THE LOCATION OF INDUSTRY AND POLLUTION CONTROL POLICIES:

A CASE STUDY OF SÃO PAULO, BRAZIL

Peter M. Townroe
(The University of East Anglia, Norwich, U.K.)

and

Vinod Thomas
(Urban and Regional Economics Division, The World Bank)

March, 1982

This paper was prepared under the auspices of the National Spatial Policies in Brazil Research Project (RP0672-13) as NSP Working Paper No. 8. The views reported here are those of the authors, and they should not be interpreted as reflecting the views of the World Bank or its affiliated organizations.

Urban and Regional Economics Division
Development Economics Department
Development Policy Staff
The World Bank
Washington, D.C.
A. Introduction

On occasion political leaders in newly industrialising nations have expressed the view that their country is not in a position to afford policies to control pollution, whether the pollution comes from households, from vehicles or from industrial plants. The need to keep industrial costs low and internationally competitive, and pressing requirements elsewhere for government expenditures, make governments reluctant to pay subsidies or develop controls to lower pollution levels. Even in high income countries, attack on pollution is of recent origin; and willingness to abate pollution is far from uniform between countries. The hesitation of governments in poorer nations is very understandable.

However, when public action is absent, sooner or later pollution levels become intolerable to the population at large, the electorate. Pollution moves from being an irritant to being a proven cause of ill-health and of damage to property. (Crocker, 1971; Herman, 1977; Lave and Seskin, 1977). This will normally occur first either in the center or in the key industrial areas of a nation's largest industrial city. The climate and geography of the city may accelerate the problem as the city continues to grow, both in population and income. Public awareness and the consequent political response will
eventually override industrial and commercial arguments and demand a control policy.

The form which this control policy should take, however, is not entirely clear. This is inspite of all the analytical attention pollution control has received in recent years. The first instinct of most economists is to recommend some form of "polluter-pay" principle to govern policy design, leaving it up to the individual polluting agency to determine how they will respond to a tariff of charges or fines. This tax would be based upon an identification of the trade-off between the marginal social benefit of any reduction in the pollutant and the full marginal social cost of achieving that reduction. The instinct of the economists, however logical and socially optimal in the abstract, has proven difficult to turn into practicable policy. For some forms of pollutant, the principle of marginality has been attacked as inappropriate. Elsewhere, knowledge is imperfect, markets do not work as anticipated, and the long term and short term costs and benefits seem to require different treatment. The administration of monitoring and enforcement is a major problem of bureaucratic design in itself. (Mills, 1978).

Given these problems, different countries have used different mixtures of fines and charges, standards and controls, and outright prohibitions for different sources of air and water pollution. This paper, using as a case study a city in a rapidly industrialising nation which has recently introduced a pollution control policy, considers just one aspect of the most appropriate form of pollution
control. It focuses on the effects of policy on manufacturing industry, which is only one source of air and water pollution, bringing out the interaction between pollution control and the locational distribution of industrial plants. Drawing on empirical evidence from Sao Paulo, it demonstrates the locational impact of one form of policy. It contributes to the policy choice issue of whether to offer subsidies to polluting industries to encourage relocation out of the urban core area.

The next section of the paper considers the impact of different forms of pollution control on the location both of existing and of new industrial plants in general terms. Different controls lead to different responses. As one would expect, the response depends upon the demand and supply elasticities of each product manufactured in the control area, and also, in the longer term, upon the costs of relocation and the relative costs of production in less polluted areas. A comparison is made between those policies which directly influence industrial location in order to reduce pollution and those which seek to control pollution and to indirectly influence industrial location.

Section C of the paper provides a brief portrait of Sao Paulo and its recent history of industrial growth. It demonstrates that a relative decentralization of population and employment growth has started to take place, and that the pollution control is potentially a new and significant factor encouraging industrial dispersal from the metropolitan area into the hinterland of the state. The section outlines the
magnitude of the pollution problem in São Paulo, in both air and water, and describes the policy measures introduced over the past seven years.

Section D draws upon a recent survey of companies in the manufacturing sector which chose a new plant location in the State of São Paulo between 1977 and 1979 to consider the extent to which the new pollution control policy was a contribution both to the decision to look for a new site and to the choice between possible alternatives. Section E examines the aggregate pattern of locations chosen for new plants in the same years, diagnosing by sector the extent to which the most polluting industries are avoiding the most polluted areas. The final part of the paper returns to the issue of the choice of instruments for pollution control policy.

B. The Effects of Pollution Controls on the Location of Industry

Depending upon the form in which they are introduced, controls on pollution emissions of industrial plants can have a number of possible consequences for the location of industrial investment. (Thomas et al 1981; Thomas, 1981). The imposition of a complete ban on new contributions to pollution in the air in a local area or in a local water source can only have the effect of diverting new investment to locations where such a ban is not in force, given that these alternative locations also provide cost and revenue conditions which allow minimum profit levels to be achieved. If not, the pollution control results in foregone investment, or a switch of investment into another line of economic activity. There is a presumption that the economic costs associated with such prohibitions are high, and the question becomes whether benefits from the environmental improvement
justify these costs. Clearly, non-economic benefits are also usually associated with such direct policies affecting industrial location. In the sub-section (i) below we elaborate on the direct policies on industrial location, which have indirect effects on pollution levels.

