The Economics of Industrial Pollution Control

An International Perspective

January 1992
THE ECONOMICS OF INDUSTRIAL
POLLUTION CONTROL
An International Perspective

David Wheeler

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INTRODUCTION

Industrial pollution is created when firms release harmful process byproducts into the environment. Excessive pollution occurs when they do not confront the true scarcity value of environmental absorptive capacity. While undervaluation of the environment reflects a universal externality problem, it is particularly serious in countries which have begun industrializing rapidly without commensurate development of their regulatory institutions. Excessive pollution is also encouraged when governments promote heavily polluting industries or subsidize material inputs and energy in pursuit of growth objectives.

The need for government regulation of pollution may be clear, but there has been an extended controversy over alternative intervention strategies. Environmental economists have been nearly unanimous in advocating control through market-based incentives, but environmental policy regimes in the U.S., Western Europe, and Japan have been built almost entirely on mandated control of pollution at the source. Why such a wide gap between the economists' prescription and regulatory practice? It seems very probable that something important is missing from the model which has led to such uniform advocacy of market-based approaches. Particularly suspect is the common assumption that the regulatory systems associated with different policies all operate efficiently and costlessly.

This paper begins with a review of the conventional theoretical argument for the superiority of market-based approaches and asks what difference it makes if uncertainty and regulatory implementation problems are taken into account. As part of the analysis it proposes a simple framework for comparing regulatory policy instruments, including: (a) quantitative emissions targets; (b) effluent taxes; (c) tradable rights to pollute; (d) subsidization or taxation of industrial outputs and inputs; and (e) promotion of technologies for pollution prevention. It suggests that appropriate instrument choices may differ according to local circumstances, and that direct controls may sometimes be preferable. In the second part, the paper surveys the experience of pollution control in ten countries, comparing regulatory regimes, institutions, instruments, implementation practices, and results. The concluding section considers policy implications and identifies some unresolved issues for future research.
EXECUTIVE SUMMARY

i. Environmental economists generally advocate market-based instruments for pollution regulation, but environmental policy makers have favored quantitative controls. This paper argues that both sides have a case: Appropriate instrument choice depends on many factors, including uncertainty; social values; transactions costs; institutional capability; enterprise ownership; pollutant risk; and the characteristics of the region within which regulations are to be implemented.

ii. The first part of the paper advocates a broadening of the conventional theory to incorporate some of these factors. In particular, a more realistic theory could help promote the design of regulatory systems which are appropriate for resource-constrained developing economies. As a first step, the paper suggests a simple framework for comparing regulatory policy instruments, including: quantitative emissions targets; effluent taxes; tradable rights to pollute; subsidization or taxation of industrial outputs and inputs; and promotion of technologies for pollution prevention.

iii. The second part of the paper surveys the actual experience of pollution control in ten industrial and developing countries, comparing regulatory regimes, institutions, instruments, implementation practices, and results. Principal findings include the following:

(1) Even very poor economies are rapidly enacting industrial pollution regulations. This is partly a reaction to huge remediation costs in the OECD economies. In addition, new sectors such as synthetic organic chemicals are creating toxic emissions problems earlier in the industrialization process. Finally, exposure risks are reaching unprecedented levels in huge, densely populated third world cities.

(2) Inappropriate economic policies can create major industrial pollution problems. Eastern Europe provided a clear illustrative case: Heavily subsidized materials, energy, and water discouraged recycling and promoted excess pollution. State investment policy explicitly promoted pollution-intensive heavy industries such as metals and chemicals. Finally, near-total insulation from world market forces totally retarded adoption of newer, more efficient, and cleaner technologies.

(3) Concern for market reputation and potential liability have promoted significant industrial cleanup in OECD economies which mandate emissions reporting by firms. Transparent environmental accounting may therefore be a potent instrument for new regulatory systems in developing countries.

(4) "Command-and-control" does not accurately describe existing systems with quantitative pollution controls. Actual regulation generally features negotiations at the plant level, with settlements reflecting differential access to information, local labor market conditions, relative political power, etc. Regulatory agents are key players, and rapid deepening of human resources should be an investment priority for new environmental protection agencies.
PART I

THE ECONOMICS OF INDUSTRIAL POLLUTION CONTROL

I. THE RATIONALE FOR POLLUTION REGULATION

A. The Pollution Problem

1.01 Pollution exists because the environment has limited absorptive capacity. Some hazardous byproducts (e.g. lead; dioxin; plutonium) are termed *stock pollutants* because the environment has almost no capacity to assimilate them. The others (e.g. carbon dioxide; biodegradable organic wastes) are known as *fund pollutants.* Most have a critical threshold beyond which they cannot be assimilated.

1.02 The limited absorptive capacity of the environment is, by itself, no more of a problem than the scarcity of other economic resources. The particular problem of pollution is created by an externality: The environment is a shared resource because a complete, legally enforceable system of private environmental property rights is not feasible. In the absence of a market, the economic decisions of firms and households do not assign any scarcity value to environmental absorptive capacity. Since its market price is effectively zero, this capacity is overutilized. The problem is compounded in the case of stock pollutants, whose byup highlights the fact that environmental resources are not only scarce but depletable. Sharing therefore has an inevitable time dimension; future generations must be at least implicitly consulted in the disposition of stock pollutants.

1.03 At a more concrete level, environmental problems are also differentiated by geographic and technical considerations. Pollution can have local, regional, or global impacts, with important consequences for policy design and the allocation of regulatory authority. It is a composite problem in three media -- air, water, land -- requiring a coordinated regulatory response. In the absence of coordination, for example, removal of some pollutants from airborne waste streams may simply lead to their deposition as hazardous waste in landfills. Technical differences by medium are also important. Air pollutants must be captured at the source, but this is not necessarily true for water pollutants or solid wastes. Scale economies may be captured by routing them to common processing sites for cleanup and byproduct extraction.

B. Policy Issues

1. The relevance of industrial pollution control for LDC's

1.04 No one denies that there is an industrial pollution problem. However, substantial disagreements emerge as soon as discussion turns to policy strategy. At the most basic level, there has been a traditional belief that the cost of industrial pollution control is not justified by the benefits in the early phase of industrialization: Pollution damage is still modest; aesthetic amenities don't have priority; and sophisticated regulatory and control techniques are unavailable. This view also holds that "poverty is the worst form of pollution" -- unrestrained industrial growth is better for national income growth and public health promotion while levels of sanitation, preventive medical care, and nutrition are very low. Recently, however, these traditional assumptions have been challenged on several grounds.

---

1/ See Tietenberg (1988) for an excellent discussion.

2/ There is a common but mistaken belief that LDC environmentalism is an import from the industrial world. Jose Lutzenberger, Brazil's Environmental Secretary, provides this illustrative history of environmental action in the Amazon case: "When we noticed that a significant part of the forest devastation was caused by multinational companies and financed by the multilateral development
Supporters of early intervention argue that stock pollutant buildup implies huge cleanup costs for future generations. The U.S., for example, now faces an enormous treatment cost for buried hazardous wastes after a century of unregulated industrial disposal. According to a recent estimate by the U.S. Office of Technology Assessment, at least 10,000 burial sites will ultimately be considered dangerous enough to require cleanup under the Superfund Act. Tietenberg (1988) argues that it will not be technologically or economically feasible to clean up more than 20% of these sites during the next few decades.

From the perspective of developing countries, rapid stock pollutant buildup in recently industrialized countries may provide even more persuasive evidence. Eastern Europe clearly has a severe problem: Wallich (1990) cites an estimated cleanup cost of $25 billion for existing environmental damage in Poland. In Korea, it has already become politically impossible for the government to use existing land for dumping industrial wastes. It is currently attempting to reclaim western seacoast land as an alternative (Clifford, 1990).

An emerging ecological crisis in Brazil's Amazon wetlands is also traceable to stock pollutant buildup. Robinson (1990a,b) reports that as many as one million miners are annually dumping tons of highly toxic mercury into the watershed after using it to separate gold from tailings. This is now being cited as the Amazon's primary environmental problem by Brazilian experts, in light of recent satellite data which indicate far lower rates of rain forest destruction than those previously estimated.3

Advocates of early intervention also note that developing countries are encountering complex toxic emissions problems far earlier in the industrialization process than their OECD counterparts. A good example is provided by industrial chemicals production. One major subsector, synthetic organic chemicals, is essentially a new industry, having entered volume production only since World War II. The associated hazards are suggested by the high ranking of synthetic organic chemicals and many other chemicals subsectors among U.S. sources of toxic, carcinogenic, and mutagenic pollution (Table L1 (a,b)).

Industrial chemicals production is currently growing at about 7.5% per year in developing countries versus 2.5% in developed countries (UNIDO, 1990). Growth is particularly rapid in Asia, where the rapid increase of organic chemicals consumption (Table L2) has stimulated ambitious plans for local capacity expansion (Vergara (1990)). In the absence of significant pollution regulation, the emissions intensity of the new production is likely to be even higher than in the U.S.

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Table I.1: TOXIC EMISSIONS: U.S. INDUSTRY, 1987

(a) U.S. Toxic Chemical Release Coefficients

<table>
<thead>
<tr>
<th>Industry</th>
<th>Lbs/S'000 of Value Added</th>
<th>Lbs/S'000 of Gross Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Chemicals</td>
<td>99.71</td>
<td>52.42</td>
</tr>
<tr>
<td>Primary Metals</td>
<td>56.80</td>
<td>21.48</td>
</tr>
<tr>
<td>Paper Products</td>
<td>56.46</td>
<td>23.87</td>
</tr>
<tr>
<td>Petroleum Refining</td>
<td>41.43</td>
<td>5.78</td>
</tr>
<tr>
<td>Textiles</td>
<td>13.45</td>
<td>3.47</td>
</tr>
<tr>
<td>Leather, Fur Products</td>
<td>12.18</td>
<td>3.62</td>
</tr>
<tr>
<td>Rubber, Plastic Products</td>
<td>8.26</td>
<td>3.20</td>
</tr>
<tr>
<td>Metal Products</td>
<td>4.06</td>
<td>1.05</td>
</tr>
<tr>
<td>Pottery, Glass Products</td>
<td>3.54</td>
<td>1.92</td>
</tr>
<tr>
<td>Electrical Machinery</td>
<td>3.10</td>
<td>1.72</td>
</tr>
<tr>
<td>Furniture</td>
<td>2.85</td>
<td>1.60</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>2.45</td>
<td>0.99</td>
</tr>
<tr>
<td>Food Products</td>
<td>2.35</td>
<td>0.97</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>2.08</td>
<td>1.13</td>
</tr>
<tr>
<td>Wood Products</td>
<td>1.26</td>
<td>0.52</td>
</tr>
<tr>
<td>Professional, Scientific Eq.</td>
<td>1.14</td>
<td>0.75</td>
</tr>
<tr>
<td>Non-Electrical Machinery</td>
<td>0.83</td>
<td>0.45</td>
</tr>
<tr>
<td>Tobacco Products</td>
<td>0.73</td>
<td>0.50</td>
</tr>
<tr>
<td>Printing, Publishing</td>
<td>0.71</td>
<td>0.47</td>
</tr>
<tr>
<td>Wearing Apparel</td>
<td>0.14</td>
<td>0.07</td>
</tr>
</tbody>
</table>

(b) Top Ten Industries Producing Hazardous Waste in the United States, 1987

<table>
<thead>
<tr>
<th>SIC</th>
<th>Category</th>
<th>Volume (million tons)</th>
</tr>
</thead>
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<tr>
<td>2859</td>
<td>Industrial organic chemicals</td>
<td>60-80</td>
</tr>
<tr>
<td>2800</td>
<td>General chemical manufacturing</td>
<td>40-50</td>
</tr>
<tr>
<td>2811</td>
<td>Petroleum refining</td>
<td>20-30</td>
</tr>
<tr>
<td>2892</td>
<td>Explosives</td>
<td>10-15</td>
</tr>
<tr>
<td>2911</td>
<td>Plastic materials/resins</td>
<td>5-10</td>
</tr>
<tr>
<td>2879</td>
<td>Agricultural chemicals</td>
<td>5-8</td>
</tr>
<tr>
<td>2813</td>
<td>Cyclic materials, intermediates</td>
<td>5-8</td>
</tr>
<tr>
<td>2812</td>
<td>Inorganic pigments</td>
<td>3.5-5</td>
</tr>
<tr>
<td>2812</td>
<td>Alkalis, chlorine</td>
<td>2.5-4.5</td>
</tr>
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</table>

Sources: USEPA, Toxics Release Inventory, 1987
          USEDC, Census of Manufactures, 1987
          UNIDO, Industry and Development: Global Report, 1980/91

Table I.2: DOMESTIC USE OF MAJOR PETROCHEMICALS

<table>
<thead>
<tr>
<th>Region</th>
<th>Korea (80-88)</th>
<th>India (80-88)</th>
<th>China (82-87)</th>
<th>Thailand (80-87)</th>
<th>Malaysia (80-87)</th>
<th>Indonesia (81-87)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>16.3</td>
<td>14.1</td>
<td>9.8</td>
<td>13.3</td>
<td>11.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Propylene</td>
<td>12.3</td>
<td>14.0</td>
<td>12.2</td>
<td>13.0</td>
<td>10.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Butadiene</td>
<td>7.3</td>
<td>--</td>
<td>11.9</td>
<td>16.0</td>
<td>14.2</td>
<td>15.6</td>
</tr>
<tr>
<td>Benzene</td>
<td>13.6</td>
<td>14.2</td>
<td>11.7</td>
<td>12.6</td>
<td>--</td>
<td>17.6</td>
</tr>
<tr>
<td>Methanol</td>
<td>7.0</td>
<td>--</td>
<td>17.0</td>
<td>30.7</td>
<td>20.2</td>
<td>45.2</td>
</tr>
</tbody>
</table>

Source: Vergara (1980), Tables 3.2; 3.4; 3.8; 3.10; 3.12
1.10 **Benefits and Opportunity Costs of Early Intervention** The argument that "poverty is the worst form of pollution" is also being scrutinized more carefully. As information about pollution costs accumulates, it is becoming increasingly difficult to argue for completely unregulated industrial growth in poor countries. Table I.3 presents estimates of relative air pollution severity for 45 major world metropolitan areas. Extremely high levels are currently prevalent in China, India, and Indonesia. The myriad laboratory and epidemiological studies cited in Krupnick (1990) and Bradley (1990) suggest that air pollutant exposure at such levels can obstruct breathing and increase the incidence of coughs, colds, asthma, bronchitis, and emphysema. In some cases, associations with heart and lung disease are also reported. The presence of many known toxins, carcinogens, and mutagens in existing emissions is well documented.

1.11 There is no doubt that high rates of exposure to hazardous pollutants can be extremely dangerous. The thousands of deaths attributable to "killer fogs" in the earlier history of British industrial development are well documented (Brimblecombe, 1987). In the 1970s and '80s, similar problems have emerged in the NICs. Findlay (1988) reports an atmospheric inversion on September 3, 1984 in Cubatao, Brazil, during which particulate concentrations in excess of 875 \(\mu g/m^3\) led to the declaration of a state of emergency and partial evacuation of the city. He also reports that the residents of Cubatao have experienced respiratory illness, infant deformity, and infant mortality at rates far above those in neighboring areas.

1.12 Among stock pollutants which are accumulating rapidly, the impact of excess lead has been carefully studied. The EPA (1986) has concluded that excessive lead intake can cause severe neurological impairment, particularly in children. Mercury contamination has also emerged as a serious problem. In Minamata, Japan several hundred people died or suffered irreversible brain damage from a regular diet of mercury-contaminated fish. Recent evidence from Thailand, reported in Table L4, indicates that in the decade 1978-1987 there was a tenfold increase in poisoning cases among workers with significant occupational exposure to toxic substances.

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Table L3 combines Global Environmental Monitoring System (GEMS) measures for sulfur dioxide and suspended particulates in a composite index of air pollution for 45 metropolitan areas. The index is constructed from WRI (1990) Table 24.5, "Air Pollution in Selected Cities." This table presents summary data on pollution from sulfur dioxide (SO\(_2\)) and total suspended particulates (TSP) for GEMS stations since their first year of operation. Mean series length is 8 years for SO\(_2\) readings and 10 years for TSP. The composite index presented in Table L3 is based on the maximum annual number of days during which the city's air pollution was above a critical health threshold (150 \(\mu g/m^3\) for SO\(_2\); 230 \(\mu g/m^3\) for TSP). Both series in the table are incomplete, but they are highly correlated. For this paper, missing observations have been filled in using crossed log-log regressions. Each completed series is standardized to the range (0,50) and the two series added to get the composite index.

In the GEMS sample, heavily-industrialized metropolitan areas in poorer Asian nations obviously have the most polluted air. The worst recorded case—Shenyang, China—has a truly spectacular air pollution problem. In 7 years of readings, Shenyang has been over the EPA's critical threshold for total suspended particulates (TSP) for 347 days in the worst year and 219 days on average. For sulfur dioxide (SO\(_2\)), Shenyang's worst year has seen 236 threshold-exceeding days, with 146 days on average (WRI, 1990).
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Table 1.3: AIR POLLUTION INDEX: MAJOR WORLD METROPOLITAN AREAS

<table>
<thead>
<tr>
<th>Country</th>
<th>Metropolitan Area</th>
<th>Total Index</th>
</tr>
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<tbody>
<tr>
<td>1 China</td>
<td>Shenyang</td>
<td>100</td>
</tr>
<tr>
<td>2 China</td>
<td>Beijing</td>
<td>82</td>
</tr>
<tr>
<td>3 Indonesia</td>
<td>Jakarta</td>
<td>60</td>
</tr>
<tr>
<td>4 China</td>
<td>Xi'an</td>
<td>71</td>
</tr>
<tr>
<td>5 India</td>
<td>Calcutta</td>
<td>66</td>
</tr>
<tr>
<td>6 India</td>
<td>Delhi</td>
<td>58</td>
</tr>
<tr>
<td>7 China</td>
<td>Guangzhou</td>
<td>56</td>
</tr>
<tr>
<td>8 China</td>
<td>Shanghai</td>
<td>47</td>
</tr>
<tr>
<td>9 Italy</td>
<td>Milan</td>
<td>47</td>
</tr>
<tr>
<td>10 Philippines</td>
<td>Manila</td>
<td>43</td>
</tr>
<tr>
<td>11 India</td>
<td>Bombay</td>
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<td>12 Korea, Rep</td>
<td>Seoul</td>
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<td>45 Japan</td>
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Source: WRI (1990), Table 24.5

Table 1.4: THAILAND INCIDENCE OF OCCUPATIONAL DISEASES

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<th>84</th>
<th>85</th>
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<tbody>
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<td>.040</td>
<td>.020</td>
<td>.030</td>
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<td>.020</td>
<td>.008</td>
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<td>.02</td>
<td>.02</td>
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<td>.04</td>
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<tr>
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<td>---</td>
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<td>.06</td>
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<td>.06</td>
</tr>
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Source: Kritiporn (1990), Table 4.6, p. 78

1.13 There are, of course, many sources of morbidity and mortality in poor countries. For public health improvements, the real question is whether the net benefits of pollution control are positive when the resources employed are valued at their opportunity cost in foregone public health investments. Benefit/cost measures are subject to great uncertainty in this area, but there seems to be a sound economic argument for some industrial pollution control, even in very poor countries. Both UNIDO (1990) and Kritiporn (1990) note
that the costs of pollution abatement typically rise very slowly at low levels of removal and accelerate only after substantial abatement has occurred. Solid empirical evidence is currently lacking, but if the most dangerous industrial pollution can be eliminated at relatively low cost, it is highly likely that early pollution control satisfies an appropriate benefit/cost criterion even if current public health effects are considered in isolation from all other factors.

