as an instrument for mitigation of industrial pollution, this paper provides econometric estimates of the linkages between input use and the effluent intensity of final output. Using a sample of intermediate linkages between over three hundred United States manufacturing sectors, we estimate the contribution of individual inputs to final production of several major categories of air, water, and land pollution. Our results indicate that, despite the apparent complexity of production technologies in this and other countries, most of the variation in effluent levels can be explained by varying the intermediate use of a small number of inputs. This suggests that a relatively simple tax scheme for such inputs might provide an attractive substitute (or complement) to a much larger set of final output and process standards.

A second important motivation for the present research arises from the trend toward inter country comparison of environmental conditions and policies, particularly between developed and developing countries. Many efforts to appraise environmental conditions and standards in the latter rely upon engineering estimates and effluent data obtained from the former. While there is little alternative until detailed empirical work is done in developing countries, this approach has serious limitations[3]. For example, applying effluent coefficients from the United States to Indonesian industry ignores important differences in technology, resource intensity, and input composition which exist between sectors in the two countries. It is hoped that, measuring effluent contribution by inputs will account for many of these differences when estimates based on one country's data are transferred to another.

In the next section, the sample and basic econometric methodology are presented. This is followed in Section III by the estimation results. Section IV provides some comparative estimates of sectoral effluent intensities for six major economies. Concluding remarks and some discussion of possible extensions are given in the final section.

II. DATA AND ESTIMATION METHODS

In order to trace the origins of pollution deeper into the production structure, we have estimated effluent production functions using data on effluent output by sector and detailed information on the composition of intermediate demand. The estimations were carried out with the IPPS (Industrial Pollution Projection System) database developed at the World Bank. The IPPS component used here represents data on intensities of pollution for about a dozen effluents, on a per unit of output basis, for 345 United States (5-digit ISIC) manufacturing sectors.

The basic estimation model is quite simple, explaining the production of each effluent type (or group of effluents) by the level and composition of intermediate demand[4]. Total emissions depend linearly on the absolute level of intermediate consumption of pollutants. This yields

$$E_i = \sum_j {}_j C_{i,j} + u_i \tag{2.1}$$

where E_i is the absolute level of pollution emission (expressed in metric tons or other physical units) of the sector i, $C_{i,j}$ is the absolute intermediate consumption in value of the product j by the sector i, and u_i is a disturbance term, assumed to be independently and normally distributed among the sectors. Capital and labor are not in themselves assumed to pollute.

Given this type of specification, the interpretation and comparison of coefficient absolute values with each type of intermediate consumption is delicate. Indeed, this is not a really physical relationship, since the base price of each intermediate consumption is included in the measure of consumption used here. Consider a simple example, based on the estimation of toxic atmospheric emissions (see Table 3.2) which illustrates this question. The coefficients obtained for mineral chemicals and industrial chemicals are respectively 4.156 and 0.005. The coefficient of the former is equal to approximately 900 times the latter. Now assume that the price of one kilogram of industrial mineral is 100 times higher than the price of one kilogram of mineral chemicals. This implies

$$\begin{aligned} E_i &= a + 0.005 * 100 * V_{ind.chmcls} + 4.156 * 1 * V_{mil.chmcls} + u_i \\ E_i &= a + 0.5 * V_{ind.chmcls} + 4.156 * V_{mil.chmcls} + u_i \end{aligned} \tag{2.2}$$

where $V_{ind.chmcls}$ and $V_{mll.chmcls}$ are, respectively, the physical measures of consumption of the industrial chemicals and minerals chemicals. Here one can indeed say that the consumption of a kilogram of mineral chemicals is 9 times more air-polluting than the consumption of a kilogram of industrial chemicals, or that consuming one dollar in mineral chemicals is 900 times more air polluting than consuming one dollar in industrial chemicals. This implies an assumption, for the country where the estimates are applied, that the same relative prices among intermediate consumption prevail in the base year.

The choice of exogenous variables for the model was determined by the availability of data on intermediate production technology. The following table itemizes the types of intermediate consumption which are aggregated at the four-digit level of the International Standard Industrial Classification (ISIC) code. The aggregation was done to conserve degrees of freedom and minimize the risk of multi-collinearity. The ISIC (revision 2) classification was chosen to facilitate international comparisons and implementation with different sectoring schemes.

The intermediate consumption of the following products are extracted from the 1988 Social Accounting Matrix for United States[5]. This table details interactions between 487 production activities, but only those intermediates which explain a significant proportion of effluent output are discussed here. These 487 sectors are aggregated in 345 sectors in order to match with the IPPS sectoral classification. The IPPS data set does not contain pollution estimates for the 345 sectors. The number of sectoral estimates varies between 332 and 85, depending on the type of pollutant, and constitute the sample used below. The sample also uses intermediate demand data based on producer prices, which are thought to be more comparable to world prices and therefore more likely to satisfy the relative price assumption imposed across countries. The intermediates are expressed in millions of US dollars.

Table 2.1 : Intermediates Making Significant Contributions to Industrial Pollution

Coalmin	(ISIC : 2100) :	Hard coal, lignite.
Petgasmi	(ISIC : 2200) :	Coal gazified, crude petroleum and natural gas.
Oremin	(ISIC : 2301) :	Iron ores.
Nonfrmin	(ISIC : 2302) :	Uranium and thorium ores, non ferrous metal ores.
Chmclmin	(ISIC : 2902) :	Chemical and fertilizer minerals.
Othmin	(ISIC : 2909) :	Peat, Gypsum, anhydrite, abestos, mica, quartz, gem stones, abrasives, asphalt, other non metallic minerals.
Contpap	(ISIC : 3412) :	Containers and boxes of paper.
Indchmcl	(ISIC : 3511) :	Nuclear fuel, basic chemicals, nitric acid, ammonia, nitrate of potassium, urea, activated carbon, anti-freeze preparations, chemicals products for industrial and laboratory use.
Fert	(ISIC : 3512) :	Nitrogenous, phosphatic and potassic fertilizers, pesticides.
Paint	(ISIC : 3521) :	Paints, varnishes, lacquers.
Petref	(ISIC : 3530) :	Refined petroleum .
Petcoal	(ISIC : 3540) :	Miscellaneous products of petroleum and coal.
Plastic	(ISIC : 3560) :	Plastic products.
Nonfer	(ISIC : 3720) :	Non ferrous metals.
Constr	(ISIC : 5000) :	Construction services; oil and gas extraction excluding surveying.