In most countries however, pollution controls do not take the form of complete prohibition of new pollutants. The controls normally take the form of specified physical standards to be achieved, either at the point of emission from the plant or in the receiving medium; or the controls involve a mechanism for imposing prices or charges which vary with the volumes or concentrations of polluting materials emitted. (Dewees, 1975; Baumol and Oates, 1979; Mills, 1978). The consequence here for the location of both new and existing industrial investments is more indirect. Some companies will be in a market situation in which the additional costs of meeting the controls can be met, with prices and outputs adjusting to new cost conditions. The controls effectively impose new costs, either capital and running costs of pollution control equipment (filters, purifiers, precipitators, and the like) or the costs of meeting the schedule of imposed charges. (Friedlaender, 1979). Even if these additional costs can be met, the controls clearly change the pattern of geographical advantage of alternative locations for a plant. An incentive is introduced to consider either locations outside the control area, or those locations where the standards or the charges are less demanding. There is a presumption that well conceived pollution standards can have net social benefits, in spite of their indirect effect on the location of industrial plants. The degree of locational impact under any such anti-pollution policy is discussed in section (ii) below. The locational impact of an anti-pollution policy depends upon its variation
across locations. Indeed, an optimal policy regime in an economic sense requires different pollution taxes for different communities where labor is mobile. (Berglas, 1977). Different policy strategies vary in their encouragement to industry to relocate. This point is brought out in subsection (iii) by considering three distinct approaches to pollution control.

(i) **Use of licensing restrictions to indirectly control pollution.**

Often direct restrictions are placed on locating new industry in certain areas. These indirectly lower (potential) pollution. The zoning and licensing policies for industries in metropolitan São Paulo belong to this category (EMPLASA, 1979; Pazzaglini and Greco, 1981). This indirect effect of controlling the quality of the environment may be intended as part of an overall pollution abatement strategy. Sometimes, the impact may be an unintended effect of an industrial location policy guided by other considerations.

A given environmental quality objective in an area can be met by setting direct controls on allowable emissions by industry or by controlling the volume of industrial output in that area. On pollution criteria alone, the welfare cost of these two approaches, however, can be quite different. In general, regulating output, being an indirect means to regulate emission, is likely to be a more costiy policy than directly restricting emission. The costs of these alternative means, however, would not be necessarily different if little or no possibilities exist in substituting away from polluting fuels and using control equipment. In such a case, the only way to lower emissions would be to cut down on production. There may also be circumstances where consequences
of further deterioration in quality are prohibitive. In such cases, rather than placing ridiculously high emission restrictions, it might be easier to prohibit further addition to output. And, furthermore, as noted previously, restriction of output in certain areas and induced relocation elsewhere may have certain benefits, other than those associated with pollution abatement.

(ii) The indirect locational impact of a pollution control standard

The spatial impact of any particular policy may be brought out by considering one industry located in two different regions. The existing distribution of output of X between locations A and B - with X in A and in B - is the result of both cost factors and demand considerations. Pollution restrictions or standards adopted on cost and benefit grounds change production costs - possibly differentially in A and B. In a long run equilibrium the net result could either be a displacement of part of the existing output from one location to the other, perhaps with an overall rise in average prices and so a fall in the combined output; or (closely related) a switch by some producers to new less polluting products. The result is accentuated if the policy distinguishes between new and existing productive capacity in the two areas, unless the new investment reduces costs by generating scale economies, allowing a margin for additional costs imposed by the pollution policy. For new investments, the impact of the policy is also influenced by expectations of future levels for standards or
charges. What may be sustainable for a new plant today may become unprofitably costly tomorrow, as new equipment and new treatment are required to meet higher standards.

Figure One: Spatial Effect of Differential Controls for the Same Industry in Two Locations

In Figure One, it is assumed that only firms in area A with a combined output $X_1$ face a pollution control policy. Such a differential treatment for the two locations could be optimal if area B containing $X_2$ suffers negligible damages. As a result of the restriction, $MC_1$ shifts to $MC'_1$ and output in location A falls from $X_1^*$ to $X_1^\prime$ as a first-order effect. This decline in output is the normal reaction of consumers' demand to a price increase. In addition, there could be
a second order effect: a change in price of $X_1$ with no change in price of $X_2$ can effect the market area of each. In Figure One, the second-order effect of the price differential between $X_1$ and $X_2$ created by pollution control is a leftward shift in the demand for $X_1$ from $D_{X_1}$ to $D'_{X_1}$ and a rightward shift in the demand for $X_2$ from $D_{X_2}$ to $D'_{X_2}$. The result is a further decline in the output in location A to $X'_1$ and an increase in location B to $X''_2$.