Finally, there is a good case to be made for early regulation in order to prepare a developing economy for the potentially severe environmental stress which will accompany rapid industrialization. In the earliest period of a typical industrialization process, concentration in agro-industry and light assembly generates relatively modest emissions. Pollution rises sharply during the phase of heavy industrialization, and then falls as services and more technologically sophisticated manufacturing increase in importance. Since the potential consequences of pollution are likely to be most severe in the middle phase of development, it is sensible to have an adequate regulatory system in place at the appropriate time. This requires considerable advance work, because regulatory institutions, procedures, and instruments must be developed, staff must be trained, and industry must have time to adapt.

To summarize, there are many persuasive arguments for initiating industrial pollution control in the early stages of the development process. Appropriate regulation should substantially lower the present discounted cost of stock pollutant buildup; prevent the rapid onset of toxic emissions from new industries such as synthetic chemicals; prevent the most severe medical and ecological damage at justifiably low cost; and assure relatively smooth functioning of the regulatory system before the middle phase of industrial development puts the environment under severe stress. These practical arguments are given more force by a scientific trend toward lower estimates of ultimate environmental absorptive capacity (Pearce, 1989). This is reflected in the rapid emergence of global and regional commons issues such as ozone layer reduction, global warming, and pollution of international waters such as the Mediterranean.

2. **Alternative strategies for reducing pollution**

Having accepted the need for some pollution control, policy makers in many developing countries are now debating the cost effectiveness of alternative regulatory approaches. In one camp are policy professionals and environmentalists, who tend to favor quantitative control of industrial pollution through emissions restrictions or mandated installation of abatement equipment. The appeal of this approach lies in its simplicity, clarity, and ability to command broad political support. In another camp are advocates of market-based incentive systems who argue that their preferred approach maximizes firms' response flexibility and minimizes the cost of implementation. Much of the discussion within this group has traditionally focused on the design of administratively simple instruments which confront polluters with the true social cost of their activity. Recently, attention has also focused on the environmentally damaging impact of price and allocative distortions intended to serve broader industrial growth objectives. Subsidies for many raw materials, dirty fuels, and differentially polluting heavy industries have been particularly criticized (Anderson, 1990; Repetto, 1988; Hughes, 1990).

The past few years have also witnessed rapid emergence of a third camp, which focuses on pollution prevention rather than "end-of-pipe" control. Its partisans argue against diverting major resources to traditional direct regulation, noting that it can never be more than a palliative in a rapidly-growing industrial system. They advocate more emphasis on charges or quantitative restrictions on raw materials or consumer

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5/ Systematic surveys of LDC policy makers' preferences are unavailable. However, Kelman (1981) reports the results of an attitude survey of staff members of legislative environmental committees and environmental organizations in the U.S. Only 23% favored a market-based approach to regulation.

6/ For a good discussion and recent review of existing work, see Eskeland/Jimenez (1990).
products whose use or disposal creates the most serious pollution problems. Some argue for encouraging the creation and rapid diffusion of clean industrial processes and public dissemination of detailed emissions information to enhance the regulatory influence of affected local communities.

1.18 All three broad strategies for pollution control reflect economists' preference for viewing regulatory problems as analytically-resolvable contests among abstractly-defined instruments. In the conventional economic analysis, the regulatory agency takes its general objectives from the political leadership and translates them into technical regulations. These are transmitted to industry, which automatically responds in the appropriate way. While they do not question the value of such abstract analysis, Wyne (1987), Vogel (1986), Russell (1986), and many other students of regulatory implementation have argued that it is not sufficient for choosing an effective regulatory strategy. Regulation itself is not a one-way process, but a continuing negotiation among politicians, regulators, and industrialists in which incentives, differential access to information, and the political need for mutual accommodation all play a role. Each regulatory problem is somewhat unique, because it must be solved for a particular pollutant; different emissions possibilities (air, water, solid disposal); and a discrete geographic region with particular economic, demographic, and meteorological characteristics.

1.19 Such complexities will remain in the background while this paper introduces the formal analytical treatment of optimal pollution control. They will not, however, be forgotten. Later sections of Part I will re-introduce them in attempting to explain the large existing gap between theory and international practice. They will also emerge significantly in Part II, which reviews several country cases in more detail.
II. THE MICROECONOMICS OF DIRECT INDUSTRIAL POLLUTION CONTROL

2.01 It is technically correct to say that pollution becomes a problem when the scale of waste disposal exceeds the assimilative capacity of the environment. However, this is always a relative statement: "the environment" can mean anything from a bend in a river to the entire planet. Operationally, it is necessary to define a control region -- an area for which a particular regulatory policy is set. The traditional theoretical analysis assumes that the control region exists at some arbitrary geographic scale and defines broadly-applicable principles for optimum pollution control within it. The risks inherent in this approach are best highlighted with an illustration.

2.02 Suppose that the polluting activity is production in a heavily-industrialized region which is traversed by a river. Polluting byproducts include airborne sulfur dioxide, a potential source of respiratory problems; waterborne sources of biological oxygen demand, which poses a threat to aquatic life; and toxic solid wastes. At very low emission levels, these byproducts pose no threat because they are too thinly dispersed in the air, water, and land to be medically or ecologically damaging. However at some point, termed the threshold assimilative capacity, damage starts to show up and the region has "a pollution problem".

2.03 The choice of an appropriate control region, even in such a simple case, is not obvious. Its scale depends on the inherent toxicity of each pollutant, the intensity of its presence in each medium (air, water, land), and geographic circumstances such as the density of affected human, animal, and plant populations; wind speed and direction; the rate and volume of river flow; and the existence of terrain suitable for landfills. If regulatory policy is set after an assessment of assimilative capacity in any arbitrarily-selected region, the result may be quite unfortunate for "outside" populations which are downwind or downstream. A classic current example of this problem is acid precipitation in the eastern U.S. and Canada generated by tall-stack dispersion of airborne SO₂ to meet local regulatory requirements in the U.S. Midwest.

A. Optimal Pollution Control

2.04 Pollution is a byproduct of economic activity. For a particular pollutant in a particular medium, Figure II.1 depicts the hypothetical impact in a marginal social damage (MSD) schedule, which shows increasing effects as emissions increase past a region's threshold assimilative capacity. Pollution can be reduced by scaling back polluting activities or by diverting resources to cleanup, but there will be a cost to society in either case. Diminishing returns will apply; more resources will have to be devoted to cleaning up each additional unit of pollutant. This escalation is traced by the marginal cleanup cost (MCC) schedule depicted in Figure II.1. It slopes upward to the left because it measures the cost of reducing the variable -- pollution -- which is measured on the horizontal axis.

Although the conventional analysis is not generally very precise about this, the general tendency is to assume aggregation of human, economic, and ecological damage effects with some common unit of measurement. Nowhere is this presently done in actual regulatory practice. The construction of such composite indices has recently been identified by the EPA's Science Advisory Board as a critical priority for empirical research (USEPA, 1990).
Figure II.1

$\$\]$ MCC

Figure II.2

$\$\]$ $P_B$ $P_A$ $P_1$

$N_2$ $N^*$ $N_1$ $N^0$

$N_A^0$ $N_B^0$ $N_A^1$ $N_B^1$
If the government knows the location of both MSD and MCC, it can readily identify the socially optimal level of pollution in Figure II.1. Suppose the control region before regulation is at pollution level $N_1$; MSD is significantly above MCC. In this case, reducing pollution by one unit will reduce environmental damage by far more than it will increase the cost of cleanup. Logically, cleanup is worthwhile. At $N_2$, by contrast, cleaning up a unit of pollutant will cost far more than it is worth. The optimum is at $N^*$, where $MSD = MCC$ — the gain to society from cleaning up one unit of pollutant exactly matches the social cost.\(^2\)

The conceptual framework illustrated in Figure II.1 is appropriate for a general analysis. This paper focuses on industrial pollution control, however, and the policy issues are more easily dealt with if the problem is recast in the language of industrial economics. A firm pollutes when it is more profitable to dispose of harmful byproducts than to recycle or market them. From the perspective of the firm, the environment is the medium of disposal. From the perspective of society, environmental absorptive capacity is a form of social capital whose services are used by the firm when it pollutes. When "use of environmental services" is substituted for "pollution," one more input can be added to the standard list — labor, capital, skills, materials, energy. The calculus of profit maximization or output-constrained cost minimization then leads to a derived demand function which relates the use of environmental services to their unit price. If the price of environmental services rises, the firm may substitute toward capital by increasing the use of pollution control equipment; or toward labor by devoting more hours to recycling. It may also move away from the use of complementary inputs such as dirty fuels. All these activities amount to "cleaning up" because the firm pollutes less.

Now suppose that the control region has numerous plants in two competitive industries, A and B. Within each industry, a representative firm produces polluting byproducts whose disposal uses up scarce environmental services. The firms' input demand schedules $(D_A, D_B)$ in Figure II.2 relate use of environmental services $(N)$ to their price $(P)$. The overall difficulty of substituting other inputs for $N$ determines the steepness of the demand schedules.

Even without any regulation or legal liability for damage, firms must incur some disposal cost to move pollutants offsite. The marginal cost of disposal, assumed constant (and equal among firms) for the illustration, is the flat line at $P_1$ in Figure II.2. If private profitability is the only criterion, the two firms will choose to pollute (or use environmental services) at the point where their input demand curves cross the marginal disposal cost curve, at $N_{A}^*$ and $N_{B}^*$. Total industrial demand for environmental services $(D_T)$ is obtained by summing across all firms in industries A and B (Figure II.3). This demand schedule is analogous to society's marginal cleanup cost curve.

From society's perspective, there should also be an environmental supply schedule for industry. This has already been introduced as the marginal social damage function in Figure II.1 and is relabeled $S'$ in Figure II.3. As industrial pollution grows, $S'$ measures the associated increase in marginal social cost.

\(^2\) Many people with strong feelings about environmental preservation are uncomfortable with the notion of an "optimal" pollution level because it sounds like an optimal level of evil. Pollution could of course be made zero by forcing firms to halt all use of environmental services. At our present state of knowledge, this would effectively close down the economy.
2.10 If other markets in the economy are assumed to be competitive, so all input and output prices faced by firms reflect social opportunity costs, the optimum level of industrial pollution can readily be identified as $N'$, at the intersection of $S'$ and $D_r$ in Figure II.3. At $N'$, the extra benefit which industry derives from an additional unit of pollution is just balanced by its social cost, or shadow price $P'$. When industry faces only the private marginal disposal cost, $P$, it chooses too much pollution, at $N_1$. Since $N'$ and $P'$ are determined simultaneously, "too much" has dual interpretations: Environmental services are overused in the amount $(N_1 - N')$ or underpriced by the amount $(P' - P)$. Either interpretation provides a satisfactory economic definition of the industrial pollution problem for a particular control region.

B. The Social Cost of Regulation

2.11 This simple analytical model of optimal pollution control provides a good conceptual starting point because it highlights two logical principles: (1) Pollution should be reduced until the damage from the last unit removed is just equal to the cost of removing it; (2) The polluting firm should pay for the damage which it causes. When differentially polluting firms have to absorb the cost of the environmental services they use, appropriate information about the scarcity value of these services is propagated into the economy through differential product prices. These in turn provide incentives for firms and households to shift their activities in environment-protecting ways.

2.12 However, there is one obvious respect in which the simple model is lacking. It assumes zero transactions costs, defined by Dahlman (1979) as "... search and information costs, bargaining and decision costs, policing and enforcement costs" (p. 148). This definition accurately describes the costs of the regulatory system itself:

- The first steps in environmental regulation involve search, information processing, and decision-making. Target pollutants are selected from a huge population of potentially-harmful industrial byproducts. Ambient standards are then established for environmental resources (air, water, land); policy instruments are chosen and set at appropriate levels. Accompanying investments are made in new regulatory institutions, possibly including markets for recyclable byproducts and tradable rights to pollute.

- Once the system is in place, substantial bargaining, policing, and enforcement costs must be incurred. The regulatory system monitors both firm compliance with formal requirements and general attainment of ambient standards. Close interaction with affected firms may be required, if for no other reason than conveying information about expected performance.

- Sanctions are set and enforced by some means.

2.13 Analytical work has focused almost exclusively on one phase of the regulatory process -- the choice of policy instruments. The conventional assumption of zero transactions costs involves an implicit decision to exclude the other regulatory stages from consideration. When a government incurs regulatory costs, a gap opens between $(N', P')$ and the actual optimum. As manager of the environment, a government with few regulatory resources is somewhat like an absentee landlord. It can post rental claims or occupancy rules but may not be able to keep very close track of the tenants. Out of deference to the law or fear of punishment, some will pay the rent and respect the proprietor's rules anyway. The lighter the monitoring or the sanctions, however, the higher the delinquency rate will tend to be. Heavier monitoring or sanctions will be necessary if the rent escalates or the rules become more burdensome. Process costs will rise as sanctions increase because the accused will fight conviction more energetically and appeal to higher authorities more frequently.

2.14 Figure II.4 incorporates this basic notion into the determination of optimal pollution. Society is initially at pollution level $N_p$, where only private disposal cost is included in firms' calculations. The
government would like to move to \((N', P')\), but it can only do so by implementing some "feasible" regulatory system (including sanctions) which collects effluent fees or imposes pollution limits. By the logic of the previous argument, the marginal cost of implementation tends to rise as the fees get higher, the limits get tighter or, beyond a certain threshold at least, the sanctions get tougher. Regulation is socially efficient when it is implemented to the point where the gain from eliminating a unit of pollution is equal to the sum of marginal cleanup cost and marginal implementation cost.

2.15 In Figure II.4 industry demand \((D_t)\) and social supply \((S')\) remain as before, but now there is also MCI, which traces the escalating social marginal cost of implementing the feasible regulatory system as standards progressively tighten. The true social marginal cost of cleanup is now \([D + MCI]\), and the optimal feasible control point is \((N_t, P_t)\), with more pollution than \((N, P)\).

2.16 Three implications follow from this line of reasoning:

- Optimal pollution levels will be greater if transactions costs are incorporated, because governmental regulatory processes require real resources which have opportunity costs. But it is in most cases better than the "do nothing" equilibrium at \((N_t, P_t)\).  

- Polluting firms should be confronted with the full opportunity cost of pollution, including the cost of the system which is required to monitor and control it.

- For any regulatory system, the location of MCI will vary with regulatory productivity, resource opportunity costs and management efficiency levels. Since these vary internationally, appropriate regulatory systems may differ from country to country as well.

C. Regulatory Instruments

2.17 Figure II.4 suggests two basic ways for the government to move industry to the optimum pollution point. It can choose a price-based (PB) approach, confronting all firms with the shadow price \(P_r\) and ensuring optimal environmental use at \(N_r\). Or it can opt for a quantity-based (QB) solution, ordering firms to cut back pollution in such a way that aggregate environmental use is restricted to \(N_t\).

2.18 The most common PB instrument is the effluent charge (EC), which is levied per unit of pollutant discharge into the air or water. Where discharge monitoring is difficult, governments sometimes opt for deposit-refund (DR) systems, which require firms to pay in advance for estimated pollution and provide rebates on proof of lower emissions. In the discussion which follows the abbreviation EC will refer to both charge systems. Tradable permit (TP) systems specify an aggregate limit on pollution, but allow it to be allocated among firms in a secondary market for pollution rights. QB regulation may operate through baseline emissions standards (ES) or mandated installation of pollution control equipment (MIC) when discharge monitoring is difficult.

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2/ This need not always be so, of course. If MCI is steep enough and far enough to the right, its associated optimal pollution level will be greater than \(N_r\). Regulation is then so unproductive or, equivalently, transactions costs so high that the optimal policy is passivity. Coase (1988) stresses the importance of this case: Negative externalities are ubiquitous in urban society, but many should be ignored because the transactions costs associated with doing anything about them are simply too high. But Coase's argument must be interpreted dynamically to avoid excessive passivity. New regulatory systems become effective only after a learning period, and the initial unit cost of regulation is likely to be much higher than the ultimate cost.
2.19 In the theoretical optimization model, it is easy to show that ES is less economically efficient than an EC or TP system. Suppose, as in Figure II.2, that the government dictates pollution reduction for two representative firms from different industries (A and B), ordering both to cut back their pollution by 50%. The environmental demand curves of A and B have different slopes and positions, reflecting the underlying differences in their production economics. At the new constraints imposed by the government, A and B confront very different shadow prices for the use of environmental services.

2.20 B now has a much greater willingness than A to pay for an additional unit of these services. Since the analysis presumes perfect competition in all other markets, this implies that society as a whole would be better off if the marginal unit could be transferred from A to B. Thus, the government cannot do better than specifying a common emissions charge $p_t$ or, equivalently, setting $N_t$ and allowing firms to trade freely in rights to pollute until equilibrium is attained at $p_e$. It would have to be uncommonly lucky to specify an ES rule which matched the allocation of pollution cutbacks effected automatically by the EC or TP approaches.

2.21 This idea can be generalized by imagining a list in which all industries are ranked according to the relative elasticities of their environmental demand curves. If the industries in an economy are all relatively close to one another on this list, the opportunity cost of the ES approach is fairly small. As they diverge, the cost rises.

2.22 Numerous simulation studies in the U.S. have supported this theoretical result, suggesting very high costs for actual ES-based pollution regulation when compared with equivalent pollution reduction in an hypothetical EC system. Air pollution studies have considered sulfur dioxide (Roach, 1981; Spofford, 1984); nitrogen dioxide (Krupnick, 1983; Seskin, 1983); and suspended particulates (Atkinson, 1974). The estimated ES/EC cost ratios for meeting the same pollution target have a median value of 4.2. For water pollution, simulation studies of biological oxygen demand (Johnson, 1967; Eheart, 1983) have a median cost ratio of 1.6 (under the assumption that the QB approach is proportional reduction from existing effluent levels).

D. Regulatory Cost and Optimal Instrument Choice

2.23 Consideration of regulatory system costs may well influence the choice of techniques for information gathering, monitoring, and enforcement in developing countries, but it has no clear implications for optimal instrument choice. Given some regulatory budget and ambient goal, the core activities of a regulatory system are essentially the same, and pursued at about the same intensity, whatever control instrument is chosen. The regulator has to locate polluters (not always a trivial task in countries with large informal sectors); inform them about regulations; monitor performance and local ambient conditions; determine the nature of violations and appropriate sanctions; and pursue legal means of enforcement where appropriate.