The endogenous variables represent most major categories of air, water, and soil pollutants and were drawn individually and as composite indices from the IPPS inventory. These will be explained as their corresponding results are presented in the next section.

III. RESULTS

Estimation results are presented for thirteen categories of pollution. None of the intermediate goods was excluded *a priori* from the set of explanatory variables except services and electricity. Electricity is often a significant input, but is not expected to pollute when it is consumed. Preliminary regressions were carried out with an intercept, but this parameter was never significant. The criterion for each equation was global fitness measured by the R^2. All retained explanatory variables were significant at the 5 per cent level and most were significant at the 1 per cent level. The t-statistics are given between parentheses. Adding a few dummy variables for sector groups generally improved the quality of the estimations which take into account the main outliers and/or describe process attributes of production which are not captured by the linear specification. In order to identify the set of possible explanatory variables for each kind of emission, simple binary correlations between effluent intensity and intermediate demands were calculated. We retain from this set all the variables which are significantly correlated with the emission concerned at the 1 per cent level. The results below are organized by effluent category, the dependent variable.

1. Total toxic pollution

Toxic effluents are segregated by medium, namely Air, Water and Land, since it is apparent (Wheeler:1994) that these three types of emissions are not highly correlated and therefore need to be explained separately. Table 3.1 presents the set of possible explanatory variables inferred from simple correlations. Given the number of observations (332), a correlation coefficient in this sample is significantly different from zero at the 1per cent level if it exceeds 0.14.

Table 3.2 presents the results of estimation, with the dependent variables expressed in thousands of metric tons and the independent variables expressed in millions of US dollars. Intercepts were not significant at the 5 per cent level for the three types of emissions.

The intermediate consumption of mineral chemicals is important in explaining (with different magnitude), all three groups of emissions. This is not surprising since the major pollutant sectors are chemical manufactures and these processes are leading consumers of toxic products generally, and mineral chemicals in particular. Consumption of mineral chemicals is approximately seven times more land-polluting than air-polluting. Industrial chemicals are also important determinants of all three types of emissions, again with different impacts.

The other significant variables are also linked to chemicals, such as fertilizers (and pesticides) and paints. Non ferrous metals and petroleum-based products consumption are also significant. Judging from the dummy variable results, the pulp and paper sector is well above average in toxic effluent production.

One of the most noteworthy aspects of these results is the small number of intermediate inputs which explain the vast majority of effluent output. Given that the original sample contained 88 inputs and the correlated subsample (Table 3.1) 24, it is remarkable that over 90 per cent of the variation in effluent output can be explained by only 10 inputs for airborne media, 5 inputs for waterborne media, and 8 inputs for land polluting media. These results support the use of input monitoring and regulation as a substitute for output monitoring and regulation.

Table 3.1 : Total Toxic Pollution by Media Correlation Coefficients

	Air	Water	Land
Oremin	0.19	0.35	
Nonfrmin	0.40	0.28	0.15
Coalmin	0.18	0.30	
Petgasmi	0.25	0.29	0.27
Chmclmin	0.82	0.90	0.60
Othmin	0.65	0.67	0.58
Constr	0.48	0.49	0.39
Apparel	0.22		0.15
Sawmill			0.28
Contpap	0.24		
Pulpaper	0.21		0.24
Othpap	0.26		
Indchmcl	0.86	0.82	0.62
Fert	0.38	0.34	0.41
Resin	0.23		
Paint	0.23		
Drug	0.16		
Clean	0.15	0.14	0.16
Othchmcl	0.39	0.19	0.15
Petref	0.51	0.51	0.54
Petcoal	0.27	0.32	
Plastic	0.39		
Mineral	0.15		
Nonfer	0.16	0.18	

Table 3.2 : Total Toxic Pollution by media Econometric Estimations

	Air		Water		Land	
Nonfrmin	0.055	(19)			0.076	(3.7)
Coalmin	0.005	(5.4)				
Chmclmin	4.156	(23)	8.908	(12)	28.874	(26)
Petgasmi					0.003	(8.6)
Oremin					0.209	(16)
Othmin	0.014	(2.9)			0.118	(3.6)
Contpap	0.000	(3.2)	0.004	(3.2)		
Indchmcl	0.005	(13)	0.011	(6.7)	0.010	(4.9)
Fert			0.099	(11)		
Paint	0.016	(4.7)				
Petref	0.005	(4.8)	0.027	(5.8)		
Petcoal	0.035	(5.8)			0.274	(6.5)
Plastic	0.007	(15)				
Nonfer					0.005	(2.6)
Sectoral dummy variables						
d-Pulp and paper	16.83	(11)	287.14	(36)	45.91	(4.4)
d-Apparel	43.74	(16)				
R^2	0.966		0.910		0.933	
Number of observations	331		332		332	

2. *Bio-accumulative Toxic Pollution*

Now we present results on subgroups of toxic effluents, beginning with those which accumulate in living tissue and pose a significant long term risk to food chains and the reproductive integrity of species. This group of emissions is again classified according to originating media, before being taken up by living organisms. Included are the main metal elements that were discharged in 1988 by the US manufacturing plants: aluminum, antinomy, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, silver, thallium, vanadium and zinc.

Table 3.3 presents the set of possible explanatory variables deduced from simple correlations. Given the number of observations (210), the correlation coefficient is significantly different from zero at the 1per cent level if it exceeds 0.175.

Table 3.3 : Bio-Accumulative Toxic Pollution by Media Correlation Coefficients

	Air	Water	Land
Oremin	0.93	0.67	0.76
Nonfrmin	0.22	0.18	
Coalmin	0.90	0.38	0.79
Stone	0.29		0.48
Constr	0.69	0.28	0.79
Apparel			0.24
Leather	0.19		0.18
Indchmcl			0.18
Petref	0.24		0.37
Petcoal	0.18		
Cement	0.88	0.37	0.80
Mineral	0.24		0.31
Ironstee	0.63	0.25	0.56
Nonfer	0.33	0.21	
Metprod	0.20		

Econometric results are presented in Table 3.4. The three dependent variables are expressed in metric tons and the independent variables in millions of US dollars. The intercepts are not significant at the 5per cent level for the three types of emissions. The results are encouraging, since most of the intermediates explaining bio-accumulative pollution are metal-based, like non-ferrous metal ores, mineral ores, or non-ferrous metals. The consumption of construction services is more suspect but likely reflects second-order correlation with intermediates used in building. The non-ferrous metals, engines and ship building sectors, whose metal intermediate consumption is important, are well above average in bio-accumulative toxic pollution.