A number of factors govern the degree of the above type of relocation of production. In Figure One, the degree of differential treatment offered in locations A and B, the ability of $X_1$ to adapt to controls (i.e. the shift of $MC_1$), elasticities of $MC_1$ and $MC_2$, elasticities of $D_{X_1}$ and $D_{X_2}$, and the responses of $D_{X_1}$ to a change in the price differential between A and B, are all determinants of shift in output among the two locations.

In Figure One, output in A falls by $X'_1 X''_1$ and in B increases by $X'_2 X''_2$. Total Change in output $\Delta X$ is the sum of these changes, $X_1$ and $X_2$. According to Figure One

$$\frac{\Delta X}{\Delta S_1} = \left[ \frac{\Delta X_1}{\Delta S_1} \right] + \left[ \frac{\Delta X_2}{\Delta S_1} \right]$$

where $S_1$ is a required abatement of a pollutant for firms in area A.
\[
\frac{\Delta X}{\Delta S_1} = \left[ \frac{\Delta X_1}{\Delta MC_1} \frac{\Delta MC_1}{\Delta S_1} \right] + \left[ \frac{\Delta X_1}{\Delta P_1} \frac{\Delta P_1}{\Delta S_1} \right] + \left[ \frac{\Delta X_2}{\Delta P_1} \frac{\Delta P_1}{\Delta S_1} \right]
\]

(2)

The above equation may be approximated assuming linearity of the MC and \(D_X\) schedules in Figure One, in the range of small changes from equilibrium.

\[
\frac{\ddot{s}_1}{X} \frac{dX}{dS_1} = \left[ \frac{dX_1}{dMC_1} \frac{\ddot{s}_1}{X_1} \right] + \left[ \frac{dX_1}{dP_1} \frac{\ddot{s}_1}{X_1} \right] + \left[ \frac{dX_2}{dP_1} \frac{\ddot{s}_1}{X_2} \right]
\]

(3)

From Figure One, it is seen that:

\[
\frac{dX_1}{dMC_1} \frac{\ddot{s}_1}{X_1} = \frac{n_1}{1 + n_1/\varepsilon_1} \frac{dMC_1}{dS_1} \frac{\ddot{s}_1}{X_1}
\]

(4)

where \(n_1\) is price elasticity of demand (absolute value) and \(\varepsilon_1\) price elasticity of supply, of \(X_1\).

Similarly,

\[
\frac{dX_1}{dP_1} \frac{\ddot{s}_1}{X_1} = \frac{\varepsilon_1}{(n_1 + \varepsilon_1)} \frac{dX_1}{dP_1} \frac{\ddot{s}_1}{X_1}
\]

(5)

And
\[
\frac{dX_2}{dP_1} \frac{dP_1}{dS_1} \frac{S_1}{X_2} = \frac{\varepsilon_2}{(n^2 + \varepsilon_2)} \frac{dX_2}{dP_1} \frac{dP_1}{dS_1} \frac{S_1}{X_2}
\]

Where \(n_2\) and \(\varepsilon_2\) are absolute values respectively of the demand and supply elasticities of \(X_2\).

Substituting (4), (5) and (6) into (3),

\[
\gamma = \left[\frac{n_1}{(1+n_1/\varepsilon_1)} S_1 \right] + \left[\frac{\varepsilon_1}{(n_1 + \varepsilon_1)} S_1 \right] + \left[\frac{\varepsilon}{(n_2 + \varepsilon_2)} S_2 \right]
\]

where \(\gamma\) is elasticity of sums of output changes (absolute values) in A and B with respect to emission control in A, \(S_1\) elasticity of MC_1 with respect to \(S_1\); \(\beta_1, \beta_2\) elasticities of \(D_{X_1}\) and \(D_{X_2}\) respectively with respect to \(S_1\); and \(s_1\) and \(s_2\) shares respectively of \(X_1\) and \(X_2\) in \(X\).

Regulation of existing companies will of course influence the locational choices of new entrants into the industry and of net additions to capacity by those already there. When a new pollution control is introduced, a key issue is whether the new charges or standards will be made to apply to all existing industrial plants or only where investments are being made in new plants and equipment. Quick results in
improving the quality of the air and the water in a local area clearly
demand that the policy shall apply to all factories, old and new, with
a time allowance for existing units to purchase and install pollution
control machinery. Such a strategy, however desirable envi-
ronmentally, imposes an immediate competitive disadvantage on all
companies operating in the control area. Their costs have been raised
while the costs of their competitors elsewhere remain unchanged. If
the control area is a major manufacturing center, few governments will
be able to withstand the outcry from the owners and managers of the
affected plants. The governments of most smaller nations are also
acutely sensitive to anything that might impair the export competitive-
ness of their manufacturing sector.