2.24 Most of these activities are clearly identical across instruments. It is at the monitoring stage that costs might be presumed to differ most strongly in favor of price-based regulation. But a comparison of monitoring requirements for the major instruments shows that this is not really true. In all cases the government has to know the actual volume of firms' emissions. For an EC system, this is necessary for levying the appropriate total charge. In a TP system, it is necessary for verifying that firms are not discharging beyond the limits specified on their tradable permits. Refunds in a DR system will depend on the difference between actual and predicted emissions. Emissions standards cannot be enforced unless emissions are monitored; and the true effect of an MIC system cannot be known unless post-installation emissions are known as well.
III. SOURCES OF VARIATION IN OPTIMAL INSTRUMENT CHOICE

3.01 The conventional economic analysis of regulatory policy assumes the existence of a single "control region" with unique marginal social damage and cleanup cost functions. A unit of pollution is assumed to make the same contribution to aggregate social damage, whatever the location of its source. For such a region, the conventional analytical model suggests that price-based regulation is the dominant solution. In the relatively few cases where true price-based instruments have been employed, they have undeniably proven themselves quite effective. The recent history of Dutch water quality policy illustrates the pollution-reducing potential of effluent charges.\(^{10}\) By the late 1960's, waste discharge into Dutch surface waters had drastically exceeded their assimilative capacity. Under the 1970 Pollution of Surface Waters Act, the government instituted an EC system based on a unit charge per 'inhabitant-equivalent' (IE)--the approximate amount of organic pollution of waste water normally produced by one person. In 1969, fourteen pollution-intensive sectors produced about 29.2 million IE--90% of total industrial organic water pollution in the Netherlands. Starting in 1970, a fee of $4.00 per IE was levied on polluting plants. During the following decade the fee rose about 83% (in 1970 dollars), reaching $7.30 per IE in 1980, and total organic pollution from the fourteen sectors dropped by 69% to 9.1 million IE. Since real Dutch industrial output grew about 27% during the decade, the implication is an approximately unitary long-run response elasticity.\(^{11}\)

3.02 At least one notable success has been achieved by a TP system as well.\(^{12}\) Both Hahn (1989) and Tietenberg (1988) cite the USEPA's lead trading program as a model TP exercise. This program was initiated in 1982 and scheduled from the outset for termination at the end of 1987. Its purpose was to promote flexibility and cost savings in the refining industry's response to mandated reductions in the lead content of gasoline. Superior performers were allowed lead credits, which could be traded to inferior performers in an open market. Since the aggregative targets were fixed by law and easily monitored, the purpose of this program was explicitly cost-effective compliance with the regulations, not extra reduction in pollution. Hahn (1989) estimates that total savings to refiners under the program must have been somewhat higher than $250 million, when compared with an ES regime forcing concurrent reduction at every refinery.

A. The Dominance of QB Regulation

3.03 Despite these impressive results, PB approaches have rarely been implemented. Even where PB systems are in effect (including the two cases just cited) quantitative limits such as baseline effluent standards (ES) are always employed. When ES systems are difficult to monitor, policy makers have frequently resorted to another QB approach--mandated installation of specific pollution abatement equipment. This option is based on the expectation that verification of installation can substitute for continual inspection. While there are obvious reasons why this might not be true--equipment can be badly maintained or simply disconnected--such requirements have featured prominently in industrial regulation almost everywhere. In the

\(^{10}\) See Bressers, 1983. Other examples of EC systems are cited in the country case analyses which constitute Part II of this paper.

\(^{11}\) It is important to note that this is a partial equilibrium result which undoubtedly overstates the response elasticity of total industrial pollution to water charges. High intermediate substitution elasticities exist for many processes. For example, if water pollution charges are high but cheap landfill sites remain available, toxic pollutants can be separated from the waterborne waste stream and transported off-site as "solid waste." Wynne (1987) and others have noted the rapid growth of toxic waste shipments from Netherlands and other West European countries during the period when water pollution was falling rapidly.

\(^{12}\) A more detailed treatment of existing TP systems is included in the country case studies.
U.S., for example, the Clean Water Act of 1972 required that by 1977 industrial dischargers meet effluent limitations based on the "best practicable control technology currently available." By 1983, this was to become the "best available technology economically achievable" (Tietenberg, 1988, p.412).

B. QB vs. PB Systems: Sources of Variation in Optimal Choice

3.04 Why this sharp divergence between theory and practice, even in the face of some successful applications of market-based instruments? Schelling (1983) provides a suggestive insight:

'Economists are aware of all that is attractive about pricing mechanisms, and what is attractive comes out of economic theory, whereas administrators and legislators are aware of all the practical reasons why pricing would rarely work well enough for the theoretical virtues to outweigh the practical objections.'

1. The role of political preferences

3.05 Some of these objections are political, and apparently quite potent. QB appeals strongly to three broad political constituencies. The first, and (as yet) least numerous, associates pollution with wrongdoing and is therefore averse to policies which legitimize it by explicitly pricing it for sale (Nelson, 1990; Kelman, 1981). Their objection is in principle no different than the rejection by others of state lotteries, state liquor stores, or tax-supported abortions. From this perspective, a "commandment" to reduce pollution is considered more ethically defensible as a means, even if the end--reduced pollution--is the same.

3.06 The second group, probably more numerous, values what it perceives to be guaranteed results. Attainment of ambient goals looks more certain if a quantitative ES is set, performance is mandated, and compliance is enforced. Harrington (1987), however, argues persuasively that this "certainty" is mostly illusory because of severe practical difficulties with monitoring.

3.07 The third group is the business community itself. Business groups have historically favored direct controls because they have felt better able to steer the regulatory process (OECD, 1989). In addition, business people are aware that effluent charges have never been imposed in isolation from quantity standards. All existing charge systems follow the "polluter pays twice" principle--firms have to pay for cleaning up to baseline standards, and pay the charges as well. Therefore, charges look like an extra source of cost to business people. Industry incumbents are also apt to favor an approach which generally imposes stiffer controls on new entrants.13

3.08 Regulators themselves may also prefer quantity controls. Institutional precedent is powerful; historically, regulatory bureaucracies have had an orientation toward QB systems. In short, price-based regulation has to be significantly better than the quantity-based approach to stand a chance of adoption in most political systems.

2. Prices vs. quantities in real regulatory situations

3.09 Price-based regulation will undoubtedly be preferable under the following conditions: (1). All markets in the system are competitive. (2). The control region is populated by many privately-owned, cost-

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13/ This "new source bias" has been particularly notable in the U.S. but appears to be emerging in Europe as well. See Kopp (1990); Haigh (1989); Huber (1983).

14/ For some industries, the competition-limiting impact of new source bias seems to have registered significantly in stock prices. See Maloney (1982); Hughes (1986).
minimizing, fully informed firms engaged in heterogeneous activities with low transactions costs. (3). The government is fully informed about industry's environmental demand curve and the control region's environmental supply curve.

3.10 When these assumptions are relaxed to reflect the variety in actual regulatory cases, price-based regulation does not always turn out to be optimal. In fact, each of the common instruments -- EC, DR, TP, ES, MCI -- is best in some cases. This section will compare quantity-based and price-based systems, while the following section will look at the properties of alternative price-based instruments.

3.11 In general, at least four factors determine whether a PB or QB system has a significant advantage in a specific control region: The heterogeneity of industrial activity; the nature of uncertainty about environmental demand and supply; the heterogeneity of the region itself; and the presence of a significant number of public enterprises with soft budget constraints.

3.12 Industrial diversity Other things equal, QB regimes are suboptimal to the extent that industrial diversity gives firms very different environmental demand schedules. If these schedules were nearly identical there would be few potential "gains from trade" and government simulation of a market through a PB regime would result in very little cost savings. In practice, the potential gains appear to be large because most pollutants are emitted by plants in diverse industrial sectors with very different cleanup costs. For example, Crandall (1983) contrasts an airborne particulate cleanup cost range of $36 to $680 per ton removed in the utility sector with $1,010 to $3,030 in a secondary aluminum plant and $30,880 in a coke oven.

3.13 Uncertainty: Where industrial environmental demand is concerned, a more significant problem is the absence of any good information about the shape or position of the demand schedule. This can be extended to the supply schedule as well, highlighting uncertainty as a major problem. Theoretical work by Weitzman (1974) has considered the relative merits of quantity- and price-setting under uncertainty when there are alternative prior beliefs about the slopes of demand and supply schedules. Adar (1976) has extended this to the case of environmental regulation.

3.14 At issue is the cost of being wrong, on the assumption that policies are hard to change quickly once they have been implemented. A PB system should be superior if the environmental supply curve is relatively flat (small changes in pollution don't make much difference for marginal social damage); and the demand curve relatively steep (cleanup is very expensive for firms). In such a case, small reductions in pollution may radically increase industry's cost without much benefit for society as a whole. Price-based policies are better because they assure that the opportunity cost for industry will not be inordinately high.

3.15 The converse is true when the pattern is reversed -- steep supply curve, relatively flat demand curve. In such a case, a small deviation of the actual impact of an effluent charge from its expected impact can cause a large change in pollution and marginal social damage. Conversely, a quantitative restriction can offer considerable certainty about marginal social damage, but will not change industry's cost much even if it is somewhat overdone.15

3.16 Heterogeneity within control regions This may be the most important reason for the prevalence of quantity-based regimes. In the conventional abstract analysis, the "control region" is the

15/ Judgments about instrument choice obviously have to be case-specific in this context, and there are few published studies. Tietenberg (1988, p. 329) reports a study by Kolstad (1982), who considered the relative merits of charges and tradable permits for pollution from electricity production near the Four Corners wilderness area in the western U.S.. Using an engineering estimate of the industry demand curve and a variety of hypothetical supply curves, Kolstad concluded that permits were generally preferable.
geographic area within which a single QB or PB instrument is applied for a particular environmental medium and pollutant. In different circumstances, an actual control region may encompass the entire planet (e.g., the Montreal Protocol on CFC reduction) or remain focused around one heavily-polluting plant. If control is plant-specific, none of the abstract analysis is relevant—quantity and price controls are identical. Only as the number of firms in the control region grows substantially does the use of single averaging instruments like uniform price or quantity rules become appealing. For the reasons cited below, regulatory administrators may often treat their official control regions as sets of micro regions which are too small to warrant implementation of PB systems.

3.17 **Geographic variation** Students of regulatory implementation (e.g., Vogel, 1986; Wynne, 1987, Russell, 1986) invariably find that plant-level negotiations are the norm in regulatory processes. One major reason is geographic variation. Wind and water characteristics vary; sunlight exposure differs; exposed populations are non-uniformly distributed; separate pollutants, when mixed, can have highly nonlinear effects on exposure risk (Rich, 1990). When these phenomena are taken into account, actual control regions become single plants in many cases.

3.18 **Pollutant toxicity** When a plant generates extremely toxic emissions, the regulatory agency has to treat it as a separate control region and impose quantity controls. While some highly poisonous substances are easy to identify (e.g., plutonium), the identification of most other pollutants as sufficiently toxic to warrant QB controls involves somewhat arbitrary judgments. At present, the number of such substances is growing rapidly. In part, this is because of widespread worry that stock pollutants may haunt future generations. It also owes something to uncoordinated environmental regulation in the OECD countries. The installation of stack scrubbers and settling basins has generated large volumes of solid wastes which contain previously-dilute effluents in highly concentrated form (Wynne, 1987). These become "toxic wastes" from the regulatory perspective, so hazardous on short exposure that they have to handled under restrictive licensing regimes.

3.19 **Employment impacts** Models of optimal pollution in a control region generally assume that social and private marginal costs differ only in the use of environmental services. The conventional environmental demand curve (\( D_e \) in Figure II.4) does not include any provision for the social costs of adjustment in other input markets. If a heavily polluting firm is also a large employer, however, these costs may include mass layoffs and serious community disruption. Findley (1988) cites an illustrative, albeit extreme, case for Brazil. A large cement plant in Contagem, in the metropolitan region of Belo Horizonte, was ordered closed in 1975 by the municipal authority because of failure to install stack filters to control hazardous emissions. Plant employees resisted bitterly, waging a pitched battle with government troops called in to enforce the order. After closure, the plant owner appealed to Brasília for relief and got a Presidential restraining order which overrode the local decree. The ensuing negotiations resulted in a postponement of compliance in exchange for a company agreement to install the required filters.

3.20 **Attaining a uniform ambient standard** Oates (1988) notes a practical problem in the enforcement of regional ambient standards which reduces the theoretical appeal of charges, even in conditions which are otherwise optimal for them. In an extensive control region there are specified points \( r \) at which air or water pollution is monitored. The ambient standard is generally defined as the maximum allowable pollution at any of the monitoring points. In a QB regime, emissions controls are tightened until this standard is attained. Since QB is a "crude" system, this will typically force such extensive pollution reductions that ambient conditions will be considerably better than the standard at many monitoring points. Unless the standard is unrealistically taken to be a threshold below which lower pollution is ignored, this "overcontrol" has social value.

3.21 A more sophisticated PB policy, on the other hand, prices so as to achieve the standard at minimum cost. At non-binding monitoring points, there is "excess" environmental capacity which can be used without any penalty. Therefore, the PB policy will generate higher levels of emissions and pollutant
concentrations, on average, than the QB policy. The differential social valuation of the extra emissions must be netted out before a true comparison can be made.

C. Comparing PB Approaches: The Relative Merits of EC and TP

3.22 In the U.S., environmental economists have advocated tradable permit (TP) systems because they combine some advantages of QB and PB. Since TP systems mandate aggregate reduction of emissions, they are believed by some to have more political appeal than emissions charges. They also match straight quantity controls as an antidote to uncertainty about the slope of the environmental supply schedule in a control region.

3.23 While the advantage under uncertainty is clear, the actual political appeal of TP for QB constituency groups is questionable. Some may be satisfied with mandated aggregate reduction, but others are no more likely to favor a "license to pollute" than a "price for pollution." Businesses who object to the "polluter pays twice" principle in mixed systems will make the same objection to TP. And the need for new market creation in TP often represents a profound break with regulatory tradition -- more so than effluent charges in many cases.

3.24 All other previously-mentioned factors which handicap PB systems apply with equal force to TP-based regulation. In general, then, it seems more reasonable to compare the relative merits of TP and EC for situations where price-based regulation is appropriate.

3.25 There is a presumption in the literature that TP may be better than EC because it has lower regulatory costs. The most commonly-cited operational critique of EC systems focuses on the problem of finding the appropriate charge when the long-run industry demand curve is not known. In the idealized EC system some fee is assessed at the outset; pollutant reduction is tracked; and the fee is adjusted to compensate for overshooting or undershooting a pollution target which is presumed to be known. But implementation could clearly be a problem. First, the idealized experiment is conducted ceteris paribus (while other variables obviously do not remain constant) and the tracking period is of indeterminate length, making it difficult to measure the independent effect of the effluent charge.

3.26 Second, the charge is assessed per unit of effluent. Good assessment requires accurate, continuous monitoring of effluents from all relevant sources. The cost of a comprehensive system, as E.J. Mishan (1990) has recently noted, might well outweigh the benefits of undertaking the program in the first place. Finally, EC clearly involves considerable "fine tuning", requiring variation in the levy over long periods of time. Implementation would call for frequent, large, and seemingly arbitrary shifts in charge schedules whose impact on profitability would have to be significant if it were to be effective.

3.27 Is a TP system superior? It is the dual solution to the optimization problem, and duality implies rough symmetry. In fact, the two major weaknesses of EC--high monitoring costs; iterative adjustment-afflict TP as well. Monitoring requirements are basically the same: Effluent volumes must be measured for taxation under EC and compliance with permit limits under TP. The two systems have dual iterative solutions: Under EC, the charge must be adjusted as the pollution consequences are revealed. Under TP, the overall

16/ OECD (1989) suggests that Mishan's assumption is often valid. In France, for example, water pollution charges are kept quite low and assessed on bulk flows rather than discharges of individual pollutants. The regulators monitor only the largest polluters; all others are charged at rates taken from standard tables. But this provides the small firms with an implicit bargaining chip: If the standard discharge fee is set very high, they can be expected to lobby actively for individual monitoring on the grounds that their own discharges are overestimated. The regulator stays with modest fees, knowing that total monitoring will not be cost-effective.
pollution limit must be adjusted as its true social opportunity cost (rising unemployment, falling output and profits, etc.) is revealed. Ultimately, there is convergence to some politically tolerable pairing of pollution limit and shadow price.

3.28 In short, the conventional argument for the superiority of TP over EC doesn't seem very persuasive. Both systems will be partially monitored at best; TP systems have a particularly difficult monitoring problem because the regulatory system may not be capable of adjusting quickly when permits are traded. Firms may then be able to pollute illegally for long periods, purchasing traded permits only when they are put on notice of inspection. TP remains clearly better than EC only in the case where there is considerable uncertainty about the environmental demand and supply curves but a presumption that the latter is relatively steeper.

3.29 Although economists may regard TP as a realistic alternative to EC, policy makers don't seem to agree. Charges are relatively common, although they generally bear little resemblance to idealized instruments. All recent surveys of policies in the OECD countries (Hahn, 1989; Kopp, 1990; OECD, 1989a) report that governments have almost never raised effluent fees to a point anywhere near the marginal cost of abatement. They simply use modest fees as a source of revenue for public abatement investments and subsidies to firms for abatement projects. A most striking exception seems to be the Netherlands case cited earlier, but Bressers (1983) found that the Dutch government also intended water charges only to be a source of funding for public abatement facilities. Because the Netherlands are densely settled, the required facilities were very expensive. The resulting fees were high enough to induce serious private abatement, but this was an unintended benefit.

3.30 Environmental economists generally prefer effluent charges because they provide appropriate incentives for pollution reduction, not because they raise money. The revenue is considered a windfall gain for the treasury and should ideally be allocated among public expenditures in proportion to the weights of general social objectives. But governments seem to use EC only to raise money, and they use the revenues only to promote pollution reduction. This might, after all, be sensible. Governments which go beyond modest effluent fees may induce small-firm demands for costly monitoring systems. In addition, governments do require a steady source of funds for investments in public pollution treatment facilities. Anderson (1990) argues that targeted effluent charges serve this need very well. The winds of political support for any program shift over time, and drawing pollution expenditures entirely from the general revenue fund makes them vulnerable to the short run exigencies of the political process. Continuity is assured if pollution abatement investments are linked to EC revenues. The industries which are taxed are also more likely to cooperate if they perceive a direct linkage between their expenses and environmental cleanup. Finally, the effective

17/ The collapse of the Pittsburgh steel complex provides a good illustration of the social opportunity cost of much stricter pollution standards. The U.S. iron and steel industry was among those hardest hit by rapidly-tightening environmental standards in the 1970's. It is probably not coincidental that the 1970's also witnessed the emergence of two major new steel sources for the U.S. market: NICs such as Korea and Mexico, which tolerated pollution levels much higher than the new U.S. standards; and "standalone" electric-arc steel minimills which could feed on scrap. For a theoretical treatment, see Merrifield (1988).

18/ In the U.S., much of the necessary iteration seems to occur before the fact in committee hearings and media reports. According to Rosewicz (1990), petrochemical producers began filing cost-based exemption cases from the moment the U.S. Congress passed the recent revision of the Clean Air Act.

19/ The government can prevent this by remaining the sole auctioneer of permits at regular intervals, but the attendant uncertainty will reduce the economic appeal of permits as implicit environmental property rights.
planning and implementation of regulation itself depends on an expert cadre whose support can be linked directly with effluent charge revenues.

3.31 In short, modest EC systems mixed with emissions standards have prospered because they finance regulatory operations and provide at least some incentive for cleanup in the long run. Operationally, EC is also better than TP when a control region contains too few firms to support a market in permits. If firms in the control region have significant market power, additional complications arise (Misiolek, 1989; see Krishna, 1988, 1990, for similar problems in export quota markets). Tradable permits are property rights; polluting firms cannot operate without them. Dominant firms therefore have a natural incentive to take preemptive positions, particularly when there is substantial uncertainty about the future market value of the permits. They may also be able to bargain strategically for lower permit prices, thereby lowering the incentive to reduce pollution.

3.32 Hahn (1989) cites both geographic limitation and imperfect competition as reasons for the failure of the Fox River program, one of the few U.S. experiments with TP. Although simulations had estimated the yearly savings over ES at $7 million, the program generated only one permit trade in its first six years of existence. Neither of the two major discharging industries—pulp and paper; municipal waste treatment—was competitive in structure. Furthermore, the two points on the river where pollution tended to peak were treated as separate control regions, with no trading between regions allowed. This limited the potential market to 6 or 7 firms per region, a number which seems to have been too small to support permit trading.
IV. STRATEGIES FOR POLLUTION PREVENTION

4.01 Industrial pollution control remains a complex task at each stage of industrial development: Regulatory coverage must expand with increasing demand for environmental amenities at higher incomes and growing complexity in the pattern of industrial emissions. It is therefore unlikely that environmental protection agencies at any stage of development will be capable of directly controlling all regulated pollutants at their points of emission. The challenge is to design and implement regulations which apply scarce resources at key leverage points in the economic system.