Table 3.4 : Bio-Accumulative Toxic Pollution by Media Econometric Estimations

	Air	Water	Land
Oremin	1.164 (12)	0.039 (4.1)	38.507 (65)
Nonfrmin	0.631 (12)		23.830 (26)
Coalmin	0.535 (11)	0.057 (11)	
Constr		0.032 (9.3)	
Nonfer	0.059 (12)		0.488 (7.1)
Sectoral dummy variables			
d-Non-Ferrous metals	81.70 (4.8)		
d-Engines and turbines	68.40 (2.7)		
d-Ship building	137.61 (4.4)		
R^2	0.965	0.937	0.962
Number of observations	209	208	209

3. *Other Air Pollutants*

This group includes five major air pollutants: Sulfur Dioxide (S02), Nitrogen Dioxide (N02), Carbon Monoxide (CO), Volatile Organic compounds (VOC) and Particulates (PART). Table 3.5 presents the set of possible explanatory variables deduced from single correlations. Given the sample size (86), the correlation coefficient is significantly positive at the 1per cent level if it exceeds 0.260.

The corresponding econometric results are presented in Table 3.6. The dependent variables are expressed in thousands of metric tons and the independent variables in millions of US dollars. Consumption of Petroleum, refined or crude and petroleum-based products is significantly and highly air-polluting. The pulp and paper sector is also much more air-polluting than the average for other sectors.

These results should be interpreted with care, however, since only 86 observations are available. Particulate (PART) emissions are more difficult to explain, as is apparent from the lower R^2 for that equation. The IPPS provides data for a sub-group of ten particulates, but no significant direct correlation between this kind of emissions and intermediate consumption was found.

Table 3.5 : Major Air Pollutants
Correlation Coefficients

	SO2	NO2	CO	VOC	PART
Oremin			0.91		0.31
Coalmin			0.91		0.34
Petgasmi	0.74	0.74		0.83	0.27
Othmin	0.27	0.28			
Constr	0.57	0.60	0.78	0.43	0.44
Spinning	0.31				
Leather		0.28	0.67		
Sawmill					0.29
Furnwood				0.33	
Paint				0.27	
Clean	0.29	0.28			
Petref	0.79	0.79	0.35	0.65	0.42
Petcoal			0.34		
Ironstee			0.60		

Table 3.6 : Major Air Pollutants
Econometric Estimations

	SO2	NO2	CO	VOC	PART
Coalmin			0.122 (27)		0.011 (5.7)
Petgasmi	0.004 (5.6)	0.002 (5.0)		0.003 (23)	
Indchmcl				0.003 (2.6)	
Paints				0.114 (9.5)	
Petref	0.079 (5.0)	0.049 (6.2)	0.008 (2.0)		0.013 (7.6)
Petcoal			0.165 (6.1)	0.086 (4.1)	
Sectoral dummy variables					
d-Spirit				53.56 (6.1)	
d-Sawmill			22.58 (4.0)		6.85 (2.5)
d-Pulp and paper	121.5 (8.5)	53.81 (7.7)	44.65 (6.5)		15.44 (5.2)
d-Glass		45.22 (4.7)			
d-Cement	99.87 (7.1)	56.25 (8.2)			20.96 (6.1)
d-Other machinery				24.62 (3.9)	
d-Wood Furniture				28.25 (6.3)	
R^2	0.894	0.904	0.927	0.894	0.692
Number of observations	85	85	86	86	85

4. *Other Water Pollutants*

This group includes two major water pollutants: Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS). Table 3.7 presents the set of possible explanatory variables deduced from simple correlations. For this sample size (229), the correlation coefficient is significantly different from zero at the 1per cent level if it exceeds 0.168.

Table 3.7 : Major Water Pollutants
Correlation Coefficients

	BOD	TSS
Oremin		0.93
Coalmin		0.99
Chmclmin	0.52	
Othmin	0.39	
Constr	0.25	0.71
Dairy	0.27	
Apparel		0.19
Sawmill	0.40	
Indchmcl	0.45	
Fert	0.17	
Petref	0.37	0.25
Petcoal		0.18
Mineral		0.20
Ironstee		0.67
Metprod		0.15

The corresponding econometric results are presented in Table 3.8. The dependent variables are expressed in thousands of metric tons. The two explanatory variables are primary products of the mining sector, crude coal (with a correlation coefficient of 0.99) for BOD and mineral chemicals for TSS. Clearly, these two inputs would be attractive candidates for regulation to mitigate BOD and TSS pollution.

Table 3.8 : Major Water Pollutants
Econometric Estimations

	BOD	TSS
Coalmin		2.942 (171)
Chmclmin	5.150 (22)	
Sectoral dummy variables		
d-Dairy	27.82 (9.5)	
d-Pulp and paper	107.59 (28)	118.82 (4.3)
d-Drug		222.02 (4.8)
R^2	0.855	0.992
Number of observations	228	227

5. *Implementation of the results for other countries*

To apply these results to environmental evaluation in other countries, the input-based emission coefficient estimates reported above must be made compatible with local output accounting. The first step is to assure the concordance in the composition of sectors between the United States and the country concerned. If the number of sectors is greater in the United States than in the other country, the coefficient is transformed by the following weighting scheme

$$ {}_{b,j} = \sum_{i}^{n} {}_{a,i,j} \quad {}_{a,i,j} \qquad \text{with} \qquad \sum_{i}^{n} {}_{a,i,j} = 1 \tag{5.1} $$

where b denotes the new country and a the United States. The input emission coefficient for product j in the country b is equal to the sum of the coefficients for subsectors of the product j in the US, a, weighted by the United States shares of each subsectors i,j that constitute sector j. If the number of sectors is lower in the United States than in the other country, the sectors are aggregated in country b to conform with country a. The second step is to express the coefficient in its local currency, by dividing it by the exchange rate, e (number of local currency for one US dollar, middle of period). If the years of data sampling do not match, the coefficient can also be divided by the inflation rate in the United States (l+r). This would yield

$$ {}_{b,j,lc} = {}_{b,j,\$} \Big/ \left(Er * (1 + r)\right) \qquad (5.2) $$

where c denotes the local currency. Coefficients for the dummy variables are transformed in the same way, in terms of sector disaggregation and currency. They are also divided by the level of production in the corresponding US sector. Indeed, this dummy is directly associable to the level of production of the specified sector. This procedure accounts for output expansion and contraction in the dummy sector, and the level of emission of the sector i is then given by

$$ E_i = \sum_j {}_j C_{i,j} + {}_i XP_i \qquad (5.3) $$

where XP denotes the production of the sector i.