Over time, a policy directed at new investments only will
cumulatively cover the stock of industrial plants in a control area.
Industrial plant and equipment wears out and becomes outmoded. Firms
have to replace that equipment to remain competitive. So over ten
years or so controls on the pollution emitting potential of new invest-
ments will effectively result in a very high percentage of the stock
of industrial processes in an area being covered by the policy, reducing
pollution levels below what they could otherwise be. To be successful,
this incrementalism does of course require a monitoring of good behavior
to ensure that standards are met (as the investments get older). A
pricing or charging policy based on actual emissions rather than on a
capacity to emit does effectively provide such a monitoring. A policy
of standards however requires a mechanism for policing.
Comparing spatial effects of alternative policies

The full spatial impact of alternative pollution control policies will vary according to the type and intensity of the policies applied to different locations. Chart One sets out the likely spatial effects - intended or unintended - of some approaches to emission control. Indicated are the directions of change under alternative policies; the degree of change would clearly depend as the intensity of controls and its differential between locations. Not shown in the chart is the policy with the most likely spatial effect - i.e. limiting output itself in certain regions.

Three policies are considered: (i) an optimal policy, setting maximum allowable emissions according to the net benefits of so doing in various places; (ii) a policy requiring a uniform percentage abatement on the part of pollution sources irrespective of their location; and (iii) a policy, setting the same maximum allowable emission in all places, thus equating the level of discharges spatially. In the particular example considered in Chart One, location A is assumed to contain large producers and B relatively smaller ones. Compared to B, A faces greater incremental damages from pollution, since it is more polluted and also more densely populated. Shown are possible spatial effects of applying each of the three above policies to this situation. Given the relative seriousness of the pollution problem in A, it is also worth considering the possibility under each of the policies that implementation occurs only in location A, with B being free to pollute.
Furthermore, often for administrative, political and sometimes economic reasons, potential new entrants are the targets of more stringent policies. Hence, Chart One also distinguishes possible differential stringency for existing and new sources under each of the policies.

In general, least spatial shifts are induced by a uniform abatement policy. If new sources are singled out in an anti-pollution policy, or if they face significantly stricter restrictions, the existing locational pattern among A and B tends to be frozen. If producers in A alone face restriction, however, relocation in B is encouraged depending on the policy's specification. In the present example, an optimal policy would normally require more abatement in A, thereby encouraging both some displacement of existing output from A to B and inducing new entrants into B. An extreme, but realistic possibility, is that an optimal policy concerns itself with only A, which may be a highly built up urban center, and sets no control in B which could represent a highly rural situation. Under an optimal policy new entrants would bear a heavier burden of cleaning up the air only if their control costs (economically as well as administratively) are less than existing ones. A uniform maximum emission policy requires relatively more smoke collection of larger polluters who are assumed to be located in A. Such an approach would be more stringent for A and thus may displace more output from A to B compared to the optimal policy, if pollution levels in A and B differ widely. The reason is that it is likely that as abatement is increased in A, incremental costs rise faster.
relative to incremental benefits such that maximum allowable emission in A may stop short of being equal to that in B under an optimal policy. A mitigating possibility is that if economies of scale in pollution control are significant, II and III may be closer to each other in their effects. If new entrants are discriminated against under III, the effect would generally be felt much more by potential larger producers in A and B. If the regulation applies only to A, the likely shift to B is increased.

In most instances, regulations are uniform across space, as for example, in the case of "process weight" standards in the US. New sources often (for example, in the US) face stricter standards which are also uniform spatially. As a result, incentives for relocation of output by industries are kept low, as discussed above. In Brazil, federal legislation seeks uniform air quality targets everywhere. If this were to be met in practice, inducement for relocation of output would be very great indeed. In reality, however, uniform abatement levels rather than uniform standards are enforced. Besides, most efforts are devoted to limiting pollution by new sources. This would have implied very little spatial adjustment of output, if it applied to all places. In fact, anti-pollution measures are effective only in certain areas, most importantly within the São Paulo metropolitan area. As a result, implicit emphasis is contained in the strategy to induce some output away from these places. Within metropolitan São Paulo, licensing policies contribute further to this effect. These policies may now be outlined in the next section.
C. Pollution in Metropolitan Sao Paulo

The population growth rate of the metropolitan area of Sao Paulo has slowed from 6.1 percent annually in the nineteen fifties to 4.4 percent annually in the nineteen seventies. However, even this slower rate of the past decade has been faster than that of the State of Sao Paulo as a whole (3.5%) and that of Brazil (2.8%). Gran Sao Paulo (GSP), the area of the city of Sao Paulo and its surrounding 36 municipalities, now (1980) has a population of 12.6 million. This is 50 percent of the state total, 10 percent of the national total; and up from 2.7 million in 1950. The growth of the GSP area has been fuelled by high rates of in-migration from elsewhere in Brazil and by high rates of natural increase. Behind it lies the growth of manufacturing industry.

Since the 1930s, GSP has grown to become the dominant center for manufacturing industry in Brazil. By 1970 the State of Sao Paulo accounted for some 36 percent of the net domestic product of the nation with only 19 percent of the national population. Forty nine percent of the net national industrial product was generated in the State and 48 percent of the country's industrial labor force was employed there. Per capita income within the state was more than twice the national average in 1970. Within the state, GSP provided 70 percent of the domestic product, 50 percent of the industrial establishments, 74 percent
of the industrial man power and 75 percent of the industrial value added. Within the metro area, activity has been particularly concentrated in the City of Sao Paulo (which had 76 percent of the industrial establishments in GSP in 1970), but it has now begun to spread well out into the surrounding districts.