A. Eliminating Pollution Promotion from Economic Policies

4.02 Pollution control has been a significant policy concern for only twenty years in the OECD; less than a decade in Eastern Europe and the NICs. Since the mix of taxes and subsidies in an economy often builds up over long periods, it would be sheerly accidental if economic policy regimes reflected environmental concerns. Anderson (1990) and Wilczynski (1990) argue, in fact, that the existing policy mix in many countries provides strong incentives for pollution-intensive production. Part II documents the extent to which policy-induced price distortions, intended to serve industrial growth objectives, have had the unintended side effect of encouraging industrial pollution in Eastern Europe and the NICs. Dirty fuels and highly polluting heavy industries are frequently subsidized. Water use charges are often held at very low levels, encouraging the adoption of processes which generate large volumes of waste water. Recycling of industrial byproducts is discouraged by subsidies which keep natural resource prices at artificially low levels.

4.03 Regulatory problems are compounded in Eastern Europe by the absence of well-functioning markets. Both QB and PB systems have much of their impact "downstream" from polluting firms, as price increases induced by cleanup costs propagate through the system. The effectiveness of environmental regulation is therefore greatly reduced if agents do not respond to price signals. State enterprises in particular have little incentive to reduce pollution-generating activity when material inputs are heavily subsidized and energy allocations are administratively fixed.

4.04 Continuance of implicitly anti-environmentalist policies for long periods causes economies to "lock in" to self-reinforcing patterns of production and consumption which are environmentally destructive and very costly to reverse. Eastern Europe and the Soviet Union are now facing an enormous adjustment cost, and evidence is mounting that costs will be high in NICs such as Korea and Taiwan. Countries which are in the early stages of industrial development can avoid this problem by carefully analyzing economic policies for anti-environmental bias.

20/ In the U.S., for example, there are approximately 63,000 chemicals in commercial use and new chemicals are being introduced at the rate of several thousand per year (USEPA, Office of Toxic Substances, cited in USCEQ (1990)). Very few of these have been tested systematically, but ongoing laboratory work continually adds to the list of toxins, carcinogens, mutagens, and substances which threaten the viability of existing ecosystems (Epstein, 1987; Davis, 1990). The U.S. Clean Air Act of 1990 recognizes the need for explicit policies to control emissions of 189 toxins, but the USEPA is anticipating further regulation by requiring industry to report on emissions of over 300 toxins under the Superfund Act of 1986 (National Library of Medicine, 1989).

21/ For evidence on the East Asian NICs, see Bello (1990), Gadacz (1986), Song (1989).

22/ Eskeland and Jiminez (1990) have recently proposed a major World Bank research project on this topic.
B. Strategic Intervention Through Indirect Regulation

4.05 Eliminating pollution-inducing policies, while certainly desirable, does not remove the externality problem. Even where the policy regime is environmentally neutral, excessive pollution will remain until appropriate regulations are implemented. Until recently, almost all regulatory attention has focused on direct (or end-of-pipe) approaches in which each emissions source is monitored and subjected to PB or QB controls. However, all end-of-pipe control systems share a major weakness -- the difficulty of monitoring and enforcement (USEPA, 1988). Russell (1986) notes that most industrial emissions are essentially self-monitored even in the U.S., where enormous resources have been poured into environmental protection. While some easily identifiable emissions sources can undoubtedly be regulated with targeted end-of-pipe instruments, no sensible policy maker would contemplate pollution reduction based on government monitoring, charges, and/or quantitative controls for many thousands of pollutants and emission sources.

4.06 Pollution reduction may therefore be best effected in many cases by indirect instruments, applied at a manageable number of strategic points in the economy. As in the case of direct regulation, much of their ultimate impact is downstream from the point of control as changes in relative costs induce changes in production and consumption patterns. Indirect instruments are, of course, no panaceas. They are second best in the sense that they will have distorting effects elsewhere in the economy. Their defense rests on the argument that the combined value of regulatory cost savings and cleanup outweighs the distorion effects. Inevitably, judgments have to be case specific.

4.07 Indirect instruments can be applied upstream or downstream from emissions points. As in the case of direct instruments, they can be QB or PB, and can take on a number of basic forms -- quantity controls, process/equipment controls, quantity taxes, deposit/refund arrangements, and process/equipment taxes. No single instrument seems optimal in all cases, but there has not really been much research on optimal indirect regulatory strategies for economies at different stages of development. A few relevant cases and plausible solutions will be identified here.

1. Upstream regulation

4.08 In LDC's whose industrial systems concentrate on processing a few material inputs, indirect taxes have strong appeal. Anderson (1990) persuasively argues that administrative ease makes fuels taxes particularly appropriate, since it is much simpler to tax a few major producers of a highly-polluting fuel than to monitor and directly regulate all industrial fuel users with either QB or PB instruments. An analysis of OECD data in Part II suggests that differential fuel prices, partly tax-determined, have significantly affected comparative rates of decline in emissions of sulfur dioxide and nitrogen oxides.

\[23/\] USEPA (1989) estimates annual emissions of volatile organic compounds (VOC's) from all sources at 46 billion pounds. This is over 17 times the volume reported by industry in the 1987 Toxic Chemicals Release Inventory mandated by the Superfund Act. Over half the VOC's are estimated to be emitted by mobile sources.

\[24/\] Use of indirect instruments is often promoted with the argument that it lowers monitoring and information processing costs. However, some information costs rise under indirect regulation because it is largely an exercise in forecasting the consequences of alternative interventions. The regulator must anticipate the consequences of different levels of intervention; the ultimate impact of relative cost changes on production and consumption decisions; the risks associated with different pollutants; the processes by which they are released; and the consequences for health, economic activity, and ecosystems.
4.09 In principle, indirect regulation could be applied to a much broader class of material inputs as industrial systems become more complex. There are, however, at least three major problems associated with broader upstream regulation:

- The greater the number of interventions, the larger the probable magnitude of ultimate distortions;
- For an industrial economy of even moderate complexity, setting appropriate priorities would require a very large (and presently unavailable) materials accounting matrix;
- Many substances become hazardous pollutants in some industrial uses but not in others. Furthermore, the magnitudes of the associated hazards often depend on the degree to which recycling is economically feasible.

4.10 Global commons problems are currently the main arena for experimentation with indirect regulation in industrial economies. The U.S., for example, will enforce the Montreal Protocol on reduction of chlorofluorocarbons (CFCs) with a mixed-instrument system. CFCs generally must be phased out on a fixed schedule, with interim taxes levied in proportion to hazard assessments: Halon 2402, used as a fire suppressant, is taxed more heavily than freon, which is used as a refrigerant. The scheduled tax rate also rises steeply. The tax on freon, for example, will rise from $3.02/kg. in 1991 to $10.80/kg. in 1999 (Lancaster, 1991; WWI, 1991).

2. Downstream regulation

4.11 QB and PB instruments can be applied to consumer goods as well, provided their points of origin are sufficiently limited to validate the regulatory efficiency argument or monitoring is relatively easy for other reasons. At present, downstream regulation is generally applied to consumer goods containing easily-recyclable materials or those whose concentration after mass disposal makes them hazardous. Monitoring problems are significant, so PB systems rely on deposit/refund (DR) arrangements and QB systems on outright bans. Presently, DR systems are used for products as diverse as soft drink containers in the U.S. and lead acid batteries and auto bodies in the EEC. Denmark has banned throwaway containers for soft drinks and beer (WWI, 1991). Germany's environment minister has recently made a radical proposal which mixes elements of QB and PB: deposits on almost all containers for liquid products; requirements that retailers, distributors, and manufacturers collect used packaging from consumers; exclusion of packaging waste from government disposal systems; and a ban on the large-scale incineration of cardboard, plastic, and laminated packaging (Business Europe, 1990).

3. QB vs. PB in indirect regulation: Dynamic effects

4.12 Anderson (1990) notes the progressive changes which are stimulated when the price of environmental services is raised to a socially-appropriate level. In the short run, substitution possibilities are limited. However, the higher shadow value of environmental services signals the possibility of rents from development of cleaner technologies, stimulating a long-run process of innovation and diffusion. The clear intention of pre-announced programs like the U.S. CFC tax policy (which is PB) and the German waste disposal policy (strongly QB) is to signal that the appropriate shadow value of environmental services is much higher than the current value.

4.13 Even more stringent measures are currently either implemented or under negotiation. Among recent QB initiatives, the most spectacular has been provided by California's Air Resources Board, which has targeted radical reduction of motor vehicle pollution by the year 2000 (Mathews, 1990). The Board has announced a forced schedule for market replacement of conventional motor vehicles by electric, natural gas, or hydrogen-powered vehicles. The associated technological and system support problems have not been
addressed, and massive coordinated investments by the public and private sectors will be required. No single manufacturer would undertake the required investments independently. Whatever the cost (and it could easily be judged excessive, given the goal), this targeted policy seems to be stimulating the desired response. Industry consortia are rapidly forming in the wake of the announcement because the California market is too large to ignore.

4.14 By contrast, current negotiations on reduction of CO₂ emissions to curb global warming focus on possibilities for the taxation of the carbon content in fuels. The European Commission, for example, currently supports a common carbon tax in the EEC (WWI, 1991). This approach is clearly an alternative to the position of the California Air Resources Board. Which is the best strategy for signaling the higher shadow price?

4.15 There is currently no consensus answer to this question. A rapidly growing theoretical literature shows that multiple equilibria can exist in an industrial system where productive innovations have a lumpy character (Arthur, 1990; Drazen, 1990; Murphy, 1989; Romer, 1986; Lucas, 1988). In the case of industrial pollution, Jaffe and Stavins (1990) note that the diffusion of waste-reducing innovations may be very slow when firms face discrete, lumpy adoption decisions in conditions of great uncertainty. They may be reluctant to place bets on radically new approaches unless their survival is in question or they are sure that competitors will be compelled to move along the same track. Relatively massive intervention of some kind may be required to move the system to a "greener" path. Specifically, mandated targeting of objectives may play an important role in accelerating the diffusion process.

4.16 For inducing large-scale change over extended periods, the identity of the indirect instrument (QB or PB) may be less important than the cost-effectiveness of control at a few strategic leverage points when monitoring and enforcement in the entire system are difficult. Where systems approaches of this type are involved, control region heterogeneity ceases to be an important factor in the choice between QB and PB. Uncertainty undeniably continues to play a major role, as do political preferences. Where a major end-use product like the automobile is involved, it may make sense to use quantitative controls downstream. At the other extreme, upstream taxation may be the optimal response to a pervasive problem such as CO₂ emission. There seems to be no substitute for informed judgment about whether QB or PB will serve better in particular circumstances.

C. Promotion of Clean Technologies

4.17 Technical progress provides the main hope for a cleaner environment in the long run. Without it, industrial growth will inexorably press environmental demand outward against a fixed world supply. Environment-protecting technical progress can take a variety of forms, including recycling; process modification; and development of input substitutes (USCEQ, 1990). Anderson (1990) and others have cogently argued that innovation will be enhanced when regulators price environmental services appropriately. An important question is whether direct promotion of cleaner technologies can play a useful supplementary role.

1. Promoting development and diffusion of cleaner processes

4.18 The classic case for intervention in support of innovation or diffusion rests on market failures. These may be related to problems of financing initial learning about new processes or appropriability of rents
from clean technology adoption. Intervention on such grounds remains controversial. Proponents of pre-competitive R&D support, for example, argue that it compensates for insufficient private investment when competition threatens innovation rents. Opponents argue that the expected temporary super-profits from first-mover advantage may in fact lead to overinvestment in R&D by competitive firms.

4.19 In the case of industrial pollution, governments have frequently chosen direct promotion for another reason: monitoring and enforcement are expensive, and greater cooperation with environmental regulations can be induced by subsidies. Two forms of promotion have been common:

- public support of R&D on cleaner technologies, including in-process recycling, improved pollution abatement equipment, and possibilities for adapting production processes to the use of cleaner inputs;
- grants, loans at subsidized interest rates, and provision of direct technical assistance to firms making cleanup investments.

4.20 Environmental regulation has been supplemented with substantial grants or below-market loans in France (OECD, 1989), Korea (Song, 1989) and China27. Technical assistance has been a significant part of regulatory interaction in the U.K. (Vogel, 1986) and Brazil (Findley, 1988). Table IV.1 documents public spending on R&D in recent years. Pollution abatement has been supported in all the OECD countries, albeit at relatively modest levels.28

<table>
<thead>
<tr>
<th>Table IV.1: PUBLIC EXPENDITURE FOR POLLUTION RESEARCH AND FINANCING &quot;END-OF-Pipe&quot; POLLUTION CONTROL</th>
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<tr>
<td>Year</td>
</tr>
<tr>
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<tr>
<td>1975</td>
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<tr>
<td>1983</td>
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<tr>
<td>1985</td>
</tr>
</tbody>
</table>

Source: OECD, 1985

a/ All values in SUS million (1975)
b/ % of total public expenditure on R&D

4.21 R&D targeting has also played a role in some cases. For example, the forced reduction of CFC production and use under the Montreal Protocol will necessitate a radical change in refrigerator technology during the next few years. In response, the EPA has entered into a cooperative arrangement with the Association of Home Appliance Manufacturers and Underwriters Laboratory to promote rapid development of safe home refrigerators which will employ non-CFC refrigerants (Hoffman, 1990).

27 Interview with Roger Batstone, ASTEN, World Bank

28 For example, U.S. data for the period 1975-1980 show that the government allocated approximately 10% of its total R&D budget to pollution abatement. See U.S. Census Bureau, "Pollution Abatement Costs and Expenditures, 1982," Table C, p. 11.
2. Promotion of recycling

4.22 For convenience, both in-process recycling and resale for re-use are referred to here as "recycling" because they involve the channeling of industrial byproducts back into production. Industrial byproducts, whether gas, liquid, or solid, become "wastes" in the absence of regulation if recycling cannot be conducted profitably or firms fail to capture available opportunities. If disposal costs rise sufficiently, firms will find it in their interest to reduce waste byproducts or recycle them even at some loss because the alternative (namely disposal) involves even higher costs. The key parameters which determine the firm's interest in recycling a byproduct are therefore disposal cost, the cost of waste-reduction, and the resale value of the byproduct. The latter will in turn be determined by the production cost of virgin material and the ease with which the recycled product can be substituted for it.

4.23 When the potential profitability of recycling is high enough, markets tend to form. Good examples are provided by aluminum, paper, and glass (Table IV.2). Yet even where recycling markets are well-established, there is reason to remove explicit and hidden subsidies for virgin materials, raise disposal costs through appropriate regulation, and subsidize basic R&D on waste reduction and in-process recycling technologies.

Table IV.2: Recovery Rates for Aluminum, Paper, and Glass, 1985

<table>
<thead>
<tr>
<th>Country</th>
<th>Aluminum</th>
<th>Paper</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>40</td>
<td>46</td>
<td>33</td>
</tr>
<tr>
<td>Italy</td>
<td>36</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>West Germany</td>
<td>34</td>
<td>40</td>
<td>39</td>
</tr>
<tr>
<td>Japan</td>
<td>32</td>
<td>31</td>
<td>17</td>
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<tr>
<td>United States</td>
<td>28</td>
<td>27</td>
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</tr>
<tr>
<td>France</td>
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<td>United Kingdom</td>
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<td>Switzerland</td>
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</tr>
<tr>
<td>Sweden</td>
<td>18</td>
<td>42</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: Pollock (1987)

4.24 If it is not feasible to remove existing subsidies for virgin materials or increase disposal costs sufficiently, raising the profitability of recycling may be an appropriate second best policy. The means may include government purchase and resale of recyclables, or subsidized collection, sorting, and transport. Even if first best policies are feasible, the government may still play a role in initial market development. Three possible forms of intervention can be considered.

- **Standards**: Establishing and enforcing materials quality grading and inspection procedures. Since processing costs rise with variety in recyclable materials, this kind of policy can include the enforcement of limits on the number of materials grades permitted in circulation. Precedents already exist for standardized, refillable containers. Denmark and Norway now permit no more than 20 different returnable packages for beer and carbonated beverages.

- **Government purchase**: A major problem for recycling markets is achieving critical scale. The government can accelerate this process by instituting mandatory procurement programs for some recyclable materials. The U.S. Resource Conservation and Recovery Act (RCRA) of 1976 attempted to promote recyclables by requiring all levels of government and government contractors to purchase "items composed of the highest percentage of recovered materials"

There can be many reasons for this, including lack of appropriate information; myopic decision-making; "lock-in" to polluting technology systems; and satisficing behavior in non-competitive markets.
practicable, consistent with maintaining a satisfactory level of competition." (VandenBerg, 1986) Thus far the RCRA provision has been largely ignored, but thirteen U.S. states have passed procurement laws of their own. The state of Maryland, for example, has had a program to buy recycled paper since 1987; a total of $17 million in recycled paper products has been purchased (Pollock, 1987).

Information: Search costs are particularly high in new markets, where the initial sources of supply and demand may be widely scattered. These are compounded when recyclable materials come in several varieties, and can be processed only with new technologies. Government collection and dissemination of relevant information may play an important catalytic role in such cases. There may also be scope for subsidized projects which demonstrate the feasibility of particular recycling technologies.
V. IMPLICATIONS FOR THE DESIGN OF REGULATORY SYSTEMS

5.01 The previous section has identified some indirect policies which move the focus of environmental management from end-of-pipe control to pollution prevention. While these policies can enhance the productivity of existing regulatory resources, their effectiveness will depend in part on changes in the design of the regulatory system itself. The most important issues which need to be addressed involve: (1) cross-medium regulation; (2) risk reduction strategy; and (3) methods of valuation.

A. Cross-Medium Regulation

5.02 Because the technical problems of regulation vary considerably across media, national regulatory systems have traditionally developed along functional lines (Wynne, 1987). National EPA's typically have specialized divisions for measuring and controlling pollution of the air, water, and land. In the U.S., for example, there are three separate departments of the EPA for air pollution, water pollution, and solid wastes. They maintain completely separate, overlapping databases and control pollution in largely uncoordinated ways.

5.03 Patterson (1989) notes that this policy has frequently led to the diversion of pollutant emissions to the least controlled medium: "Examples of transfers include the control of industrial air pollution that results in the generation of polluted scrubber water or solid wastes; treatment of that air pollution scrubber water to prevent water pollution, but in the process generating a toxic sludge; and disposal of that sludge to a landfill, which leaks (as they all eventually do) to contaminate the groundwater." (p. 1032)

5.04 Plentiful intermedium substitution possibilities and uncoordinated, QB-oriented control of emissions into separate media make it harder to attain regulatory objectives. Conceptually, the appropriate response is to change the intermedium allocation of regulatory resources until net benefits are equalized. An integrated approach would involve reducing the regulatory authority of departments which specialize in technical problems of control in specific media. It would also require information about firms' possibilities for intermedium substitution, the costs of substitution, and the consequences for total pollution. Finally, cross-medium pollution estimates would have to be integrated using appropriate risk indices.

5.05 Is such integrated regulation really feasible? In the U.S., Japan, and Western Europe, the requisite databases and analytical capacity already exist but many regulators and industrialists have vested interests in the current system. Their resistance could make significant reform very costly. The developing countries, however, have a "latecomer's advantage." With no vested regulatory interests to overcome, they may be able to pioneer in the development of cross-medium information and regulatory systems.