IV. SOME COMPARATIVE ESTIMATES

The relative scarcity of engineering estimates for pollution rates in some countries obliges researchers occasionally to borrow coefficients obtained from other economies. This is a second-best procedure whose credibility is limited by differences in technologies, output mix for aggregated sectors, input mix, and time of sampling. The basic tenant of this paper is that one should at least move one step back up the production process, attributing effluent production to input use, and the econometric results of the last section indicate that such an abstraction can still explain most of the variation in sectoral pollution output.

In this section, a few comparative results are presented to give an indication of differences which can arise in effluent production rates between countries. Using a sample of input-output tables from six geographically and structurally diverse economies, we have applied the input-based effluent coefficients of the previous section to estimate pollution output intensities (kilograms of effluent by US dollar of output) for fourteen aggregated sectors. The results of this exercise are reported in Tables 4.1 and 4.2. Units in these tables are, for each effluent category, ratios to the economy-wide (Table 4.1) and sectoral averages (Table 4.2) across all six countries. In other words, in the composite category of toxic airborne pollutants (toxair), Brazil's effluent production, per unit of total output is estimated to be 1.7 times the simple average for the six countries (Table 4.1). In the agricultural sector this ratio is estimated to be 2.1 times the average for the six countries (Table 4.2).

The disparity in effluent intensities between countries at the economy-wide level is apparently quite substantial (Table 4.1). Brazil and China seem to use more pollutant input mixes than the United States. Japan is always very close to the average of the six countries.

Table 4.1 : Relative Total Effluent Intensity Across Country

	Brazil	China	Indonesia	Japan	Mexico	USA
TOXAIR	1.7	0.9	0.8	1.0	1.3	0.4
TOXWAT	1.5	1.7	1.2	0.6	0.5	0.4
TOXLAND	1.6	0.9	0.9	0.9	1.5	0.3
BIOAIR	1.1	1.5	0.9	1.2	0.8	0.5
BIOWAT	1.4	1.4	0.8	1.0	0.3	1.1
BIOLAND	1.2	1.0	1.1	0.8	1.8	0.2
SO2	2.0	0.8	1.4	0.9	0.4	0.4
NO2	2.0	0.8	1.4	0.9	0.4	0.4
CO	2.0	1.4	0.3	0.9	1.0	0.4
VOC	2.4	0.6	0.5	0.9	1.1	0.5
PART	1.9	1.1	1.3	0.9	0.4	0.4
BOD	0.3	1.4	1.6	0.8	1.6	0.4
TSS	0.5	3.5	0.1	0.9	0.5	0.5

Note : Units are ratios of total output effluent intensity to averages across countries

The disparity in effluent intensities between countries at the sectoral level is even more substantial (Table 4.2). Using output-based coefficients, only differences due to output mix in the 14 aggregate sectors would be discernible, and would be significantly smaller. Sectors 8, and 9, for example, are aggregated from only two sectors of input-based estimates, and thus would be relatively uniform across countries with output-based effluent estimation. Another important source of international differences in these estimates is the time of sampling. The input-output table of Brazil, for example, is from 1980, when many production processes were likely to have been more resource- and toxic-intensive than they are today. This may explain the generally higher relatives for this country. Mexico and the United States by contrast, were respectively sampled in 1989 and 1988, so their relatives may be biased downwards. For the remaining three countries, the input-output tables were sampled for 1985, and yet quite substantial differences in effluent intensity emerge. Thus it is unlikely that estimates relying on output-based coefficients transferred from another country will provide reliable guidance to policy makers and engineers.

Given the diversity of production technology across countries, the inter-country variance of effluent intensity by sector is also a useful indicator of the potential for sectoral pollution reduction. Input mixes in agriculture, wood, and plastic and rubber production vary more across countries than in paper, mineral or metal production. Hence, pollution abatement through transfers of clean technology seems more promising in the former sectors than in the latter, since the distance between the cleanest and the dirtiest technology is bigger .

Cross-country comparisons of pollution intensity are of interest in themselves and are useful for contrasting input-based and output-based measurement techniques. Of more immediate relevance to policy makers, however, are the relative pollution intensities of domestic production activities. To illustrate how these differences emerge from input-based pollution estimation, the same data set of input-output tables was used to compute within-country relative pollution intensities across sectors. Results for the 6 countries are given in Table 4.3. Units in the table are ratios of sectoral pollution intensity to the simple (i.e. not output weighted) average across all sectors within the same economy. For example, in terms of all toxic air emissions, Brazilian mining (1.0) is of average pollution intensity for the economy, but is about 4-5 times more toxic air intensive than agriculture (0.2) and about 3 times more so than food processing (0.3).

Some sectors appear to be environmental "hot spots" in most countries, particularly chemicals, mineral, and metal sectors. The ordering varies significantly with the type of effluent, however, and some countries appear to have specialized problems. The United States, for example, has relatively little trouble with total toxic air emission from the minerals sector, yet minerals' SO2 and NO2 emissions are multiples of the national average. In the case of toxic water pollution, most countries might want to focus their regulatory attention on Chemicals, but in Brazil and the United States Agriculture is at least as problematic.

In addition to temporal differences, it should be noted that the estimates of the previous section are implemented with the assumption that relative input prices are comparable in countries where the input-based coefficients are applied. While this assumption affects the ordering of sectors across countries, it has relatively little effect on the ordering of sectors within countries.

What emerges from these estimates is a diagnostic map which can help policy makers to identify their priorities for domestic pollution abatement. These estimates are necessarily approximate and an imperfect substitute for precise local measurement and surveillance. We do feel, however, that the relative measures in Table 4.3 are robust enough to provide reliable guidance for environmental research and policy design. It is hoped that their use will also provide impetus for more direct observation and improved sampling methods in developing countries.