Like other fast growing metropolitan areas in the world, GSP has suffered environmentally from the rapid growth of industry. Although the additions to the resident population and the rising numbers of road vehicles have been important sources of pollution, the prime source of environmental decline has been industrial activity. In many of the most densely populated and industrialized areas within GSP the quantity of effluents and discharges far exceeds the natural self-cleansing capacity of the environment. Air and water pollution by the mid-1970s, had reached levels which were not only unpleasant but which were directly harmful to both public health and to property.

Manufacturing and power generation account for 65 percent of particulate matter in air pollution in GSP, and for 18 percent of the hydro-carbon emissions. Industrial power generation yields 88 percent of the sulfur oxides and 24 percent of the nitrogen oxides. The industrial air pollution emissions are concentrated spatially, 9 municipalities in GSP accounting for about 95 percent of all emissions. They are also concentrated industrially. Just 284 enterprises yield 97.5 percent of particulate pollution for example. (Gianneschi et al, 1979).
The impact of these emissions has been monitored since 1976 by the State of Sao Paulo Environmental Protection Agency (Companhia de Tecnologia de Saneamento Ambiental - CETESB). This agency has been responsible for laying down standards which cover the major air pollutants. In 1978 the daily air quality standards were exceeded 299 times for carbon monoxide, 121 times for particulate matters and 17 times for sulfur dioxide. Light winds and temperature inversions exacerbate the problem. Increases in air pollution levels have been associated with increases in morbidity and mortality and with an increased incidence in respiratory and cardio-vascular diseases.

The situation with water pollution is no better. Only 36 percent of the population of GSP was connected to the sewage system in 1978. This system is grossly overloaded with only 5 percent of both domestic and industrial sewage undergoing primary treatment. The remaining 95 percent flows untreated into the sewage system and into storm water canals and nearby rivers and reservoirs. Industrial sewage accounts for 44 percent of the biochemical oxygen demand in local water bodies; and the toxic heavy metal concentrations are many times the international drinking water standard in many places. Many of the shallow wells used as sources of drinking water in GSP are contaminated. The health hazards from this pollution not only include the communicable diseases, such as hepatitis, typhoid fever, dysentry and meningitis, but also include carcinogenic and mutagenic effects from chemicals and toxic metals in supplies of drinking water.
Further details of present pollution levels are available elsewhere. (World Bank, 1980) The figures given above are enough however to suggest the need for urgent action to meet the growing problem. A policy response to pollution and environmental degradation has been slow in coming in Brazil. Pollution was seen as an inevitable if not desirable consequence of industrial growth, and growth came first. But attitudes changed as the problem became more acute. Legislation has now been introduced at the federal, state and municipal levels of government in GSP to try to reduce pollution levels. (CETESB, 1979).

**Federal Legislation:** Following the establishment in 1973 of the Special Secretariat of the Environment in the Ministry of Interior, legislation in 1975 provided the means to enforce pollution controls throughout the country. The weapons were to be either the restriction of fiscal incentives or the full suspension of production activities. The legislation delegated pollution control responsibilities to the states, recognizing the competence of both states and municipalities to set pollution standards and to apply sanctions; but reserving for the federal authorities the right to refuse to close down, on pollution control grounds, those activities deemed to be of great importance for the development and the national security of the country. (State industries remain largely free of state and municipal controls).
In 1976 the government issued regulations which classified the interior waters of the country, setting water quality standards for each class with permissible levels of industrial effluents. Further regulations set minimum air quality standards for the four main pollutants: particulates, sulfur dioxide, carbon monoxide and photochemical oxides.

A more direct influence of pollution legislation on the choice of new industrial locations came with Resolution No. 14 of 1978. This banned the granting of federal incentives to projects in GSP, except for special cases involving light industry. Projects in this category may be installed only if they are non-polluting, they depend upon their urban location, and they are proposed by small and medium sized Brazilian owned enterprises. This discrimination against GSP in the granting of incentives was reinforced in November 1980 by a federal government decision to limit payments for technological upgrading to only those companies in the GSP area which export at least 50 percent of their output and/or have a low net foreign exchange requirement. 1/

Further federal legislation came in July 1980 to permit states and municipios to zone land uses on pollution based criteria. In fact GSP was ahead of the federal government in this respect, as will be seen below.

1/ Foreign owned or controlled firms, which employ more than half of the industrial labor force in GSP, are not permitted to benefit from these incentives.
State Legislation: CETESB was established in the state of Sao Paulo out of an existing agency in 1975. In 1976 provision was made in state legislation for sanctions against violations of pollution standards; but the system of application of the standards was to be more elaborate than merely the threat of punishment. CETESB was given the power in 1977 to require that any new industrial investment, in old or new buildings, be previously sanctioned by two licenses: one before the investment is installed and a second before the machinery is brought into use. The investing enterprise pays a fee for the licence. If the enterprise does not comply, then it becomes liable for a fine and eventually for closure.