B. Risk Assessment

5.06 Two recent studies (Mendeloff, 1988; USEPA, 1990b) identify a significant weakness in the current regulatory approach to risk. The current system relies on fixed ambient standards, which are based on a risk model originally applied to occupational health and safety regulation in the OECD countries. The model is based on the notion of thresholds which separate "harmless" from "harmful" exposures. Many
uncertainties surround the estimation of threshold levels from high-exposure animal experiments. As a hedge, thresholds have been conservatively set at low exposure levels; these in turn have been institutionalized as mandated ambient standards by national EPA's.

5.07 According to USEPA (1990b), the present consensus in the scientific community is that any level of exposure to many pollutants is potentially hazardous in some ways. For a human population at risk, the generally-accepted dose response function linking average exposure to morbidity and/or mortality has the logistic shape displayed in Figure V.1a, which is overlaid on the more traditional threshold (E_t). The associated marginal benefits of reduced exposure are displayed in Figure V.1b. Mendeloff (1990) notes that the total cost of exposure reduction rises more than proportionately with the degree of reduction (V.1a), generating the marginal reduction cost curve displayed in V.1b.

5.08 The optimal exposure is at E^*, where marginal benefits and costs are equalized. To illustrate the results of current policy, a conservative regulatory standard is posited at E_t. When E_t is compared with E^*, it is clear that little extra benefit is gained for the large increase in cost. Since such high opportunity costs are generally incurred by conservative exposure standards, regulators in the OECD have been reluctant to expand coverage to very many substances. A few are tightly controlled at very high cost, while dozens or even hundreds, perhaps equally hazardous, are simply ignored. The solution to this problem seems clear conceptually: regulatory emphasis should move from threshold-based ambient standards to optimal risk reduction which equalizes marginal benefits and costs (or marginal benefit/cost ratios under a binding regulatory budget constraint). There should be considerable expansion of pollutant coverage, at higher exposures per pollutant. It is probably not realistic to hope for substantial reduction in permissible exposures for currently-regulated pollutants. Fortunately, there are not very many of these, so progress could be effected by appropriate treatment of many previously-ignored substances.

5.09 There is little sign at present that regulatory systems are actually headed in this direction. Although the major impediments are probably political and institutional, information scarcity is part of the problem. Comparable risk measures, dose-response functions, and cleanup cost estimates are not available for many substances, and much more empirical research would be beneficial.

C. Methods of Valuation

5.10 Until recently, most of the emphasis in pollution control has been on the benefits associated with reducing direct damage to human health and economic activity. There are three common methods for monetizing direct damages: (1) estimates based on expected increases in market value or productivity, which may incorporate information from output losses at market or shadow prices or earnings losses from morbidity and mortality; (2) "willingness to pay" studies, generally based on multivariate regression, which relate (a) occupational wages to relative toxic exposure hazards, or (b) geographic variations in wages or property values to differing environmental conditions, while using statistical control to incorporate the effects of other variables (Lave/Seskin, 1977; Kneese, 1984; Smith, 1985); (3) contingent valuation methods, which attempt to impute willingness to pay for pollution reduction from survey results (Brookshire, 1982; Cummings, 1986).

Human risk is frequently estimated from laboratory trials in which massive doses of hazardous substances are administered to animals. It is common practice to use a straight-line backward projection to infer human risk at much lower exposures. Obviously, there are two major problems with this approach: Animals probably respond differently than humans, and the dose-response relationship is probably not linear. See Rich (1990).
5.11 Economists generally prefer the second method, since they are skeptical about the use of *expressed*, as opposed to *revealed* willingness to pay in method (3). The use of foregone earnings in (1) raises unavoidable ethical questions about the appropriate valuation of human life in societies where earnings distributions are badly skewed and many people (e.g. retirees, children) have no current earnings (Hufschmidt, 1983; ERC, 1983; Bailey, 1980). Method (2) also has the apparent advantage of reflecting the values which individuals themselves have put on reduced risk in circumstances where it affects them directly.

5.12 Unfortunately, there seem to be severe limits to the utility of such estimates for pollution regulation. First, the uncertainties are very great even for valuation of the benefits from reducing exposure to pollutants whose effects are relatively well-understood. For example, Portney (1990) uses recent evidence from Fisher (1989) on the value of a "statistical life" to estimate benefits in the range $6-25 billion for the 1990 Clean Air Act Amendments. Second, polling data suggest that the existing professional understanding of exposure risk has not been transmitted effectively to the public (USEPA, 1990b). By implication, populations at risk would have to be much better informed before they could be expected to make rational choices.31

5.13 Finally, and perhaps most critically, the consensus of the scientific community about the relative importance of exposure factors is now changing sharply. In USEPA (1990b), the Scientific Advisory Board states one of its top-priority policy recommendations as follows:

"EPA should attach as much importance to reducing ecological risk as it does to reducing human health risk. Because productive natural ecosystems are essential to human health and to sustainable, long-term economic growth, and because they are intrinsically valuable in their own right, EPA should be as concerned about protecting ecosystems as it is about protecting human health." (Executive Summary, p. 6).

5.14 In the Board's view this priority cannot be reflected in conventional valuation methods:

"Reliance on 'willingness to pay' and similar techniques commonly used in economic analyses has distorted current understanding of the value of natural resources. While some people may not care about wetlands and assign no value to their existence, such areas still provide valuable ecosystem services to this and future generations. While few people are likely to care about and be willing to pay for plankton and fungi, such organisms play a critical role in sustaining economically valuable ecosystems." (Executive Summary, p. 8).

5.15 The general economic benefits of natural systems are simply too diffuse and too little understood for reliance on imputed private valuation to hold out much hope. From this perspective, conventional economic analysis seems to have two fundamental weaknesses. First, with conventional discounting, benefits or costs a hundred years from now mean almost nothing, although few would permit untrammeled industrial growth and waste pileup now in exchange for an eco-catastrophe a century hence. By implication, intergenerational equity must be given independent weight in some investment decisions.

5.16 The second weakness involves an inappropriate understanding of the term "nonrenewable resources." Economists have generally understood this to mean material and nonrenewable energy deposits. The existing evidence lends little if any support to the claim that exhaustion of these deposits will fundamentally constrain the world economy in the foreseeable future. Enormous reserves exist in the earth's

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31/ In this context there is a strong argument for the mandatory collection and release of emissions audit information from firms, coupled with active public education about risk factors. In addition (although this is outside the formal purview of regulation itself) there should be accompanying measures to assure recourse for local communities, either through the political process or through the courts.
crust (Goeller, 1978), although opinions differ about their probable distribution and its long-run implications for extraction cost (Skinner, 1976; Tietenberg, 1988). Price-induced innovations have until now assured high long-run substitution elasticities among materials (Rosenberg, 1973) and between capital and material resources (Brown, 1979).

5.17 From the ecosystems perspective, however, the materials depletion question is largely irrelevant. What counts is the fundamental dependence of human life and society on natural systems which are ill-understood and for which no substitutes exist. Lovelock (1979) and Daly (1989) have argued that human society is headed toward disequilibration of its life-support system, with catastrophic consequences. Widespread interest in policies which insure against such an eventuality is evident in the sudden emergence of international support for action against atmospheric ozone depletion, greenhouse gas accumulation, and the threat of mass species extinction.
PART II  
INDUSTRIAL POLLUTION AND REGULATION: AN INTERNATIONAL PERSPECTIVE  

VI. INTERNATIONAL DIFFUSION OF ENVIRONMENTALISM

6.01 This part of the paper surveys the actual experience of pollution control in ten countries which have been selected for diversity in income, location, economic structure, policy regime, and population density (Table VI.1). From the OECD, where environmental regulation has been in place the longest, the sample includes the U.S., U.K., Japan, and West Germany. Although these countries all have highly-developed market economies, they differ significantly in style of governance and settlement density (an important determinant of environmental absorptive capacity). At the intermediate income level the sample includes three countries--Korea, Poland, and Brazil--which, besides their location in different world regions, exhibit great differences in population density, political structure, and market orientation. Finally, the sample includes three developing economies--Thailand, Indonesia, and Nigeria.

Table VI.1: SAMPLE COUNTRIES

<table>
<thead>
<tr>
<th></th>
<th>GNP per Capita</th>
<th>Density [per 000 hectares]</th>
<th>Advent of Significant Environmentalism b/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>21020</td>
<td>22877</td>
<td>1985-1975</td>
</tr>
<tr>
<td>U.S.</td>
<td>19840</td>
<td>571</td>
<td>1983-1975</td>
</tr>
<tr>
<td>West Germany</td>
<td>16400</td>
<td>5112</td>
<td>1970-1980</td>
</tr>
<tr>
<td>U.K.</td>
<td>12810</td>
<td>8121</td>
<td>Pre-1980</td>
</tr>
<tr>
<td>Korea</td>
<td>3600</td>
<td>18888</td>
<td>1983-1990</td>
</tr>
<tr>
<td>Brazil</td>
<td>2160</td>
<td>562</td>
<td>1980-1980</td>
</tr>
<tr>
<td>Poland</td>
<td>1850</td>
<td>2015</td>
<td>1983-1990</td>
</tr>
<tr>
<td>Thailand</td>
<td>1000</td>
<td>2658</td>
<td>Post-1988</td>
</tr>
<tr>
<td>Indonesia</td>
<td>440</td>
<td>8861c</td>
<td>Post-1988</td>
</tr>
<tr>
<td>Nigeria</td>
<td>280</td>
<td>2108</td>
<td>Post-1988</td>
</tr>
</tbody>
</table>

a/ Computed for estimated total inhabited area  

b/ Details provided in text and Table VII.1  
c/ Computed for Java, Bali, Madura  

Sources: World Bank, World Development Report 1990  
World Resources Institute, World Resources 1990-91

6.02 The theoretical model developed in Part I suggests an inverse relationship between optimal pollution level and per capita income. With income growth, the MSD schedule (Figure II.3) moves toward the origin and steepens because imputed economic and health costs increase (both on average and at the margin) and aesthetic considerations become relatively more important. Increased scale moves D toward the origin, but a countervailing effect comes from "cleaner" industry composition (see Section I.B). As the relative price of technology-intensive cleanup resources falls with development, D flattens and optimal pollution is further reduced.

6.03 Thus, rich societies should have lower optimal pollution levels than poor ones unless scale effects dominate everything else. This does not imply, of course, that regulatory policies will actually produce lower pollution, nor does it specify the appropriate degree of reduction. For nine sample countries in the mid-1980's, Figure VI.1 does suggest a very sizable impact: a steep, roughly linear decline in the logarithm of an urban air pollution index as the log of per capita income increases. The implied elasticity is approximately one.

32/ For each country, Figure VI.1 uses the logarithm of mean index values for the metropolitan areas included in Table I.3.
The following survey of international environmentalism suggests, however, that Figure VI.1 overstates the income effect because it is only a "snapshot", taken during an extraordinarily rapid diffusion process. The OECD countries in the lower right corner have already made the "environmentalist transition"; their pollution index has dropped sharply during the past 25 years. The mid-range countries are just entering the transition, which is happening at far lower levels of per capita income than would have been predicted from the historical experience of the industrial countries. For comparison, Figure VI.1 also plots the log of U.S. per capita income for the period 1960-1985 against the log of an urban air pollution index for the same period. It is clear that the sample NIC urban areas have already matched U.S. levels for the 1960's at far lower incomes.

Figure VI.1
Urban Air Quality vs. Per Capita Income

A. Early Environmentalism: The OECD Countries

In Japan, the 1960's witnessed a strong popular reaction to damage from unregulated industrial growth, epitomized by the Minamata disaster in which hundreds were killed by poisonous levels of mercury in fish. A similar North American movement began when pesticide poisoning was widely publicized in Rachel Carson's *Silent Spring* (1962). Further impetus was provided by the Love Canal incident of 1978, which stirred public alarm about toxic waste dumps near residential areas. Britain is unquestionably the pioneer in environmentalism, with pollution inspectorates and conservation societies dating back to the Victorian Era (Vogel, 1986). The era of modern British environmental activism also dates from the 1960's, however. In 1966, the Welsh village of Aberfan was buried by an avalanche of coal sludge which killed 144 people. Shortly thereafter, the crash of the tanker Torrey Canyon led to an oil spill of 60,000 tons -- an unprecedented pollution disaster. West German environmentalism was activated slightly later, with important roles played by the perceived "death" of the Rhine River in the late 1960's and the "Waldsterben" (forest death) attributed to acid rain in the early 1980's (WRI, 1990).
B. Diffusion in the Mid-1980's: Poland, Brazil, and Korea

6.06 The remarkably rapid diffusion of environmental consciousness is exemplified by the experiences of Brazil, Poland, and Korea. From nearly complete neglect, environmentalist concerns moved to the top of the political agenda in all three countries in the late 1980's (Worcman, 1990; Miller, 1990; Clifford, 1990). What caused the sudden emergence of environmentalism when pollution problems had obvious been severe for quite some time? With the exception of Brazil, particular events do not seem to have played a notable role. Part of the answer is undoubtedly supplied by a simple diffusion lag, with the emerging middle classes in these countries somewhat slower to absorb the spreading environmentalist wave. Perhaps a more fundamental explanation is that the 1980's have witnessed a rapid movement to more representative government in all three countries. Environmentalist groups were instrumental in this process, so it is difficult to disentangle the two trends.

6.07 Poland: The country is among the world's largest emitters of sulfur dioxide (see Table VII.4); its southwestern forest regions have been heavily affected by acid rain; its rivers are extremely polluted. In 1984, the Polish Chemical Society attributed very high rates of mental retardation in Upper Silesia to high concentrations of heavy metals, particularly lead, in the air, water, soil, and food of the region. Children attending summer camp in Upper Silesia were found to have five times as much lead in their blood as children in Denmark (Diehl, 1989; Maremont, 1990). This region, along with four others, has been declared an "ecological disaster area." (Liroff, 1990). Kabala (1990) reports that life expectancy for Polish males aged 40 to 60 has fallen back to 1952 levels, and that researchers attribute some (unknown) part of this decline to very high rates of morbidity from pollution. Polish experts currently estimate pollution-related losses in the range of 10 to 15 percent of GDP annually (Wilczynski, 1990). The estimated cleanup cost for existing environmental damage is around $25 billion (Wallich, 1990).

6.08 Since the early 1980's the Green movement in Poland has expanded rapidly, and currently includes more than 40 groups (French, 1990). In the post-Communist era, the Polish government has responded actively to environmental concerns. The problem in Poland, as elsewhere in Eastern Europe, is not lack of a formal regulatory structure, but virtual absence of appropriate market signals and a pervasive failure to enforce the existing statutes. Recently, the Polish Minister of the Environment has severely tightened compliance procedures and instituted required environmental auditing by firms. In addition he has initiated an extensive new investment program, including 3,000 proposed wastewater treatment plants, to be completed by 1995 (French, 1990).

6.09 Brazil: At the first United Nations Environmental Conference in 1972, Brazilian Minister of the Interior Costa Cavalcanti summarized the prevailing attitude during the first phase of the NICs' rapid growth: "... a country that has not yet achieved a minimal standard of living is not in a position to spend its valuable resources protecting the environment." (Worcman, 1990, p. 45). As he spoke, Jose Lutzenberger was organizing AGAPAN, Brazil's first ecological organization to protest deforestation in the Amazon. During the following decade, regulatory activity was scanty and environmentalist concern was heightened by the increasing frequency of industrial pollution disasters.

6.010 In 1982 heavy rains broke the dike of a settling pond containing between 30,000 and 40,000 tons of heavy metals, the entire waste output of the Paraibuna Metals plant since its opening. Half the metals escaped into the Paraibuna River, and 370,000 residents of twelve cities downstream were denied public water supplies for an extended period (Findley, 1988).

In the 1960's, rivers classed as unsuitable for municipal water supply and industrial use were 67 percent and 23 percent of the total, respectively. By the early 1980's, 94 percent were unfit for municipal use and 38 percent for industrial use (EPA, 1990).
6.11 Even more spectacular was the case of Cubatao (Findley, 1988). Although its environmental absorptive capacity was quite limited, Cubatao had by the early 1980's become one of Brazil's heavy industrial centers. Known as the "Valley of Death," it had no birds or insects and the incidence of respiratory illness, infant deformity, and infant mortality were far above rates in neighboring areas. In February 1984, a major gasoline pipeline spill exploded, destroying 1,000 homes and killing nearly 100 people. In September of the same year, an atmospheric inversion resulted in air pollution so severe that a state of emergency was declared and the district of Vila Parisi was evacuated. In January 1985, a massive release of ammonia gas from a ruptured pipe at a fertilizer plant in this same district resulted in the hospitalization of 60 residents and the evacuation of 6,000.

6.12 With the advent of democracy and the escalating reaction to the twin crises of industrial pollution and devastation of the Amazon, environmentalist sentiment seems to have grown spectacularly during the past half-decade. In 1989, Jose Lutzenberger was invited to leave the radical environmentalist opposition to become Brazil's first Secretary of the Environment, and polls showed that interest in deforestation among Brazilians was second only to concerns about wages (Worcman, 1990).

6.13 Republic of Korea (ROK): While the Republic of Korea has not had any conditions rivaling those in Cubatao or Upper Silesia, its rapid industrialization has been accompanied by very severe air and water pollution. A 1978 WHO survey noted that Seoul had the highest atmospheric sulfur dioxide concentration of any of the world's major cities (Hepinstall, 1985). The government's immediate response was to suspend reporting air quality data to the WHO, although the reporting resumed in 1984 as cleanup initiatives began. (Gadacz, 1986). In 1989 published reports that Seoul's tap water was heavily polluted precipitated a political crisis and a public commitment by President Roh Tae-Woo to attack the nation's environmental problems.

6.14 In the wake of this incident, large-scale environmentalist protest suddenly erupted. The major catalyst was apparently the perceived threat of massive industrial waste dumping and toxic emissions from new chemical complexes on the densely-populated peninsula. In June, 1990, Oriental Chemical Industries completed a $112 million plant in Kunsan, but was unable to open it after a protest petition was signed by 100,000 local residents. In July, 1990, 5,000 protesters in Pusan took an Environmental Ministry official hostage, built barricades, blocked roads, and won a government moratorium on the construction of a new industrial dump. The government has apparently abandoned all plans to locate new dumpsites on existing land and is planning land reclamation projects on the west coast to create future sites for factories and landfills (Clifford, 1990).

6.15 To summarize, the 1980's have witnessed an extremely rapid spread of environmentalism in NIC's whose income levels still lag far behind those of the OECD economies. The emerging middle class has frequently served as the entry point for environmentalism, but not always. Many of the recent dumpsite protests in ROK have apparently been organized by poor residents of surrounding areas (Clifford, 1990). In any case, environmentalism apparently spread rapidly across income groups once the local diffusion process began.

C. Diffusion in the Late 1980's: Thailand, Indonesia, Nigeria

6.16 The three new industrial economies in the sample are all much poorer than the NICs. Nevertheless, there is clear evidence that environmentalism has begun spreading there. In at least two of the three countries—Indonesia and Nigeria—the environmentalist agenda has been advanced by a de facto coalition of government and activist NGO's. Since the three governments have no systematic environmental monitoring capability, information about mounting pollution damage has filtered upward through increases in legal liability claims, small-scale protest activities, media reports, and publicity by NGO's. The result has been rapid movement toward formal establishment of national regulatory structures.
6.17 Thailand: In the 1980's Thailand has experienced extremely rapid industrial growth and mounting pollution problems, particularly in the Greater Bangkok Metropolitan Region. In 1969, the Factory Act first made some provision for pollution regulation by the Ministry of Industry. Such rudimentary measures remained almost completely ineffective during the next two decades, as the number of significantly polluting plants increased from 211 in 1969 to 7,030 in 1979 and 26,235 in 1989 (Kritiporn, 1990, Table 2.3, p. 13). Hazardous waste generation expanded apace. In a four-category typology of industrial production by hazard class, Kritiporn (1990) finds that the composition of Thai industry shifted significantly toward more environmentally hazardous activities in the 1980's (Table VI.2).