Table 4.2 : Relative Sectoral Effluent Intensities Across Countries

	Agric	Mining	Food	Text	Wood	Paper	Chem	Petrol	Plastic	Mineral	Metal	Elec	OthMn	Serv
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TOXAIR														
Brazil	2.1	1.0	2.6	1.5	2.4	2.2	1.3	2.1	1.2	2.0	0.9	0.2	1.3	1.8
China	0.3	0.4	0.4	0.9	1.2	0.8	0.6	0.4	1.5	0.6	0.8	1.5	0.8	1.2
Indonesia	0.2	0.0	0.6	0.9	0.6	0.8	0.7	0.0	0.4	1.3	1.8	2.0	0.5	1.6
Japan	0.9	0.3	1.2	1.2	0.7	0.7	0.7	1.1	1.5	1.2	1.0	1.5	0.7	0.7
Mexico	1.8	4.2	0.5	0.3	0.3	0.8	2.2	2.1	0.6	0.8	1.3	0.3	2.1	0.3
USA	0.7	0.1	0.7	1.2	0.8	0.8	0.5	0.3	0.9	0.1	0.2	0.5	0.5	0.4
TOXWAT														
Brazil	2.1	0.8	2.3	0.6	0.6	1.4	2.1	1.7	0.9	0.5	0.7	0.3	0.4	1.4
China	1.1	0.8	0.4	1.9	4.0	1.2	1.7	0.7	3.5	0.9	2.4	0.6	4.0	1.4
Indonesia	0.6	0.2	1.1	1.4	1.0	0.9	0.5	0.1	0.4	2.0	1.5	3.7	0.6	1.9
Japan	0.6	2.4	1.2	0.9	0.2	0.8	0.7	1.1	0.4	1.7	0.5	0.8	0.5	0.6
Mexico	0.6	1.8	0.5	0.9	0.1	0.6	0.5	1.6	0.1	0.8	0.4	0.1	0.3	0.3
USA	1.0	0.1	0.4	0.3	0.2	1.1	0.4	0.7	0.7	0.1	0.4	0.5	0.3	0.2
TOXLAND														
Brazil	2.5	2.2	3.3	0.9	2.3	1.9	0.7	2.4	0.5	0.6	1.8	0.2	2.2	1.2
China	0.3	0.4	0.6	0.3	2.6	0.8	0.6	0.2	1.9	0.5	1.0	1.2	1.0	1.5
Indonesia	0.1	0.1	0.7	1.4	0.3	1.3	0.8	0.3	0.2	2.1	0.9	0.2	0.5	2.2
Japan	0.1	0.1	0.4	0.2	0.1	0.6	0.4	0.8	0.3	1.9	1.1	3.5	0.2	0.7
Mexico	2.4	3.1	0.8	3.0	0.1	0.8	3.2	2.0	1.4	0.8	1.0	0.7	1.7	0.2
USA	0.7	0.1	0.3	0.3	0.7	0.5	0.4	0.3	1.6	0.0	0.3	0.2	0.4	0.3
BIOAIR														
Brazil	4.5	2.2	3.7	0.4	0.5	1.2	1.7	0.0	0.7	2.0	0.7	0.1	1.0	0.8
China	1.1	0.4	1.6	4.8	5.1	2.5	1.6	2.5	4.8	0.6	1.4	4.2	0.6	1.4
Indonesia	0.2	0.0	0.4	0.2	0.0	0.7	1.5	0.1	0.0	1.5	1.2	0.2	2.8	3.0
Japan	0.0	0.0	0.1	0.1	0.1	0.5	0.3	3.1	0.1	1.5	0.5	0.6	0.8	0.7
Mexico	0.1	3.1	0.1	0.2	0.1	0.7	0.5	0.2	0.2	0.2	1.7	0.0	0.2	0.1
USA	0.1	0.2	0.2	0.3	0.2	0.4	0.3	0.0	0.2	0.1	0.5	0.8	0.6	0.0
BIOWAT														
Brazil	0.0	1.3	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.1	1.3	0.2	0.1	2.4
China	0.4	0.5	1.9	2.8	4.0	2.3	3.1	2.5	4.6	1.8	1.9	3.4	2.6	0.5
Indonesia	1.3	0.2	1.0	1.0	0.6	0.8	1.1	0.2	0.2	1.8	0.1	0.5	0.7	1.3
Japan	0.9	0.1	1.0	0.9	0.4	0.9	0.7	3.1	0.3	1.8	0.1	0.8	0.6	0.9
Mexico	0.0	0.8	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	1.7	0.0	0.7	0.0
USA	3.4	3.2	2.1	1.3	1.0	1.8	0.8	0.2	0.8	0.5	1.0	1.1	1.3	0.9
BIOLAND														
Brazil	5.7	2.3	5.4	3.9	3.9	2.2	2.5	0.5	4.1	2.5	0.4	0.8	1.1	1.0
China	0.0	0.3	0.0	0.2	0.9	0.4	0.3	0.0	0.1	0.0	1.4	1.6	0.6	0.0
Indonesia	0.2	0.0	0.5	1.1	0.1	1.4	2.0	0.1	0.4	1.6	1.5	0.0	0.1	3.9
Japan	0.0	0.0	0.0	0.1	0.3	0.6	0.3	0.2	0.2	1.6	0.6	0.2	0.2	0.9
Mexico	0.1	3.3	0.0	0.6	0.2	1.3	0.6	5.1	1.1	0.3	1.8	2.5	3.8	0.1
USA	0.0	0.0	0.0	0.1	0.6	0.0	0.3	0.1	0.2	0.0	0.3	0.8	0.2	0.0
SO2														
Brazil	2.3	1.2	1.7	1.1	1.5	1.7	3.6	1.6	3.8	1.3	0.9	0.3	0.9	2.0
China	0.2	0.4	0.1	0.2	0.9	0.3	0.3	0.5	0.4	1.7	1.8	0.4	1.7	0.7
Indonesia	0.5	0.4	1.5	2.2	2.6	1.1	0.4	0.4	0.9	1.6	2.1	3.7	1.2	1.9
Japan	1.3	3.7	1.6	1.9	0.4	1.5	1.4	1.4	0.5	0.5	0.7	0.9	1.1	0.7
Mexico	0.7	0.1	0.7	0.2	0.2	0.3	0.1	1.2	0.1	0.5	0.2	0.1	0.5	0.4
USA	1.0	0.2	0.5	0.3	0.4	1.1	0.3	0.8	0.4	0.2	0.4	0.6	0.5	0.3