Legislation in 1976 by the state set out air and water quality standards. Water resources in the state were classified according to their potential use and uses of land affecting protected water could be controlled. All industrial discharges fell under requirements for treatment and pre-treatment. Air pollution was tackled by the definition of eleven "air quality control areas" in the state, corresponding to the administrative regions. Each area is classified as saturated or not for each of the main pollutants. Relocation of high polluting industry out of saturated areas is encouraged. Licences are only given to new investments in saturated areas if the resulting increase in pollution is very small.

Municipal Legislation: The Gran Sao Paulo area has by far and away the most severe pollution problems in cities within the state as well as among metropolitan areas across Brazil. Because of the severity
of its problems it has become the first area in Brazil to reinforce the federal pollution standards and the state investment licencing system with local pollution based land use controls.

Under a 1978 state law the Secretary for Metropolitan Affairs was given the responsibility for establishing objectives for industrial development in the GSP area and for setting out land use zones for industry. There are five categories of zone from "strictly industrial" to "non-industrial". The definition of the zones takes into account environmental factors as well as the availability of infrastructure and the spatial relationship of the areas to other land uses close by. Industries are divided into five classes, based on the size of the average plant and on likely environmental disturbance as well as on links with the local regional economy. The first class, which includes the production of iron, asphalt, sugar and cellulose, are high polluters and are prevented from opening new plants in all zones in the GSP area. The fifth class may open new plants in all zones. Class two is restricted to the first and second zone, class three to the first three zones, and class four to four of the five zones.

The 1978 law applies only to new plants or extensions of existing plants. It does not force or encourage existing non-conforming activities to relocate until re-investment in new equipment is undertaken by the company. Under the law, a company seeking a new location or an expansion of activities within the GSP area must obtain a license from the Secretary for Metropolitan Affairs. (This is in addition to
the two licenses required from CETESB). The terms of the licence set limits on the type and extent of polluting activities allowed. These limits are designed to ensure conformity with the air and water quality standards.

The land use zoning controls, operated at the municipal level, have been extended from the GSP area to the Paraiba Valley. However, as noted above, full authority for these controls was not granted by the federal government to state governments until July 1980. Following this new legislation, a zoning system, designating land uses to specific types of industry, is now being considered for the remainder of Sao Paulo. Municipios are developing local zoning ordinances, helped in some cases by the Urban Studies Division of the pollution control agency, CETESB; but these ordinances are directed more at local taxation requirements than land use control objectives.

The Operation of the Policy: The pollution control policy in Brazil is still in its infancy. Even in the metropolitan Sao Paulo area where the policy has been applied with most vigour to date, it is difficult to reach a judgement as to whether the policy is a success. What now exists in Sao Paulo, at the end of 1980, is a tried and operating system of pollution controls under a developed administrative and technical machinery. This machinery allowed the World Bank to make a loan of $58 million at the beginning of 1980 as a contribution towards a $187 million project for air and water pollution control to run through until 1983. This project complements a 1978 to 1984 $1.2 billion sewerage collection and treatment project in GSP, to which the World Bank has contributed a loan of $110 million.
The system of licensing by CETESB of all new industrial investments in both new and existing locations is now fully operative across the state of Sao Paulo. From the end of 1976 through to the end of 1979, over 10,000 installation licences were issued for new plants, expansion projects and residential developments. An additional weapon in forcing companies to obtain licences has been to link the obtaining of a licence before the state electricity company will connect the plant to the power grid. In issuing these licences, CETESB does not specify the pollution control equipment companies need to purchase. Any will do. Some firms develop their own. CETESB just measures the results, although it will offer advice about equipment suppliers.

The licensing system is directed at new investment. However, it was noted earlier that a relatively small number of industrial plants account for a very high percentage of industrial pollution emissions in GSP. The 1980 to 1983 pollution control project is directed primarily at these existing factories by offering credit to firms to assist them in installing pollution control equipment. The need for such a program became evident in the studies leading up to the sewerage treatment project. Successful treatment of sewage required a major increase in the pre-treatment of industrial waste and a reduction of toxic components before discharge into the sewerage system. Plants passing waste into the system would also need to be monitored.
The credit line of $187 million covers both air and water pollution and includes technical advice as well as loans for the purchase of control equipment. The air pollution control is aimed primarily at particulates and the water control is focusing on toxic wastes. The loans are designed to enable the plants to meet state and federal standards. Plants within the GSP area will be the chief qualifiers although there may be some projects elsewhere. The loans are at subsidized rates of interest, with the subsidy being larger for small and medium size enterprises.