6.18 The simultaneous expansion of polluting facilities and their average toxicity, coupled with international media reports of industrial pollution disasters, seems to have promoted a rapid growth of public concern. The most spectacular manifestation of this occurred in 1986 at Phuket, when a new tantalum production plant was burned by rioters. In 1988 toxic fumes of dimethoate were accidentally released in a slum area near Bangkok Port, causing about 400 cases of acute morbidity. In the wake of these events the government has been moving rapidly toward much more active regulation of industrial pollution.

<table>
<thead>
<tr>
<th>Hazard Rating</th>
<th>End of 1979</th>
<th>End of 1989</th>
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<tbody>
<tr>
<td>High</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Medium</td>
<td>10</td>
<td>41</td>
</tr>
<tr>
<td>Low</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>None</td>
<td>71</td>
<td>42</td>
</tr>
</tbody>
</table>

Source: Kritiporn (1990), Table 2.6, p. 15

6.19 Indonesia: Indonesia's industrial development has been concentrated in the metropolitan regions of Jakarta and Surabaya on Java, whose environmental absorptive capacity is greatly reduced by one of the highest population densities in the world. Even before industrial output began growing rapidly in the 1980's, signs of severe environmental stress were emerging in the Surabaya area. By the early 1980's industrial waste accounted for about 80% of the pollution in the Brantas River, which had become virtually anoxic and was untreated by conventional methods. Faced with an environmental crisis, the Governor of the province intervened in 1987 to force cleanup by a few of the worst industrial offenders.

6.20 In the Jakarta Metropolitan Region, rapid industrialization has also generated mounting environmental damage. Although actual monitoring is very limited, it is currently estimated that there are about 4000 polluting plants in the Jakarta area, with substantial hazardous waste generation from production of pesticides, batteries, metal plating, paints, and textiles (Suhadi, 1990). Table I.3 documents the current severity of air pollution, and USAID (1987) notes severe heavy metals contamination of rivers, canals, and harbor areas in the Jakarta urban region.

6.21 During the past two years, the major impetus for environmentalism in Indonesia has been de facto collaboration by the leadership of the Ministry of Population and Environment (MKLH), environmentalist NGO's, and multilateral funding agencies. NGO's are particularly important in Indonesia, since neither
formal political representation nor aggressive media coverage play significant roles. There are currently more than 200 Indonesian NGO's involved in environmental activities and approximately 30 in Jakarta. They are reported to have good communications with MKLH (Suhadi, 1990).

6.22 Nigeria: Growth of environmental concern is also evident in Nigeria, but clearly lags by comparison with Indonesia and Thailand. Part of this is undoubtedly due to the fact that industrial growth has been much slower. There is almost no credible information on the extent of pollution or its consequences (Osae-Addo, 1990). Olokesusi (1987) claims widespread apathy and lack of knowledge about pollution, which he attributes to low literacy and lack of information dissemination.

6.23 Nevertheless, some Nigerian concern for industrial pollution has clearly been sparked by problems in the petroleum industry. In 1980, approximately 340 hectares of mangrove were killed by an oil well blowout, and a number of reports on oil industry pollution problems were subsequently published (Olokesusi, 1987). Olokesusi (1988) notes some signs of growing public awareness of environmental problems, including increased litigation by pollution victims. Undoubtedly, Nigeria's traditionally outspoken press has contributed to this spreading awareness. As in Indonesia, however, environmentalism to date seems to have been largely a matter of collaboration among government officials, some NGO's, and multilateral funding agencies. During the past two years there has been significant movement toward establishment of a national system of environmental protection.
A. Formal Institutions: Emergence of a Common Standard

7.01 Although the countries in the sample are quite diverse, they have broadly similar regulatory institutions. While other national policies reflect long periods of social, political, and institutional evolution, the environmental issue is new to almost every country. There has therefore been a marked tendency to follow the leaders, adopting the standards, institutions, and approaches developed by the OECD countries which first perceived and faced the pollution problem. International bodies such as WHO and UNEP have served as important transmission vehicles in this process.

7.02 Table VII.1 summarizes dates for standard benchmark events in nine of the sample countries (comparable information for Poland is unavailable):

- **First legislation**: Codification of an "environmental bill of rights," which establishes high-quality environmental conditions as a social goal.

- **Adoption of ambient standards** for well-known air, water, and solid pollutants, generally patterned after OECD standards.

- **Establishment of an environmental protection agency**, authorized to regulate pollution in all media.

- **Enactment of environmental impact assessment (EIA) requirements**, which force estimation and reporting of anticipated environmental costs by public and private investment planners.

7.03 The first stage of environmental regulation is typically marked by legislation of an "environmental rights" code and establishment of ambient standards. The latter reflect accepted international estimates of morbidity response thresholds; the officially-stated goal is to keep exposure everywhere below threshold limits. Although it has been unattainable in the near term for the lower-income sample countries, this goal does turn out to be of political significance. Once governments are committed to the standard, they face continual popular pressure to move toward it.

7.04 The next stage of regulatory development is the establishment of a national environmental protection agency. Typically, this agency is hamstrung during its early years by interagency conflict and weak support from the political authorities. Initial enforcement is very lax and most emissions continue unabated. A significant industry response to environmental concerns is usually not forthcoming until clearer regulatory measures are enacted, with credible provisions for monitoring and enforcement.

7.05 The first sign that enforcement standards are about to tighten is often the institutionalized requirement that every new project of significant size file an environmental impact statement (EIA). This requirement became an operational reality in the mid-late 1970's in the OECD, the mid-1980's in the NIC's, and the late 1980's in many developing countries.

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For a critique of this approach to ambient standard-setting, see Section V.B.
Table VII.1: CRITICAL BENCHMARKS IN THE EVOLUTION OF ENVIRONMENTAL POLICY

<table>
<thead>
<tr>
<th>Country</th>
<th>First Legislation</th>
<th>Ambient Standards Adopted</th>
<th>Est. of National EPA</th>
<th>EIA Institutionalized</th>
<th>Catalysing Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.K. g/</td>
<td>Pre-1960</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1986</td>
</tr>
<tr>
<td>ROK g/</td>
<td>1977</td>
<td>1977</td>
<td>1980</td>
<td>1982</td>
<td>(Olympics)</td>
</tr>
<tr>
<td>Brazil z/</td>
<td>1975</td>
<td>1976</td>
<td>1981</td>
<td>1986</td>
<td>(Seoul Tap Water)</td>
</tr>
<tr>
<td>Thailand g/</td>
<td>1975</td>
<td>1978</td>
<td>--</td>
<td>--</td>
<td>(Phuket tantalum)</td>
</tr>
<tr>
<td>Indonesia h/</td>
<td>1982</td>
<td>1989+</td>
<td>1978</td>
<td>1986</td>
<td>(Bangkok dimethoate)</td>
</tr>
</tbody>
</table>

a/ Vogel (1986) The U.K. is unique in having an institution for industrial pollution control—the Alkali Inspectorate—which dates from the 19th century. It has also been unique in lacking the formal regulatory structure detailed in this table.

b/ USCBO (1985); Japan Environment Agency (1985, 1988)

c/ OECD (1989); USCBO (1985)
d/ Grosser (1979); Gadea (1986); Song (1989); Engineering Science (1984)
e/ Findley (1988)
f/ Kritiporn (1990)
g/ USAID (1987)
h/ Olokesusi (1987, 1988); Osae-Addo (1990)

7.06 Although EIAs are generally derided as "window dressing" when they are first instituted, they actually provide a useful common standard for emissions reporting, monitoring, and environmental accounting. The industrial and regulatory systems normally take a few years to adapt to EIA requirements. At that point, resources available to the environmental protection agency are usually increased, monitoring and enforcement are tightened, penalties for non-compliance are strengthened, and serious abatement begins.

35/ EIAs are part of a broader class of information-related measures which can promote systematic reduction of emissions. In the U.S., for example, the 1986 amendments of the Superfund act initiated mandatory measurement and publication of air, water, and solid waste emissions of 330 toxic, carcinogenic, and mutagenic substances. Forced to undertake heavy information investments which competitive pressures previously discouraged, firms have found the resulting emissions accounts to be very useful for "clean" product and process planning. At the same time, public dissemination of the emissions reports is making neighboring residents much more aware of their own exposure. Fear of reputational damage has thus been added to the list of firms' cleanup incentives.
B. The OECD Countries

7.07 Numerous recent studies have compared pollution control policies and results in the OECD countries (USCBO, 1985; OECD, 1989a; Kopp, 1990; Hahn, 1989; Vogel, 1986). They are close to unanimity in their assessments of instrument choice and implementation policy.

1. Regulatory Instruments

7.08 Historically, quantitative controls have been almost entirely dominant in the formal regulatory systems of the U.S., Canada, the EEC, and Japan. In fact, there seems to be no case in which price-based incentives have been used in isolation from quantity controls. High baseline emissions standards have always been maintained, and regulatory strictness generally seems to reflect relative population density. By one measure -- reported cost of pollution abatement and control as a proportion of total investment -- Japan has been the strictest, followed in order by Western Europe, the U.S., and Canada (USCBO, 1985). Both quantitative emission control and mandated "best practice" technology requirements are commonplace everywhere but the U.K., which has developed a unique system of informal adjustment via negotiations between the pollution inspectorate and its industrial partners. (Vogel, 1986).

7.09 Unlike the U.S. and Japan, which rely almost exclusively on quantitative controls, Western Europe has made widespread use of effluent charges as a supplementary tool for environmental management. These are all "polluter pays twice" systems -- charges are levied, but effluent standards are maintained as well. Since 1985, France has levied charges for both air and water pollution. Germany has, since 1981, subjected all open water discharges to a fee based on the estimated amounts of different pollutants in the waste stream. In Sweden, plants which discharge into municipal facilities must pay the full cost of collection and treatment. This is also true for solid wastes. The government has attempted to levy an additional "environmental charge" to neutralize profits accruing to noncompliance with standards, but problems in establishing legally-acceptable verification of non-compliance levels seem to have limited the effectiveness of the system. In almost all EEC cases, such charges are set too low to have much of an incentive impact. Only in the case of the Netherlands have effluent charges apparently exceeded the marginal cost of abatement, and very significant effluent reductions have resulted (OECD, 1989a, Bressers, 1983 -- See Section III). This uniquely high charge level seems to have been politically feasible only because the historical necessity of hydraulic control has made strict systems acceptable to Dutch industry. Basically, European charge systems are designed to raise revenues for financing the regulatory system, R&D, and subsidies for industry purchase of abatement equipment.

7.10 Emissions trading has been mostly a U.S. innovation to date (OECD, 1989a; USCBO, 1985). True TP systems have been rare even in the U.S., because QB policies have focused on controlling point emissions sources within plants. Very restrictive and inflexible policies threatened to strangle economic growth in highly polluted areas during the 1970's, and the regulatory statutes were gradually revised to allow for some compensating emissions adjustments. Typically, these have allowed for changing the pattern of point emissions within a control region (known as a "bubble"), provided the overall results stay within the regulatory limits. In principle, interfirm offsets are allowable. In practice, almost all offsets take place across emissions points within individual plant sites because the transactions costs of interfirm exchanges have been very high (Hahn, 1989).

7.11 Emissions netting has apparently resulted in huge cost savings in some cases. It has allowed economic growth to continue in highly polluted areas where inflexible point source policies would undoubtedly have stifled it. Most analysts agree with Hahn (1989), however, that emissions netting has not significantly reduced total pollution.

7.12 If interfirm offset arrangements have been rare, formal markets in tradable permits to pollute have been even rarer. Hahn (1989) and Tietenberg (1988) cite a handful of cases, with one notable success in a lead permit trading program for gasoline refineries and one notable failure in an attempt to establish a
TP market for one region of the Fox River in Wisconsin. The 1990 Amendments to the U.S. Clean Air Act establish a market in permits for SO₂ emissions, which are targeted for an approximate 50% reduction by the year 2000. (Weisskopf, 1990; Coy, 1990). This may reflect a trend toward increased acceptance of the concept among policy makers, but it may also reflect the relative certainty which comes with experience. The same Amendments impose direct controls on 189 other substances, most of which have not previously been regulated.

7.13 In the EEC, the only reported implementation of transferable pollution rights is in Germany. Under the Plant Renewal Clause, licenses for new plants are refused in areas which have not attained mandated ambient standards, unless they replace plants of the same kind with substantially lower emissions. This is similar to the offset arrangement in the U.S. and is far from a true TP system.

7.14 Many continental EEC states use the carrot of subsidized abatement loans as well as the stick of direct regulation. Subsidized loans are also employed in Japan, but the U.S. and U.K. do not have significant national subsidy programs. The OECD countries are also strongly differentiated by the price which industry faces for some material inputs, particularly fuels. Part of this stems from transport costs, and part from differential tax policies. Table VII.2 shows the enormous range of prices faced by OECD industries for heavy fuel oil, which is an important source of air pollution. An indirect benefit of industry adjustment to higher fuel prices should be some reduction in the associated air pollution.

2. Implementation

7.15 The OECD countries all have roughly the same formal enforcement apparatus, with non-compliance punishable (in escalating order of severity) by citations and required compliance schedules, fines, temporary production suspensions, and shutdowns. All have also relied principally on end-of-pipe control instruments, not indirect approaches. As suggested in Part I, control region heterogeneity has created major administrative problems. Corroborative evidence collected by Vogel (1986), Wynne (1987), and others suggests that regulators in all OECD countries handle this problem by delegating great discretion to local agents: Real industrial pollution control policy is mostly negotiated at the plant level.

7.16 The actual style of negotiation can be quite different. The U.K. has the most flexible, decentralized approach, with no set standards but steady pressure on industry from inspectors who are technically knowledgeable and aware of general goals for environmental improvement (Vogel, 1986). Japan also delegates substantial authority to local regulators who can adjust national standards to local circumstances (JEA, 1988; USCBO, 1985; Kopp, 1990). The Japanese system is based on "administrative guidance," involving frequent informal consultation (Gresser, 1979). Although this consultative mode is less pronounced in Western Europe, it is much more so than in the U.S. (USCBO, 1985; Hahn, 1989). The U.S. tradition of arms' length relations between business and government has been maintained in environmental regulation, with much emphasis on formal rules-adherence and adversarial legal processes. Nevertheless, the administrative review process in the U.S. is effectively a negotiation in which the government pre-announces strict standards and then modifies them in response to countervailing political and legal pressure.

7.17 Several basic negotiating principles seem to apply in all the OECD countries:

- Factory shutdowns are anathema (although they occasionally happen). Performance standards are adjusted, or deadlines stretched out, to avoid them.

- Adjustment costs are given serious consideration. Fines, technology standards and emissions limits are tempered accordingly.

36/ The apparent reasons for this failure are noted in section III.C.
Local absorptive capacity and popular sentiment in the immediate neighborhood of the plant are taken into account by replators. Changing public attitudes toward the environment also have a powerful impact on plant managers' expectations. As environmentalism grows, managers respond more readily in negotiations even if more severe sanctions are not imposed.

Changes in performance standards are essentially regarded as ex post facto laws for existing plants. The common assumption is that adaptation will be cheaper for new installations.

One aspect of the negotiating environment is undeniably quite different—the handling of information about plant processes and costs. In informal systems like those of the U.K. and Japan, plant process and emissions data have traditionally been closely held by inspectors and plant managers. Such systems can adjust quite smoothly to changing environmental standards, as long as good relations are maintained and the inspectors have high standards of knowledge and probity. In a democracy, the public has to have very high confidence in the regulatory authority to permit such confidentiality. It has the additional effect of denying much voice to environmentalist groups which wish to promote higher environmental standards.

In the U.S., by contrast, this kind of collaborative relationship has always been regarded as a "capture" of the regulators by industry. The U.S. information system is porous: open hearings are held; environmental advocates have many channels of influence; plants are forced to disclose far more emissions information than elsewhere. The disadvantage of this more open system is that such formal, open proceedings encourage public posturing and litigation rather than flexible response. It is also true that plant managers who are too flexible in such circumstances risk being drawn to the strictest standard advocated by competing outside interest groups. This standard might in fact impose ruinous costs, and U.S. environmental law seems to have been structured, at least in part, to protect firms from the risk of openness. The more open system has a strong countervailing advantage, however. By opening the information channels, it increases the risk of reputational damage for polluters and forces more attention to prevailing environmental standards even if no formal regulatory sanctions are employed.

There are also some significant differences in the implementation of pollution control policy. The continental EEC countries make much more frequent use of systems which mix emissions charges with quantitative controls. These are used for financial support of the regulatory system, R&D, and subsidized loans for private abatement investments. The form of local negotiations is also different—legalistic in the U.S., more corporatist in the continental EEC states, consultative in Japan and the U.K.

Results

Table VII.2 compares pollution reduction records in 1974-84 for 13 OECD countries plus Finland. Emissions for two major industrial air pollutants (SO₂ and NOₓ) are measured per unit of gross domestic product. Overall, the record of reduction since 1974 is impressive for SO₂; less so for NOₓ. Japan is the clear leader, with an 81% reduction for SO₂ and 64% for NOₓ. Sweden and Norway form the next group, followed by other north-central European countries. U.S. reductions are somewhat near the center of the European group. The more recently industrialized economies in southern Europe (Greece, Portugal) had increased emissions of both pollutants.

Some of the substantial variation in pollution reduction is undoubtedly due to changes in economic structure, particularly for southern Europe. Among the wealthier OECD nations, greater environmental progress is partly due to greater regulatory capabilities, larger budgets, and a more pronounced
taste for environmental amenities. In addition, fuel price differentials have had a significant impact. This highlights the pollution-reducing potential of price-based regulation, but high European and Japanese fuel taxes do not seem to reflect explicit environmental objectives.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ (a)</td>
<td>NOₓ(a)</td>
<td>(b)</td>
<td>(c)</td>
</tr>
<tr>
<td>Japan</td>
<td>-82</td>
<td>-64</td>
<td>268</td>
</tr>
<tr>
<td>Sweden</td>
<td>-72</td>
<td>-18</td>
<td>235</td>
</tr>
<tr>
<td>Norway</td>
<td>-70</td>
<td>-21</td>
<td>189</td>
</tr>
<tr>
<td>France</td>
<td>-62</td>
<td>-20</td>
<td>182</td>
</tr>
<tr>
<td>Finland</td>
<td>-61</td>
<td>+28</td>
<td>203</td>
</tr>
<tr>
<td>Belgium</td>
<td>-40</td>
<td>+20</td>
<td>184</td>
</tr>
<tr>
<td>UK</td>
<td>-43</td>
<td>-17</td>
<td>214</td>
</tr>
<tr>
<td>FRG</td>
<td>-42</td>
<td>-3</td>
<td>187</td>
</tr>
<tr>
<td>US</td>
<td>-39</td>
<td>-20</td>
<td>145</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-35</td>
<td>-1</td>
<td>187</td>
</tr>
<tr>
<td>Denmark</td>
<td>-23</td>
<td>+7</td>
<td>201</td>
</tr>
<tr>
<td>Switzerland</td>
<td>-14</td>
<td>+28</td>
<td>210</td>
</tr>
<tr>
<td>Greece</td>
<td>+5</td>
<td>+11</td>
<td>183</td>
</tr>
<tr>
<td>Portugal</td>
<td>+30</td>
<td>+51</td>
<td>140</td>
</tr>
</tbody>
</table>

Notes:
(a) Measured as % change in emissions minus % change in GDP (measured in constant local units).
GDP: World Bank, World Tables.
(b) Source: OECD (1989c), Table 6, p. 279.
(c) World Bank, World Tables.