Table 4.2 (continued) : Relative Sectoral Effluent Intensities Across Countries

	Agric 1	Mining 2	Food 3	Text 4	Wood 5	Paper 6	Chem 7	Petrol 8	Plastic 9	Mineral 10	Metal 11	Elec 12	OthMn 13	Serv 14
NO2														
Brazil	2.3	1.2	1.7	1.1	1.5	1.7	3.6	1.7	3.8	1.3	0.9	0.3	0.9	2.0
China	0.2	0.4	0.1	0.2	0.9	0.3	0.3	0.4	0.4	1.7	1.8	0.4	1.7	0.7
Indonesia	0.5	0.4	1.5	2.2	2.6	1.1	0.4	0.4	0.9	1.6	2.1	3.7	1.2	1.9
Japan	1.3	3.8	1.6	1.9	0.4	1.5	1.4	1.4	0.5	0.6	0.7	0.9	1.1	0.7
Mexico	0.7	0.1	0.7	0.2	0.2	0.3	0.1	1.3	0.1	0.5	0.2	0.1	0.5	0.4
USA	1.0	0.2	0.5	0.3	0.4	1.1	0.3	0.8	0.4	0.3	0.4	0.5	0.5	0.3
CO														
Brazil	2.9	1.3	2.6	1.3	1.0	1.9	1.1	1.5	1.0	1.0	2.5	0.2	2.2	2.3
China	0.5	1.2	1.8	1.8	1.6	1.6	0.7	1.2	2.8	2.5	0.8	3.3	1.8	1.7
Indonesia	0.2	0.1	0.4	1.5	1.4	0.4	0.1	0.0	0.1	1.2	0.4	0.7	0.6	0.8
Japan	0.5	0.9	0.5	0.5	0.8	0.7	0.3	1.9	0.1	0.9	1.3	1.1	0.1	0.6
Mexico	0.9	1.6	0.3	0.6	0.4	0.6	3.7	1.3	1.6	0.1	0.6	0.1	0.8	0.1
USA	1.0	0.9	0.5	0.3	0.8	0.9	0.1	0.1	0.5	0.3	0.4	0.7	0.4	0.5
VOC														
Brazil	2.0	2.2	1.1	3.9	1.8	4.3	1.4	1.9	1.8	2.9	2.8	0.2	2.3	3.0
China	0.2	1.1	1.6	0.3	1.3	0.4	0.3	0.4	2.3	0.7	0.2	0.8	0.6	0.6
Indonesia	0.0	0.8	0.1	0.8	0.3	0.1	0.3	0.7	0.1	0.9	0.6	0.3	1.2	0.7
Japan	0.2	0.1	0.6	0.1	1.0	0.0	0.5	1.0	0.2	0.4	1.8	3.2	0.9	0.6
Mexico	2.8	1.0	1.0	0.8	0.7	1.0	3.2	1.5	1.3	0.6	0.2	1.0	0.5	0.4
USA	0.7	0.8	1.5	0.1	0.9	0.2	0.3	0.5	0.3	0.4	0.5	0.5	0.6	0.8
PART														
Brazil	2.3	1.1	1.6	1.0	1.1	1.6	3.4	1.4	3.2	1.3	1.2	0.3	0.8	1.9
China	0.3	0.5	0.4	0.6	0.9	0.6	0.5	0.9	1.3	1.9	1.8	1.3	2.1	0.9
Indonesia	0.5	0.2	1.4	2.1	2.1	1.1	0.3	0.1	0.7	1.6	1.3	2.9	1.0	1.9
Japan	1.3	3.5	1.5	1.8	0.9	1.5	1.4	1.9	0.4	0.5	0.4	0.8	1.0	0.7
Mexico	0.7	0.4	0.6	0.2	0.4	0.3	0.1	1.2	0.1	0.5	0.8	0.1	0.6	0.4
USA	1.0	0.2	0.5	0.3	0.7	1.0	0.2	0.5	0.3	0.2	0.5	0.6	0.5	0.3
BOD														
Brazil	0.0	0.0	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
China	0.1	0.6	0.8	0.3	5.9	0.6	1.3	0.6	3.4	0.7	2.6	6.0	3.1	2.0
Indonesia	0.2	0.0	0.4	0.1	0.1	0.9	1.3	0.3	0.1	2.1	1.0	0.0	0.0	3.0
Japan	0.0	0.2	0.3	0.0	0.0	0.8	0.1	0.5	0.0	2.1	0.2	0.0	0.4	0.7
Mexico	5.7	5.1	1.0	5.6	0.0	0.6	2.6	3.0	0.0	1.1	2.2	0.0	2.3	0.3
USA	0.0	0.0	1.8	0.0	0.0	1.4	0.8	1.6	2.5	0.0	0.0	0.0	0.2	0.0
TSS														
Brazil	0.0	0.1	0.1	0.0	0.0	0.4	0.4	0.0	0.1	0.2	1.8	0.1	0.2	0.1
China	5.7	1.7	5.4	5.6	5.9	4.1	3.9	2.6	5.7	3.8	1.7	4.2	4.4	5.8
Indonesia	0.1	0.1	0.0	0.1	0.0	0.1	0.3	0.1	0.0	0.7	0.0	0.2	0.1	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.6	0.5	3.3	0.0	1.0	0.0	0.6	0.0	0.1
Mexico	0.0	2.5	0.0	0.0	0.0	0.1	0.4	0.0	0.1	0.0	1.7	0.0	1.3	0.0
USA	0.2	1.5	0.5	0.3	0.1	0.9	0.5	0.0	0.1	0.3	0.8	0.8	0.1	0.0
Variance	135	109	88	117	133	47	81	78	132	50	38	124	68	79

Notes : Units are ratios of sectoral output effluent intensity to averages across countries. The fourteen sectors are : Agriculture, Fishing (Agric), Mining and quarrying (Mining), Food processing (Food), Textile, apparel and leather products (Textile), Wood products (Wood), Paper and Printing (Paper), Chemicals (Chem), Petrol and Coal products (Petrol), Plastic and Rubber products (Plastic), Non-metallic mineral products (Mineral), Metal products (Metal), Electricity, Gas and water (Elec), Other manufactured products (OthMn), Construction and Services (Serv). Input-output tables were obtained for the following years : 1980 for Brazil, 1985 for China, Indonesia and Japan, 1988 for USA and 1989 for Mexico.