In operation, the policy is meant to stress alternative approaches to industrial pollution control, i.e., not to accept automatically that treatment of existing discharges is the most cost effective or socially desirable method. Other alternatives for reducing emissions include cutting back on production, increasing engineering and combustion efficiencies, substituting alternative raw materials, recovery and recycling of material inputs, or relocating plants in an environment with greater capacity to assimilate the pollutants. Credit may be made available for this last alternative, relocation. This option would apply to only a minority of existing plants; and the amount of credit would be limited to the costs of establishing a plant of similar size and characteristics of the plant to be relocated, i.e. there would be no allowance for increased capacity or upgrading of the technology. The credit line is not available to new investments, already being controlled under the licencing system.
Because the pollution standards are uniform across the State, the costs to firms of meeting those standards will vary, depending upon the existing local pollution levels. Here air and water quality standards are rather different in their impact on industrial locations. Water pollution levels are measured in the effluent from the plant before it reaches the river. The control is therefore independent of the present quality of the river. Land use zoning, applied to new plants, is used to reflect the general quality of the river. Air quality on the other hand is measured in the area near a factory rather than in the smoke stack. The cost of reaching a given air quality standard therefore depends much more on existing conditions in the local area. And the monitoring of emissions depends more on complaints from local residents (there is a "hot line" phone in CETESB). Liquid effluent may be monitored more mechanically.

The pollution control policy has been in operation long enough in the GSP area for us to expect that it has had a significant impact on the choice of new industrial locations. We may begin to reach a judgement on that impact by comparing the spatial pattern of new plant locations before and after the introduction of the policy, remembering of course that other things have not remained constant, in particular the pattern of land prices. The judgement reached on the basis of analysis of secondary data may then be sharpened by consideration of replies given by 600 new plant locators to questions on push and pull factors in their choice of sites for a new factory.
D. The Pollution Policy and Industrial Locational Choice

Without undertaking a special survey of industrial plants in and around the Sao Paulo metropolitan area, or having access to the detail of the files of CETESB, the pollution licensing agency, we may provide a preliminary assessment of the impact of the new industrial pollution control policy using information from two sources. One is the summary data on the size, location and sector of pollution licences issued in the three years 1977, 1978 and 1979. These figures are made available by CETESB and may be compared with statistics on industrial growth in each local government jurisdiction from the Industrial Census of 1970 and 1975. This comparison will be made in the next section of the paper. Here we use information from a questionnaire administered in an interview survey of 581 companies establishing industrial plants at new locations in the state of Sao Paulo between 1977 and 1979.

The 1980 Sao Paulo Industrial Location Survey was funded jointly by the Urban and Regional Economics Division of the World Bank and the Secretary of the Interior of the State government of Sao Paulo. A weighted sample of 600 plants was drawn from the 1961 firms opening new manufacturing units, which employed more than 10 people, in the State, 1977-79. The weighting favored the larger units and the units locating outside the Sao Paulo metropolitan area. The survey was administered between August and November 1980 under the supervision of the Institute for Economic Studies of the University of Sao Paulo. The discussion here uses just one small part of the long questionnaire, satisfactorily returned from 581 interviews. (Townroe, 1981)
The firms in the survey were asked individually about the importance of 38 possible factors entering into their choice of a new location. On a weighted basis only 13 (9 births and 4 transfer moves) firms said that the pollution control policy was other than unimportant in their choice of a new location. It seems that the pollution control policy as presently operated in São Paulo does not attract industrial plants to new locations. It does, however, encourage a significant minority of the firms involved to search for a new location in the first place (rather than expanding in-situ or acquiring new capacity by a take-over, introducing shift work, or using existing space more intensively).

302 (or 22%) of the 1373 (16 non-respondents - weighted totals) transfer and branch plant moves agreed that the pollution control policy was of "little" or "major" importance or it was a "decisive factor" as a factor encouraging the search for a new location. The births in the survey, having a destination but no origin in the sense used here, are omitted from these totals. Table One shows the pattern of these responses for the transfer moves and the branch plant moves separately; each in turn divided into those moving from destinations in the inner (continuously built up) part of the metropolitan area, and those moving from destinations elsewhere in the State. The expectation here was that the pollution control would be likely to have a greater impact on firms moving out of the most polluted areas than those moving from elsewhere. The expectation was fulfilled for transfer moves but not for the branch plants, in comparing those moving from origins in the
inner metropolitan areas with those moving from origins elsewhere in the state. Overall, pollution controls were a decisive push factor for 110 of the firms, on a weighted basis. The controls were relatively more than twice as important for the transfer moves overall as for the branch plant moves, as summarized in the final column of Table Two.

It might be expected that the pollution control would not only encourage plants with pollution problems to move away from the most polluted areas within the conurbation area but also to move to relatively unpolluted areas. This pattern of movement is only partially confirmed in Table Two. The transfers and branches in the survey have been divided into four groups. The first group, the 'Across City' moves, are those moving within the municipality of Sao Paulo, or within the other municipalities of the inner metro area, or from these other municipalities across the boundary into the control municipality. The second group, the 'suburbanising' moves, are those moving out, from the city of Sao Paulo to the other municipalities of the inner metro area. The third group, the 'exurbanising' moves, are moving out from this inner metro area to other destinations in the state. They are decentralizers. The final group are moves between locations outside the inner metro area. Table Two shows how the third group is the one most influenced by the pollution control policy, followed by the second group. But there is no clear pattern of those moves from the inner metro area which says that the policy was a factor encouraging movement out of the area. The firms in the survey also asked if they could name a single decisive factor encouraging them to move. Only two thirds did so. Four percent said "Pressure from the
pollution control agency"; 7 percent of the suburbanising group, 5 percent of the exurbanising group, and 2 percent of the 'other moves' group. None in the Across City group.