To summarize, most OECD countries have achieved notable reductions in some forms of pollution, using broadly similar approaches to regulation. There has been strong reliance on QB systems with end-of-pipe controls. Apparently, the combined impact of political preferences, uncertainty, concern about toxic substances, and control region heterogeneity has been sufficient to outweigh the abstract efficiency argument for PB instruments. There is scattered use of charges, which are generally below abatement costs and intended primarily for fund-raising. Control region heterogeneity also seems to create many local problems which cannot be handled by central regulators. As a result, negotiations between local agents and firms seem to play an extremely important role everywhere.

A regression for SO₂ reported below, shows strong income and fuel price effects. The result is much weaker for NOₓ, but both results suggest a fuel price elasticity of approximately one. Since the sample countries have fuel price differentials approaching 100 percent, this is a very powerful effect.

Regression Results: SO₂ and NOₓ
(Variable Values from Table VII.2; t-statistics in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>SO₂</th>
<th>NOₓ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(Oil Price)</td>
<td>-1.00</td>
<td>-1.12</td>
</tr>
<tr>
<td>(2.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(GNP Per Capita)</td>
<td>-.35</td>
<td>-.10</td>
</tr>
<tr>
<td>(3.08)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>.70</td>
<td>.14</td>
</tr>
</tbody>
</table>
C. Poland

1. Instruments

7.24 The existing Polish statutes closely resemble their counterparts in the OECD countries: Regulatory institutions are in place; ambient and baseline emissions guidelines are strict and comprehensive; and environmental impact statements are required (Wilczynski, 1990). In fact, Polish regulatory policy goes quite far toward institutionalizing appropriate shadow pricing principles for environmental services. Effluent charge structures exist for both water and air pollution; fees are explicitly regarded as charges for use of environmental services, thereby institutionalizing a concept which is much advocated by Western economists but almost never implemented. The fees have a detailed structure which is not replicated in any market economy. Polish EC policy for air pollution, for example, has specific charge rates for fifty-four separate pollutants (Wilczynski, 1990). By world standards, Poland is also well endowed with technical and scientific manpower which could be mobilized for staffing an effective environmental protection agency. Nevertheless, Poland is an environmental disaster area. What went wrong? Much of the country's pollution problem can be traced, directly or indirectly, to more general problems of distortionary incentive regimes.

7.25 Price system distortion in pursuit of industrial growth and other welfare objectives had the unintended side effect of encouraging pollution. Material input prices were kept well below marginal production costs, thereby encouraging wasteful consumption and reducing incentives for recycling. Water and electricity prices were kept artificially low to stimulate industrial development and promote consumer welfare, again promoting wasteful consumption and extra pollution. State investment policy was explicitly directed toward the encouragement of heavy industries such as metals and chemicals, which are heavily polluting (Wilczynski, 1990).

7.26 One indicator of the consequences of this policy regime for operational efficiency is provided by Table VII.3. For six Eastern European economies, median energy intensity in production in 1985 (1.24 Kgoe/$) was 300 percent higher than in 8 OECD economies (.41 Kgoe/$). Since energy production has been one of the major traditional sources of air pollution, this basic pattern of inefficiency has undoubtedly contributed to the problem. It has been compounded by the heavy dependency of several East European economies on combustion of high-sulfur coal.

<table>
<thead>
<tr>
<th>Energy (Kgoe/US)</th>
<th>Poland</th>
<th>Bulgaria</th>
<th>Czechoslovakia</th>
<th>GDR</th>
<th>Hungary</th>
<th>EEC</th>
<th>U.K.</th>
<th>Italy</th>
<th>FRG</th>
<th>Austria</th>
<th>Denmark</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romania</td>
<td>1.06</td>
<td>1.43</td>
<td>1.17</td>
<td>1.11</td>
<td>1.08</td>
<td>0.92</td>
<td>0.61</td>
<td>0.51</td>
<td>0.42</td>
<td>0.42</td>
<td>0.40</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Source: Wilczynski (1990), Table 3, p. 5

38/ There is evidence that some East European states explicitly promoted export industries in those sectors which were under heaviest cleanup pressure in the EEC and U.S. during the period 1970-1985. Leonard (1988) asserts that this was particularly true for Romania.
2. Implementation

7.27 Hughes (1990) notes several institutional and economic factors which contributed to the failure of pollution control in socialist Poland. First, as in the OECD countries, much of the actual regulatory implementation was left in the hands of local governments. In Poland, many communities have been dependent on a few large enterprises which fund local communal services. This has drastically reduced the regulators' leverage in negotiations with plant managers. Second, the "polluter pays" principle could not operate effectively in a system where most major enterprises operated with soft budget constraints and many goods and services were not allocated in markets. Thus, the elaborate structure of Poland's environmental regulation bore no resemblance to actual pollution costs faced by enterprises. The overwhelming dominance of state industry and the primacy of other objectives assured very poor support for environmental regulatory agencies, lax monitoring, and general failure to enforce existing regulations. Many plants were essentially unmonitored; both fines and effluent charges were far below marginal abatement costs in all but a few isolated cases; and collection was sporadic (Wilczynski, 1990).

7.28 The general preference of non-democratic governments for secrecy also had important consequences for the environment. The state security apparatus throughout Eastern Europe adopted a policy of suppression of data on pollution and its consequences for public health. As part of this policy, environmental activities were frequently suppressed until the mid-1980's. In 1983, for example, an extensive report by the Czech Charter 77 movement had to be published clandestinely and smuggled to Western newspapers so that its findings could be distributed (French, 1990). In November 1987, the East German secret police raided an environmental library maintained by the Lutheran Church in East Berlin (French, 1990).

7.29 Such actions were intended to reduce popular pressure for enforcement of environmental standards, and did have that effect for a substantial period. Paradoxically, however, environmentalist protests provided one of the first avenues for the formation of organizations which ultimately joined together to overthrow the East European governments (Miller, 1990).

3. Results

7.30 Eastern Europe's environmental history illustrates the potential for damage when price and allocative distortions encourage pollution-intensive activities. Other important factors included the prevalence of public enterprises with soft budget constraints, lax enforcement of regulations, restricted information, and political repression. Taken together, they neutralized an elaborate system of formal regulatory control and led to high levels of emissions intensity (Table VII.4). Poland and Hungary are clearly outliers, producing far more pollutant per unit of national output than any other countries in the table, whatever their level of industrial development.

D. Brazil and Republic of Korea

7.31 Brazil and ROK have both used state policy to promote industrialization, and both have moved from authoritarian to democratic regimes during the 1980's. In most other respects their policy regimes are quite different. ROK is small and densely populated. It is an outward-looking economy whose government has consistently promoted only those industries which have successfully penetrated world markets; industrial development has been left in the hands of private conglomerates. Brazil, by contrast, is large, has much lower population density, and has until recently pursued an inward-looking growth strategy. The

39/ The treatment of Brazil in this section relies heavily on Findley (1988). the Korean material is drawn from Clifford (1990); Gresser (1979); Song (1989); Gadacz (1986); and Engineering Science, Inc. (1984).
emphasis has been on integrated production for the domestic market, and state enterprises have played an important role in industrial development.

7.32 The benchmark dates in Table VII.1 show that ROK and Brazil had a very similar pattern of institutional development for environmental regulation. Both adopted ambient standards in the mid-1970's, established environmental protection agencies in the early 1980's, and institutionalized EIA requirements in the mid-1980's.

<table>
<thead>
<tr>
<th>Country</th>
<th>( \text{SO}_2(a) )</th>
<th>( \text{NO}_x(a) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungary</td>
<td>76.3</td>
<td>15.7</td>
</tr>
<tr>
<td>Poland</td>
<td>68.3</td>
<td>21.6</td>
</tr>
<tr>
<td>Portugal</td>
<td>47.5</td>
<td>15.2</td>
</tr>
<tr>
<td>Canada</td>
<td>14.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Greece</td>
<td>11.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Thailand</td>
<td>9.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Belgium</td>
<td>6.0</td>
<td>4.3</td>
</tr>
<tr>
<td>UK</td>
<td>8.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Denmark</td>
<td>8.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Finland</td>
<td>8.1</td>
<td>5.6</td>
</tr>
<tr>
<td>US</td>
<td>7.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Italy</td>
<td>6.2</td>
<td>4.2</td>
</tr>
<tr>
<td>France</td>
<td>4.7</td>
<td>3.5</td>
</tr>
<tr>
<td>FRG</td>
<td>4.6</td>
<td>5.1</td>
</tr>
<tr>
<td>Sweden</td>
<td>3.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Norway</td>
<td>2.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Japan</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1.1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

(a) Measured as thousands of metric tons per billion dollars of GDP.


1. Instruments and Implementation

7.33 Pollution control in both ROK and Brazil has been strongly QB in orientation. (Findley, 1988; Song, 1989; Gadacz, 1986). As in the OECD countries, information problems stemming from control region heterogeneity have led to the delegation of considerable discretionary power to local regulatory agents. Brazilian regulators, like their Korean counterparts, have at their disposal a graduated system of notifications, fines, suspensions, and shutdowns for standards violations. However, the Brazilian system of implementation seems to be "softer" than the Korean system, in the sense that Brazilian policy has seldom depended on explicit emissions standards or mandated installation of abatement equipment. Rather, negotiations have generally been handled in the British style, on a case-by-case basis. This has had the advantage of permitting greater flexibility in adaptation to particular circumstances, although it is easily abused in practice. In ROK, there has been substantially more reliance on mandated controls, with the threat of highly punitive sanctions in case of violation.

7.34 Implementation patterns, however, have been quite similar. Until recently, enforcement agencies in both countries have had very limited budgets and problems fielding technically trained personnel. Regulators have been highly sensitive to the problem of continued economic viability for older enterprises when pollution controls are tightened, and the result in both countries has been a pronounced "new-source" bias in the imposition of standards. There has been scattered imposition of fines, which are generally far below the marginal cost of abatement; preference for financial carrots in the form of upgrading subsidies; and failure to effect shutdowns, even for gross infractions, in all but the most extreme public health emergencies.
Negotiated settlements have recently become stricter in response to rising environmentalist pressure. Both support for enforcement and the incidence of meaningful sanctions have increased markedly in both countries, as democratically-elected governments have come under great popular pressure to improve the environment, even at substantial opportunity cost.

2. Results

The available evidence is extremely spotty, but suggests that some environmental quality improvement has been attained. Major investments in pollution abatement equipment by some of the largest polluters in the Sao Paulo region of Brazil have reduced the incidence of extremely hazardous conditions there. Estache (1991) reports substantial recent improvements in Sao Paulo’s air quality and Cubatao no longer experiences emergency alerts. Comparable time series data for ROK are unavailable, but the implementation of measures such as forced switching toward lower-sulfur fuels in the Seoul region will in all probability improve air quality.

E. Thailand, Nigeria, and Indonesia

1. Existing Instruments

At present, Thailand, Nigeria, and Indonesia do not have well established regulatory systems. Various ministries in all three countries have fragmented responsibility for pollution control. Where pollution regulation has been implemented in response to local crises, it has almost always been QB. The earlier discussion of Indonesia noted the forced installation of abatement equipment by a few firms in Surabaya in the aftermath of a water quality emergency. The Indonesian Ministry of Population and Environment (KLH) has recently begun negotiating cleanup agreements with a few major polluters in Jakarta.

Similar conditions have prevailed in Thailand, although Kritiporn (1990) does note two interesting precedents for pollution charges there. In the early 1970’s, the Mae Klong River experienced a rapid increase in biochemical oxygen demand as a result of effluent discharges from new sugar mills. In response to a perceived crisis, the Thai government established the country’s first central treatment facility for industrial waste water. Funds were taken initially from the sugar price stabilization fund, but in succeeding years the fund was compensated with charges levied on the industrial users. In instituting this policy, the Thai government was in effect moving toward the mixed system which has long characterized water pollution control in Western Europe.

In 1988, the Thai government established the Bang Khuntien Treatment Center to remove heavy metals from the wastewater of 200 small- and medium-scale electroplating factories in Bangkok. Factories are assessed for the effluent according to the type and quantity of waste and the transport distance to the treatment center. Long-term contracts are signed to assure an adequate treatment volume for the center. At present, the system is considered an operational success.

In Nigeria, there has been almost no use of pollution control instruments in the absence of an appropriate regulatory apparatus. A traditional corpus of law has in principle given local authorities the right to take gross polluters to court and private parties the right to sue for damages under tort law, although most attempts are reported to have been ineffective. Since problems of official corruption have been rife, it is not yet clear how an effective program of local inspection and enforcement would be carried out.

The Nigerian treatment draws on Osae-Addo (1990); and Olokesusi (1987, 1988). Indonesian material has been taken from USAID (1987), and unpublished World Bank reports.
2. Institutional development issues

7.41 Formal regulatory institutions with true national powers and responsibilities are now being set up in all three countries. Since 1989, the Nigerian federal government has established the National Environmental Protection Agency, set ambient standards for air and water quality, and instituted formal environmental impact assessment requirements for new industrial projects. During the past two years, the Indonesian government has significantly upgraded the status of the Ministry for Population and the Environment and has begun promoting national ambient standards for air and water quality. Thailand has no such central regulatory authority at present, but Kritiporn (1990) suggests that one will soon be established.

7.42 At present, policy makers in all three countries are looking for appropriate regulatory strategies. Some initial experiments are currently being conducted or planned in Indonesia and Nigeria in collaboration with the World Bank and other multilateral funding institutions. In Thailand, the Thailand Development Research Institute (TDRI) has recently advanced a detailed and innovative proposal for a QB/PB system. The essential elements of the TDRI proposal are as follows (Kritiporn, 1990):

- Establishment of a central environmental fund (CEF), with authority to construct public treatment facilities, monitor industrial pollution, and assess charges where appropriate.

- Deposit-refund operation of the CEF:
  - Charge assessment on the basis of "presumptive emissions" estimated from standard emissions parameters; assessment at the presumptive maximum, not average, for the industry to insure against falsified reporting
  - Charges at estimated firm cleanup cost, not public treatment cost, to encourage waste minimization
  - Payback from the fund, with interest, on proof of emissions lower than the presumptive level
  - Use of private bonded auditing agencies for verifying claims
  - Financing of central treatment facilities for hazardous waste

- Special incentives for small-scale hazardous waste generators: fee payment for delivery of hazardous waste, in acknowledgment that search costs are too high to warrant standard regulatory treatment

- Air pollution policy: Emphasis on clean fuels
  - Elevation of the price of lignite to parity with natural gas
  - Mandated reduction of maximum sulfur content in fuel oil and diesel oil
  - Establishment of emissions standards for boilers, particularly in the Bangkok area

7.43 The TDRI proposal is designed to take account of potential problems stemming from weakly-developed regulatory institutions. Auditors are private and bonded to lower the risk of corruption. Default charges are based on pre-calculated parameters and the burden of proof for rebates is on the affected companies. Thus, the TDRI proposal attempts to automate charge calculation and privatize monitoring as a way of minimizing the regulatory burden.
VIII. CONCLUSIONS

8.01 The main message of this paper is that there is no general conflict between market-based and quantity-based instruments, either in theory or in regulatory application. Where direct regulation is concerned, policy analysts cannot realistically hope to rely on one simple principle such as "social marginal cost pricing." A reasonably sophisticated understanding of local conditions is a prerequisite for appropriate instrument choice.

8.02 The pollution regulation problem is, in fact, largely an information problem. Effective pollution control depends on answers to the following kinds of questions:

- **The control region**: What is the "control region?" What interest groups determine this?

- **The pollutants**: There are myriad potentially hazardous substances in circulation. Which should be chosen for regulation? What is known about their generation and dispersal?

- **Industrial environmental demand**: Where are the emissions coming from? What are the characteristics of these emitters? How much is emitted into four media (air, water, land, underground)? What are firms' short- and long-run substitution possibilities, both across media and among different production processes? What are the associated costs? How do incentives in the macroeconomic environment condition firms' behavior?

- **The environmental supply curve**: Once emissions are known, how is their volume related to consequences for human health, other economic activities, and the local ecosystem more generally? How are these consequences weighed?

- **The regulatory system**: Institutionally, by what means are the above questions asked and the answers combined? How is enforcement structured? Who does the enforcing, and with how much latitude for flexible response to particular circumstances?

A. Instrument Choice

1. **Different regulatory instruments are preferable in different circumstances, even where regulatory costs are not considered and static efficiency is the governing criterion.**

8.03 This paper has considered numerous direct regulatory instruments, both market-based (effluent charges (EC); deposit-refund or performance bond systems (DR); tradable permits (TP)) and quantity-based (mandated installation of control equipment (MIC); emissions standards (ES)). Environmental economists recommend market-based instruments, preferring EC (or DR as a close substitute when there are monitoring difficulties). TP is generally viewed as preferable when there is considerable uncertainty about the social marginal damage function.

8.04 At present, however, all countries operate essentially QB regimes, focused on end-of-pipe control with an occasional admixture of modest effluent charges (particularly in Europe). This near-universal emphasis on QB suggests a closer look at two conditions which must be satisfied before movement to market-based instruments is likely to yield major benefits: (1) regulated pollutants are not highly toxic; (2) control regions are homogeneous.

8.05 In practice, these conditions are very frequently violated. Although highly toxic pollutants could in principle be regulated with market-based instruments, governments have generally felt considerable political and ethical pressure to employ quantitative controls. True control region homogeneity requires
numerous small, competitive, privately-owned firms; a uniformly-distributed population; and uniform climatic
conditions (e.g. wind patterns, water flow). If there are many public enterprises with soft budget constraints,
economic incentives will not be very meaningful. Regional dependence on a few large employers introduces
other external effects which must be factored into pollution control decisions.

8.06 Thus, real-world control regions may actually comprise many micro-regions, whose unique
pollution shadow prices require more tailored effluent charges than are computationally and administratively
feasible. The micro-regions may also be too small for tradable permit systems to operate effectively.

2. When direct regulation is appropriate, mixed instrument systems may frequently be the best choice.

8.07 Mixed instrument systems represent a sensible compromise which developing countries may
want to consider. They combine some of the efficiency-enhancing properties of market-based incentives with
the insurance against uncertainty provided by quantitative standards. Experience to date warrants modest
expectations for the actual implementation of charge programs. In Europe, where pricing applications are
most advanced, effluent charges are almost always designed to support direct costs of regulation, public
abatement facilities, or cleanup subsidies, not to confront firms with the true marginal cost of abatement.
Charges are invariably part of mixed instrument systems built around base level effluent standards which adjust
through time.

3. Comparison of instruments on static efficiency grounds is generally inappropriate. Relative dynamic
efficiency is not well understood at present, and market-based systems may not always be dynamically superior.

8.08 Arguments for the dynamic superiority of market-based instruments generally note that a fixed
quantitative standard gives no further incentive for improvement once it has been met, while an effluent charge
provides a continuing incentive for progressive change. This would be the appropriate comparison if enforced
standards remained fixed. In all countries, however, they are progressively tightened as income rises and risk
tolerance falls. In realistic discussions of dynamic efficiency, the comparison should therefore be between paths
for quantitative restrictions and effluent charges. Expectations are clearly important; firms may act in
anticipation of future restrictions, even if they have not been announced.