Table 4.3 : Relative Effluent Intensities Across Sectors

	Agric 1	Mining 2	Food 3	Text 4	Wood 5	Paper 6	Chem 7	Petrol 8	Plastic 9	Mineral 10	Metal 11	Elec 12	OthMn 13	Serv 14
TOXAIR														
Brazil	0.2	1.0	0.3	1.0	0.4	0.7	2.1	1.5	0.7	3.8	1.4	0.1	0.3	0.4
China	0.1	0.8	0.1	1.1	0.4	0.5	1.9	0.6	1.7	2.0	2.3	1.6	0.4	0.5
Indonesia	0.0	0.1	0.1	0.9	0.2	0.4	1.6	0.0	0.3	3.8	4.2	1.6	0.2	0.6
Japan	0.1	0.5	0.2	1.1	0.2	0.3	1.8	1.1	1.3	3.3	2.4	1.2	0.2	0.2
Mexico	0.2	4.1	0.1	0.2	0.0	0.2	3.3	1.5	0.3	1.4	2.0	0.1	0.5	0.1
USA	0.2	0.2	0.3	2.9	0.6	0.9	2.9	0.7	2.0	0.6	1.1	0.9	0.4	0.3
TOXWAT														
Brazil	3.2	0.4	0.3	0.1	0.2	1.0	5.6	1.0	0.5	0.8	0.1	0.3	0.1	0.5
China	1.6	0.3	0.1	0.3	1.0	0.9	4.2	0.4	2.0	1.3	0.5	0.5	0.5	0.5
Indonesia	1.2	0.1	0.2	0.3	0.3	0.8	1.6	0.0	0.3	3.7	0.4	4.2	0.1	0.8
Japan	1.4	1.5	0.2	0.2	0.1	0.9	2.8	1.0	0.4	3.8	0.1	1.1	0.1	0.3
Mexico	1.9	1.7	0.1	0.3	0.1	0.9	3.1	2.1	0.1	2.8	0.2	0.3	0.1	0.3
USA	4.0	0.1	0.1	0.1	0.1	2.1	3.0	1.1	1.0	0.4	0.2	1.2	0.1	0.2
TOXLAND														
Brazil	0.2	2.4	0.2	0.1	0.1	0.3	1.5	3.1	0.2	1.9	3.2	0.1	0.4	0.3
China	0.0	0.9	0.1	0.0	0.2	0.3	2.4	0.6	1.2	3.1	3.3	0.8	0.3	0.8
Indonesia	0.0	0.1	0.1	0.1	0.0	0.3	2.3	0.4	0.1	7.7	1.9	0.1	0.1	0.8
Japan	0.0	0.1	0.0	0.0	0.0	0.1	1.1	1.3	0.1	7.2	2.3	1.4	0.0	0.2
Mexico	0.1	2.5	0.0	0.2	0.0	0.1	5.2	1.9	0.4	1.9	1.3	0.2	0.2	0.0
USA	0.2	0.4	0.1	0.1	0.1	0.4	4.5	1.7	2.5	0.7	2.3	0.3	0.3	0.4
BIOAIR														
Brazil	0.1	3.7	0.2	0.0	0.0	0.1	0.8	0.0	0.1	4.1	2.0	0.2	2.6	0.1
China	0.0	0.6	0.1	0.1	0.3	0.2	0.6	1.7	0.5	1.0	3.2	4.3	1.3	0.1
Indonesia	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.1	0.0	2.7	3.1	0.3	6.9	0.3
Japan	0.0	0.1	0.0	0.0	0.0	0.1	0.2	3.6	0.0	4.2	1.9	1.0	2.8	0.1
Mexico	0.0	6.3	0.0	0.0	0.0	0.1	0.3	0.3	0.0	0.5	5.7	0.0	0.8	0.0
USA	0.0	0.8	0.0	0.0	0.0	0.1	0.5	0.0	0.1	0.4	4.0	3.2	4.8	0.0
BIOWAT														
Brazil	0.0	4.4	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.3	4.2	1.6	0.0	3.1
China	0.0	0.3	0.1	0.1	0.4	0.2	0.7	2.4	0.8	1.3	1.4	6.0	0.2	0.1
Indonesia	0.2	0.5	0.2	0.2	0.2	0.3	1.0	0.7	0.1	5.2	0.3	3.5	0.2	1.4
Japan	0.1	0.2	0.1	0.1	0.1	0.2	0.3	6.3	0.1	2.9	0.2	2.9	0.1	0.6
Mexico	0.0	4.1	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.3	9.0	0.0	0.3	0.0
USA	0.3	4.9	0.2	0.1	0.2	0.4	0.4	0.4	0.3	0.7	1.5	3.9	0.2	0.6
BIOLAND														
Brazil	0.1	4.8	0.3	0.0	0.0	0.2	1.1	0.0	0.1	5.8	1.2	0.0	0.2	0.1
China	0.0	1.6	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	11.6	0.0	0.3	0.0
Indonesia	0.0	0.0	0.0	0.0	0.0	0.2	1.3	0.0	0.0	5.3	6.6	0.0	0.0	0.5
Japan	0.0	0.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	8.7	4.4	0.0	0.1	0.2
Mexico	0.0	6.7	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.6	5.4	0.0	0.7	0.0
USA	0.0	0.5	0.0	0.0	0.0	0.0	1.4	0.1	0.1	0.4	11.2	0.0	0.4	0.0
SO2														
Brazil	0.5	0.6	0.2	0.1	0.3	0.5	3.2	2.2	0.9	3.9	0.2	0.5	0.1	0.8
China	0.1	0.3	0.0	0.0	0.3	0.2	0.5	1.1	0.2	8.7	0.7	1.3	0.2	0.5
Indonesia	0.1	0.2	0.1	0.2	0.4	0.3	0.3	0.5	0.2	4.4	0.4	5.9	0.1	0.7
Japan	0.4	2.7	0.2	0.3	0.1	0.6	1.8	2.6	0.2	2.2	0.2	2.2	0.1	0.4
Mexico	0.6	0.2	0.2	0.1	0.1	0.3	0.2	5.6	0.1	5.0	0.2	0.8	0.1	0.5
USA	0.8	0.3	0.2	0.1	0.2	1.1	0.8	3.7	0.3	2.4	0.3	3.3	0.1	0.4