8.09 While this whole area is not well developed in the theoretical literature at present, uncertainty
may significantly enhance the appeal of quantity-based policies. A preannounced (steep) adjustment path may
enhance the likelihood of interfirm cooperation in lumpy R&D. Quantitative restrictions may also be more
flexible, because frequent charge adjustments would be strongly resisted by corporate financial planners.

B. General Regulatory Strategy

1. The rapid international diffusion of environmentalism reflects the growing awareness that
environmental protection should begin early in the development process.

8.10 As this paper has documented, environmental concerns have recently become significant for
policy in countries whose incomes are far below those at which the OECD countries first faced the problem.
Having seen the human consequences and the cleanup bill for the industrial economies, LDC policy makers
are concluding that early intervention is preferable. Reinforcement is provided by the continued accumulation
of scientific information about the impact of industrial byproducts on human and other living populations.
Growing transboundary pollution problems are also increasing diplomatic pressure on national governments
to take environmental policy seriously.

8.11 None of this, however, invalidates the proposition that optimal pollution levels vary by stage
of development. Pollution levels should generally move in an inverse U-shaped trajectory as development
proceeds, although appropriate policies can have a significant impact on the absolute level of pollution at each
stage of development. Resources allocated to environmental improvement have a high opportunity cost in
the early stages of development; possibilities for effective regulation improve as technological capabilities
increase and the human resource base deepens; and the relative pollution-intensity of the economy itself seems
to move in an approximately inverse U-shaped pattern in the transition from agro-industry and simple
assembly, through heavy industry, to more intensity in high technology and services. It is therefore not
surprising that urban China is more polluted than urban Canada. This disparity is not formally acknowledged;
official ambient standards reflect international norms geared to the risk levels which are affordable in high-
income societies. Such standards play a useful role in generating constant pressure for improvement, although
implemented standards should be less strict for poor countries.

2. Theoretically, intercountry differences in factor prices and capabilities should have implications for
optimal choice of regulatory systems. There is, however, little difference in the structure of actual regulatory
systems.

8.12 All sample countries have adopted or are on the verge of adopting a "standard" regulatory
package, which includes legal codification of environmental rights; establishment of ambient standards
according to international norms; an environmental protection agency with national power and responsibility;
the mandatory use of environmental impact statements in project preparation; and enforcement provisions
ranging from citations to (rarely-used) imprisonments and shutdowns. Only in the case of enforcement
intensity is there a clear difference. As might be expected, this varies with per capita income because wealthier
economies have stronger environmentalist preferences, greater enforcement capabilities, and more complex
industrial structures.

3. Societies which promote rapid industrial growth without appropriately shadow pricing environmental
services and enforcing regulatory standards are in effect promoting pollution.

8.13 The experience of the East European socialist economies illustrates how a policy regime can
encourage massive pollution even when an apparently sophisticated apparatus for formal regulation is in place.
Poland, for example, has an elaborate effluent charge system, but some industrial regions have terrible
environmental problems. The evidence suggests that while lax enforcement is a culprit, much of the blame
is to be sought elsewhere in the economy—in inappropriate subsidies for fuels and materials, and on industrial
strategies focused on heavy industry.

8.14 This proposition can be generalized to many other economies: Brazil and ROK have
aggressively promoted heavy industrial development with little or no concern for the environment; Thailand’s
failure to consider cross-industry variations in pollution intensity is now producing the same threat (Kritiporn,
1990); and Indonesian industrial development policies have kept raw material prices artificially low (Repetto,
1988).

4. Economies with severe allocative and price distortions, or with many public enterprises facing soft
budget constraints, will have less success in reducing industrial pollution through regulation because the true
scarcity value of environmental services will not register strongly in economic decisio

8.15 The "polluter pays" principle cannot be successfully implemented when there is a general
failure of economic accountability for state enterprises under soft budget constraints. The sample evidence
in Table VII.4 is strongly suggestive: The Eastern European economies are extreme outliers in the
international distribution of industrial emissions, followed by China. Hughes (1990) estimates that the process
of general economic reform, together with the energy conservation induced by higher energy prices, will
produce a reduction of emissions by nearly 50% in Eastern Europe, even if the pollution regulation system
remains unchanged.
5. **Under end-of-pipe regulation, the problem of control region heterogeneity seems too burdensome for central regulatory authorities.** In all sample countries with functioning EPA's, this has lead to the delegation of considerable discretion to local regulatory agents.

8.16 Regulatory implementation everywhere is heavily oriented toward negotiations and tailored local solutions which roughly reflect centrally-defined norms. Negotiating styles seem to reflect generic national differences. Thus, they are legalistic and arms length in the U.S. and Republic of Korea; corporatist in continental Europe; and collaborationist in the U.K., Japan, and Brazil.

6. **Monitoring and enforcement problems tend to grow as quickly as industrial systems.** "Command and control" is therefore a misnomer. Most regulation involves negotiation, and regulation may be more cost effective if agents employ "carrots" in the form of appropriate subsidies as well as the conventional "sticks" of charges, controls, and legal enforcement.

8.17 Regulated enterprises will not necessarily do what they are told, and what they are told frequently depends on what they choose to disclose about their own operations. In industrial economies, firms which feel unduly threatened by regulation can also influence negotiations by exerting pressure through their parliamentary allies, stalling with legal maneuvers, etc. Faced with these inevitable complications, a cost-minimizing regulatory strategy may well include subsidies as an inducement to cooperation.

8.18 In developing countries, informal sector polluters may not even choose to disclose their existence to a regulatory agency which doesn't have the resources to find many of them. In an explicit (but apparently appropriate) violation of the "polluter pays" principle, Kritiporn (1990) proposes that small-scale toxic waste producers in Bangkok actually be paid for depositing hazardous waste at cleanup facilities.

7. **Optimal pollution reduction strategy must be based on an integrated view of emissions in all media.**

8.19 Technical problems of pollution control are quite different by medium, and regulatory agencies are generally divided accordingly. But where firms have intermedium substitution possibilities for emissions (which is quite frequently the case), this segmented approach makes it likely that there will be a suboptimal balance of regulation across media. Coordinated policy becomes possible when detailed data on firm-level emissions are available.

8. **Pollution control has traditionally been viewed as a problem of meeting fixed ambient standards, but results would improve if it were viewed as optimal risk reduction.**

8.20 Regulation of complex industrial systems has been hamstrung by the traditional focus on fixed ambient standards because there is always political pressure to set these standards at levels which impose very high costs on regulated enterprises. The result is a tendency to regulate only a few of the thousands of potentially hazardous substances. An optimal damage reduction approach, by contrast, would emphasize equalization of marginal net benefits across many pollutants at a higher exposure per pollutant. Although more research on exposure risk is necessary, existing regulatory systems are so unbalanced that even relatively crude policy initiatives would probably be beneficial.

9. **Appropriate information dissemination policies are a critical part of an optimal regulatory strategy.** These include promoting diffusion of environmental information and participation by local communities.

8.21 Regulatory policy has frequently neglected widespread dissemination of environmental information as an extremely powerful instrument for pollution reduction in its own right. There are at least two major channels through which information policy has significant impacts. The first is effective empowerment of local communities. As this paper has noted, pollution problems are often local and
multidimensional. Optimum solutions require informed participation by local communities, either through the formal political system or non-governmental organizations.

8.22 The second channel is the potential effect of emissions disclosure on the reputation of the firm. In economies where environmentalism is widespread, or even limited to the affluent classes, it may be extremely damaging for a firm to become thought of as an excessive polluter. With widely disseminated and frequently-updated information about emissions, firms have a strong incentive to pursue pollution reduction which is either in line with or ahead of the public's environmental quality norm.

10. Human resource quality in the regulatory agency may be as important as the formal regulatory approach in determining pollution outcomes.

8.23 Insufficient training and understaffing of environmental regulatory agencies are critical impediments to effective pollution control, whatever the nature of the formal regulatory system. This paper has noted the degree to which regulatory implementation involves plant-specific negotiations in which the knowledge of regulatory agents is a critical factor.

C. Promising Areas for Research

8.24 Many of the World Bank's client countries are now establishing national environmental protection agencies and Bank lending for industrial pollution control projects is growing rapidly. At present, however, the conceptual and empirical foundations of an appropriate, integrated approach to industrial pollution control are very weakly developed. This concluding section of the paper offers some thoughts about appropriate directions for applied research, with accompanying suggestions for specific research projects. In each subsection, the highest-priority project proposals are presented first.

1. Incorporation of environmental inputs and outputs into models of short- and long-run firm responsiveness to changing relative input and factor prices.

8.25 With the advent of positive prices for a large new set of environmental inputs and outputs, both firms and industrial systems will undergo substantial adjustments which should be understood by policy makers and environmental regulators. In the short run, firms can adjust by reducing overall emissions somewhat, changing the relative intensity of their pollution in different media, and changing their product mix and associated patterns of factor demands. In the longer run, they can make investments in new technologies and new organizational forms which will support cleaner production. Meanwhile, concurrent adjustments will be occurring in response to more conventional market forces.

8.26 There is great scope in this area for research initiatives in expanded econometric modeling of industry responsiveness to changing relative prices, including medium-specific environmental prices imposed by regulators. However, econometric modeling alone is not likely to be sufficiently informative because it cannot convey a good understanding of the processes through which firms adapt to new circumstances. In this context, there will be no substitute for an expanded approach to industry case study work.

Research themes:

Sources of variation in industrial pollution

This project would be designed to inform policy makers about the broad strategic options for reducing industrial pollution. It would draw on an international sample of comparable plants in several subsectors for a cross-section study of industrial waste generation. The study would employ econometric analysis, supplemented by case studies, to gauge the relative importance of regulations
(by type), input prices, technology choice, ownership status, human resource quality, and infrastructure as determinants of waste generation.

**Dynamic analysis of industry response to environmental regulation**

This project would use econometric analysis of plant-level panel data, supplemented by specific plant-level case studies, to compare the dynamic efficiency of different pollution control instruments. The empirical work would focus on estimating the dynamic structure of industry response to quantitative end-of-pipe regulations, emissions charges, and changes in material input prices. The study would have at least three major goals: (1) Building a better understanding of the ways in which firms respond to changes in regulations and other variables which affect the profitability of pollution; (2) Testing the hypothesis that market-based instruments are superior to quantity-based instruments in promoting long-term pollution reduction; (3) Testing the hypothesis that firms with superior competitive capabilities also adopt pollution-reducing innovations more quickly and/or at lower cost. If the hypothesis is confirmed, there may be little dynamic conflict between environmental and industrial growth strategies. If the synergy is sufficiently great, in fact, the two strategies may be mutually reinforcing.

**Pollution prevention: the role of new technologies**

Faced with rapidly-rising disposal costs, firms in some pollution-intensive industries are now shifting from end-of-pipe pollution control to development of cleaner process technologies. This study would use sectoral data on trade and investment flows, coupled with case study information, to address four questions:

- What is the potential of these technologies for industrial pollution reduction in the 1990's?
- What would be the implications for international competition of their rapid adoption by OECD firms?
- How significant might imports of such technologies be for pollution reduction in new industrial economies?
- What policies would be appropriate for promoting the rapid diffusion of these technologies?

**Emissions disclosure, reputational risk, and pollution reduction**

Industrial firms in the U.S. are now subject to forced emissions audits whose results are published by the government; "eco-labeling" is growing rapidly in the U.S. and Western Europe. In the future, such information initiatives seem likely to increase firms' potential vulnerability, both to "cleaner" competitors in product markets and to legal action for pollution damage. There is some anecdotal evidence which suggests that such threats are proving more effective than classical regulation in moving heavily-polluting firms toward rapid waste reduction. On the positive side, imposition of mandatory emissions audits has eliminated cost penalties for firms which want to invest in integrating environmental planning with product and process development strategies. A study of this emerging phenomenon would have two objectives: (1) Measuring the independent impact of the new information initiatives on waste reduction in the OECD economies; (2) Assessing the benefits and costs of the open information model for LDC's.
Appropriate standards for "Eco-labeling"

Ideally, "eco-labeling" can serve as a useful adjunct to formal regulation by rating products according to their full estimated environmental impact—non-renewal resource inputs, process pollution, and disposability. Current trends suggest that eco-labeling will spread worldwide quite quickly, with significant influence on the purchasing decisions of middle- and high-income consumers in many economies. However, existing eco-labeling approaches are quite simplistic and potentially damaging for the market prospects of firms in NICs and LDCs. Particularly at risk are industries which are intensive in inputs from ecological "hot spots" like tropical forests, and those whose pollution levels are appropriate for their own countries but too high by current OECD standards. Research in this area should develop a careful critique of existing eco-labeling practices, recommendations for more appropriate ratings systems, and, if possible, a concrete application of the revised eco-labeling model.

2. Economic/environmental analysis of industrial systems

8.27 The point is now frequently made (e.g. Anderson (1990), Jimenez (1990)) that rapid progress toward pollution reduction requires an understanding of industrial systems as well as individual firms. This requires an expanded view of the industrial economy as a total input-output system whose aggregate interactions with the environment will change with the advent of high environmental prices: Recycling in some areas will grow rapidly; formerly polluting byproducts will become marketed intermediate inputs; patterns of cross-sector ownership and co-location will change; international patterns of comparative advantage, technology transfer, and trade flows may be significantly altered.

8.28 These very general patterns of industrial system response probably hold the greatest long-run hope for environmental improvement, and the range of relevant policy instruments differs from instruments which can be targeted at the micro-level. Indirect taxes, programs for promoting clean technologies, and new public information systems may play important roles. Their effectiveness in promoting rapid change will depend on a better understanding of response dynamics in the full industry/environmental system, with particular attention to its international dimensions.

Research themes:

Industrial pollution and the macroeconomy

While this paper has focused principally on the microeconomics of instrument choice for direct regulation, the cross-country survey in Part II suggests that differences in more general economic policies can have a very significant impact on industrial pollution. This project would attempt to develop a composite picture of industrial pollution in the macroeconomy from detailed case studies for a number of countries at varying stages of development. Variables of possible significance include exchange rates, taxes, interest rates, subsidies, investment codes, human resource and infrastructure investments, public enterprise policy, and institutional history.

Multi-level industrial pollution projection for economic/environmental policy-making

During the coming decade, policy makers in most developing countries will have to promote environmental improvement with very incomplete information about industrial emissions in their own economies. Their requirements are likely to include: (1) Detailed emissions accounting for cities and metropolitan regions, as a basis for establishing regulatory priorities; (2) extension of social accounting matrices and input/output models to incorporate emissions factors; (3) systematic consideration of the environmental implications of regional development plans; (4) projections of the environmental consequences as shifts in industrial structure are induced by changes in trade regimes; and (5) weighing the environmental consequences of alternative long-run industrialization strategies.
In many cases, such exercises will involve anticipating the environmental impacts of industrial activities which do not even exist locally. An applied research project should respond to this need by developing the best feasible approach to industrial pollution projection. The envisioned model would be capable of estimating industrial pollution at various levels of sectoral aggregation. It would integrate three basic elements: (1) detailed "benchmark" emissions parameters from large plant-level databases in the OECD economies; (2) adjustment of these parameters to conditions in different economies, using the results of exercises such as the previously-proposed cross-country study of variations in industrial pollution; (3) development of composite environmental impact measures which exploit the best available scientific information to assign risk weights to different pollutants.

Comparative advantage and environmental regulation

Optimal regulation of industrial pollution in developing countries will mean lower environmental standards for a variety of reasons. Great differences in enforced standards might significantly change relative production costs in many sectors, leading to new patterns of comparative advantage and, with time, evolution of the world economy toward new patterns of production location. Empirical research in this area would be directed toward answering three principal questions: (1) Given the current rapid diffusion of environmentalism, what will ultimately be the international range of differences in enforced environmental standards? (2) Are the projected differences likely to have a major impact on production location patterns? (3) Is there any evidence that disparities in environmental standards during the past two decades have led to a major shift in production locations? Although some analyses of investment and trade patterns have been attempted, there has been no recent, comprehensive analysis of this last question.

An interindustry model for "green tax" strategy

Taxes to discourage the use of a few polluting industrial inputs have great appeal in developing economies whose regulatory institutions are weakly developed. Such indirect ("green") taxation strategies may also contribute significantly to toxic pollution prevention in more complex industrial economies, but they will have to be based on detailed knowledge of input/output relations linking many materials, processes, and pollutants. An applied research project would initiate work in this area by constructing a prototype interindustry model, simulating its alteration during the development process, and discussing the apparent implications for dynamic development of green tax systems.

3. New regulatory models

Existing theoretical analyses of pollution control do not incorporate any systematic treatment of the performance and costs of the regulatory systems which support different instruments. Nor do they consider the possibility of important interactions between system characteristics and the performance of the instruments themselves. With rapidly spreading commitment to environmental regulation in developing countries, the study of appropriate regulatory models should have high priority. Since many new institutions are now in the formative stage, this is an appropriate time for detailed study of the cost and effectiveness of alternative regulatory instruments, monitoring systems, and enforcement practices which are now coming into place.

Research themes:

Integrated industrial pollution control policy

This paper has identified a broad range of pollution control policy instruments which are appropriate in different circumstances. The determining conditions are partly problem-specific and partly dependent on the resource endowments and policy regimes of particular countries. The proposed
study would be devoted to a much more concrete representation of the "fit" between circumstances and appropriate policy choices. It would focus on designing integrated industrial pollution control packages for a few prototype economies which reflected some of the geographic, ecological, economic, and institutional diversity of the Bank's client countries. While the study would bring to bear the best theoretical and empirical analysis available, its ultimate objective—moving the Bank toward consensus on industrial pollution control policy—would require that it be conducted in collaboration with other Bank staff from a variety of disciplines (e.g., engineering, ecology, law, management).

**Cross-medium pollution regulation**

This project would be an attempt to help newly-formed national EPA's avoid an emerging regulatory problem in the industrial world. As this paper has noted, pollution control in the OECD countries has suffered from the fragmentation of regulatory authority. One significant symptom of the problem is the rapid growth of toxic solid waste, much of it residual sludge from air and water cleanup. The objective of the study would be to lay the empirical foundations for coordinated cross-medium regulation. It would consider both the technical requirements of medium-specific control and actual cross-medium substitution possibilities available to firms in different industrial sectors.

**Monitoring and enforcement of pollution control systems:**

There is a common view that direct, or end-of-pipe (EOP), pollution control systems are generally inappropriate for developing countries because the associated monitoring and enforcement (ME) systems cannot perform properly. Since EOP systems can be quite effective in some cases, however, the evidence supporting this view should be carefully evaluated. This research project would focus critically on two hypotheses which support the critique of EOP approaches:

- **ME will not work in LDC's:** The OECD monitoring model, which depends heavily on firms' disclosure of their own emissions, checked by random audits, will not work in poor countries. Most firms will either fail to report, or grossly underestimate their actual pollution. If pollution controls imply even modest abatement costs, most firms will (successfully) opt for payoffs to ME agents. These assertions would be tested using a case-oriented survey of present ME experience in the OECD, NICs, and LDCs. The research would focus on notably successful and unsuccessful ME applications, with the objective of identifying the economic, institutional, and policy variables which have played determining roles.

- **Monitoring technologies are inappropriate for LDCs.** The only feasible monitoring systems have roughly "Leontief" (i.e., fixed-input-coefficient) technologies. Since they are intensive in factors which are scarce in LDCs—physical capital and technical skill—they are generally inappropriate. The research would begin with a counter-hypothesis: The range of feasible monitoring technologies is significantly broader than current industrial-country practice would suggest; significantly more labor-intensive approaches may be optimal for LDC's. The study would undertake a search for creative new approaches to monitoring in developing countries. It would also consider possible applications for emerging technologies in remote monitoring and sample testing.
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