Table 4.3 (continued) : Relative Effluent Intensities Across Sectors

	Agric 1	Mining 2	Food 3	Text 4	Wood 5	Paper 6	Chem 7	Petrol 8	Plastic 9	Mineral 10	Metal 11	Elec 12	OthMn 13	Serv 14
NO2														
Brazil	0.6	0.6	0.2	0.1	0.3	0.4	3.2	2.1	0.9	4.0	0.2	0.6	0.1	0.8
China	0.1	0.3	0.0	0.0	0.3	0.2	0.5	0.9	0.2	8.7	0.7	1.3	0.2	0.6
Indonesia	0.1	0.2	0.1	0.2	0.4	0.3	0.3	0.4	0.2	4.4	0.4	6.0	0.1	0.8
Japan	0.4	2.7	0.2	0.3	0.1	0.6	1.8	2.4	0.2	2.5	0.2	2.2	0.1	0.4
Mexico	0.6	0.2	0.2	0.1	0.1	0.2	0.2	5.5	0.1	5.3	0.2	0.8	0.1	0.5
USA	0.8	0.3	0.2	0.1	0.2	0.9	0.7	3.2	0.3	3.3	0.3	3.1	0.1	0.4
CO														
Brazil	0.3	0.5	0.2	0.1	0.4	0.4	1.9	4.0	0.4	0.8	3.7	0.4	0.3	0.6
China	0.0	0.4	0.1	0.1	0.5	0.3	0.8	2.3	0.7	1.5	0.9	5.9	0.2	0.3
Indonesia	0.1	0.1	0.1	0.4	1.7	0.3	0.4	0.3	0.1	3.1	1.6	5.0	0.2	0.5
Japan	0.1	0.4	0.0	0.0	0.4	0.2	0.6	5.8	0.0	0.9	2.1	3.2	0.0	0.2
Mexico	0.1	0.8	0.0	0.1	0.2	0.1	6.8	3.6	0.7	0.1	1.0	0.3	0.1	0.0
USA	0.3	1.2	0.1	0.1	1.0	0.7	0.5	0.8	0.5	0.7	1.8	5.6	0.2	0.4
VOC														
Brazil	0.1	0.4	0.2	0.6	2.1	1.4	1.9	2.7	1.1	0.9	1.7	0.0	0.6	0.4
China	0.0	0.5	0.7	0.1	4.1	0.3	1.1	1.5	3.4	0.6	0.4	0.6	0.4	0.2
Indonesia	0.0	0.6	0.1	0.6	1.5	0.1	1.6	4.1	0.4	1.3	1.5	0.5	1.3	0.4
Japan	0.0	0.0	0.2	0.1	2.8	0.0	1.7	3.2	0.2	0.3	2.5	2.3	0.5	0.2
Mexico	0.2	0.2	0.2	0.2	1.3	0.5	6.0	3.2	1.1	0.3	0.1	0.4	0.2	0.1
USA	0.1	0.5	0.9	0.1	4.1	0.2	1.3	3.0	0.6	0.5	1.1	0.6	0.6	0.4
PART														
Brazil	0.5	0.6	0.2	0.1	0.5	0.4	3.0	1.7	0.9	4.4	0.5	0.6	0.1	0.8
China	0.1	0.3	0.0	0.1	0.4	0.2	0.5	1.2	0.4	6.7	0.7	3.0	0.2	0.4
Indonesia	0.1	0.1	0.1	0.2	0.8	0.3	0.3	0.1	0.2	5.0	0.4	5.7	0.1	0.7
Japan	0.4	2.3	0.2	0.2	0.5	0.5	1.6	3.0	0.1	2.3	0.2	2.2	0.1	0.4
Mexico	0.5	0.6	0.2	0.1	0.6	0.2	0.2	4.4	0.1	5.2	0.9	0.5	0.1	0.4
USA	0.7	0.4	0.1	0.1	1.0	0.9	0.6	2.1	0.3	2.7	0.6	4.0	0.1	0.4
BOD														
Brazil	0.0	0.0	4.4	0.0	0.0	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
China	0.0	0.6	0.5	0.0	0.2	1.0	3.4	0.1	2.0	4.5	0.3	0.3	0.1	1.0
Indonesia	0.0	0.0	0.2	0.0	0.0	1.0	2.3	0.0	0.0	9.5	0.1	0.0	0.0	1.0
Japan	0.0	0.2	0.2	0.0	0.0	1.0	0.3	0.0	0.0	12.0	0.0	0.0	0.0	0.3
Mexico	0.3	3.0	0.4	0.4	0.0	0.6	4.2	0.2	0.0	4.6	0.2	0.0	0.1	0.1
USA	0.0	0.1	2.2	0.0	0.0	4.4	4.2	0.3	2.8	0.0	0.0	0.0	0.0	0.0
TSS														
Brazil	0.0	0.3	0.0	0.0	0.0	0.2	1.1	0.0	0.1	0.7	9.2	2.1	0.1	0.0
China	0.0	0.3	0.1	0.1	0.4	0.2	0.8	2.5	0.8	1.4	0.8	6.3	0.2	0.2
Indonesia	0.0	0.3	0.0	0.0	0.0	0.1	1.1	1.3	0.0	4.6	0.2	6.3	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.1	0.3	9.6	0.0	1.2	0.0	2.7	0.0	0.0
Mexico	0.0	4.8	0.0	0.0	0.0	0.0	0.8	0.0	0.1	0.0	7.8	0.0	0.5	0.0
USA	0.0	1.8	0.1	0.0	0.0	0.3	0.7	0.0	0.1	0.7	2.2	8.1	0.0	0.0

Notes : Units are within-country ratios of output effluent intensity to average across sectors.

IV. CONCLUSIONS AND EXTENSIONS

While direct regulation of effluents at their source is generally a more desirable policy, particularly when using economic instruments, this is often unworkable because of monitoring costs and limited institutional resources. In some cases, it may be more efficient or expedient to regulate input use if this can achieve comparable environmental objectives. This would be of particular interest in developing countries, where many inputs are imported or distributed from centralized sources, production can be geographically dispersed, and regulatory capacity and discipline may be limited.

The econometric results reported here indicate that such an indirect approach may indeed be feasible, since it is apparent that most effluent production is associated with use of a small number of intermediate goods. In 11 out of 13 cases of individual and composite pollution categories, over 90 per cent of the variation in effluent production can be explained by intermediate use of ten or fewer inputs. In some cases, only one intermediate explained almost all pollution.

Apart from the direct regulatory implications of these results, intermediate-based effluent coefficients can also be valuable for cross-country comparison of environmental damage. Very few countries have detailed estimates of output-based effluent coefficients, yet this kind of information is necessary for detailed environmental assessment. The trend until now has been simply to apply output coefficients which are available from other countries, like the US sample used here. This approach is fraught with uncertainty, however, because of significant differences in technology between countries. By using input-based coefficients instead, environmental appraisal can take account of differences in intermediate technology (where most pollution is in fact generated), without sacrificing much explanatory power. Ultimately, it would, of course, be preferable to have local engineering estimates of effluent intensities, but in the meantime the use of imported input-base coefficients provides a viable alternative.

NOTES

1. See Beghin, Roland-Holst and van der Mensbrugghe (1994a) for a survey of these issues and Beghin, Roland-Holst and van der Mensbrugghe (1994b) for detailed results.

2. Supervision itself may have unwanted incentive properties, particularly when salaries of public servants are low.

3. Such direct estimates are being produced for a number of developing countries by the World Bank (Wheeler:1992), but it will be some time before a large sample is available.

4. A variety of linear as well as nonlinear alternatives were also tested, but the one reported here was felt to be the most efficacious.

5. See Reinert and Roland-Holst (1992) for more information on this table.

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