There are two other ways to consider this possible link between origins and destinations for firms citing the pollution control on a push factor. One is to see if there is a distance decay effect moving away from the metro center of plants citing this factor. No such effect is found, except that the firms in the group saying that the factor was 'decisive' move to destinations further on average from the center than either the groups saying the factor was of little or major importance, or those saying it was unimportant. A second way is to examine the destinations of the 219 firms (of the 302) citing the pollution control as a factor of some importance which had an origin within the city of Sao Paulo, the central municipality. 19 of these remained within the city boundaries. 118 went to destinations within the inner metro area: 42 to Diadema, 32 to Guarulhos, 20 to Sao Bernardo do Campo (all heavily polluted industrial suburbs) and 24 to 5 other suburban municipalities. It does therefore seem as if heavily polluting plants which are not acceptable at one heavily polluted location (perhaps new residential areas) are acceptable at other heavily polluted locations in preference to other lightly polluted suburbs or hinterland towns. This does not point to the pollution control policy being a very active force promoting decentralization right out of the metropolitan area. Only 27 of the 219 Sao Paulo based units referred to went to new sites outside the total metropolitan area, 58 going to sites in the outer metro area. Of this 58, 18 went to Itaquaquecetuba, 9 to Mairipora, 9 to Mogidas Cruzes, 9 to Cotia and 7 to Caieiras: all municipalities with medium to high levels of industrial pollution.
The spatial pattern of movement of these pollution sensitive firms is of course influenced by many other factors than the pollution control policy. One key influence is the nature of the product and the process of the firms. Table Three shows that the chemicals, textiles and "other metal working" sectors contained relatively high proportions of firms citing the pollution control policy as a push factor. We may take these industrial differences further in the next section, testing to see whether in the period since the policy was introduced, new plants in these sensitive sectors are less likely to be located in the most polluted areas than was the case before the policy was introduced.

E. Industrial Growth in Heavily Polluted Areas

Monitoring of air pollution by CETESB in the metropolitan area through 1977 demonstrated that just four two digit sectors of manufacturing industry combined to account for a very high proportion of the total emissions. This is shown in Table Four. The pollution is generated both by industrial processes and by stationary final combustion. Comparable figures for water pollution are not available. In the overall air pollution totals (not shown here), vehicles are also very important. They account for 7 percent of the particulates, 9 percent of the sulfur dioxide, 94 percent of the carbon monoxide, 73 percent of the nitrogen oxide, and 72 percent of the hydrocarbons. A successful policy for industrial air pollution will therefore tackle only part of the overall social cost of pollution. Over 80 percent of the particulates however come from industrial plants and these are the most visible pollutants to the general public.
The areas CETESB has defined as "critical" in terms of air pollution levels lie at the metropolitan area. Although the boundaries are not exactly coterminous, this critical area closely corresponds to the seven central municipalities: the city of Sao Paulo, Santo Andre, Sao Bernardo de Campo, Sao Caetano do Sul, Diademan, Mana, and Osasco. These are the most heavily industrialized parts of the metro area. Together they accounted for percent of the plants in manufacturing in Greater Sao Paulo in 1975, and percent of the employment in manufacturing.

The pollution control policy was introduced between 1975 and 1976. If there was an immediate effect, we would expect to see it reflected in the pattern of industrial growth in the few industrial sectors of Table Four in the seven municipalities listed above. Information from the licensing policy for new industrial plants (not expansions) operated by CETESB between 1977 and 1979 shows that new plants in both new and existing buildings were established in most of the seven municipalities listed by companies in the far most polluting sectors. The new policy clearly did not shut off the development of these sectors in these areas. However, on inspection, the number of new plants did seem low relative to the spatial distribution of the sectors revealed in the 1975 Industrial Census, and the pattern of growth in the 1970-75 period. Was the new policy therefore having a restraining influence?

One way to judge the extent to which new plants are being established in the areas and sectors concerned move slowly in the latter period compared with the former is to estimate an expected number on the
basis of some constant share or growth criterion. Table Five shows the results of using six different such criteria, together with the actual number of new plants and additional employees between 1977 and 1979.

The bases for the expected values were:-

(i) Application of the national growth rate in production in the given sector 1977 to 1979 to the 1975 base of the number of plants and employees in the sector in each municipality.

(ii) As (i), but using the state of Sao Paulo growth rate in production. (This was slightly lower in chemicals, and slightly higher in the other three sectors than the national rate).

(iii) Allocating shares of the 1977-79 state totals for new plants and additional employees by the percentages in each municipality of the 1970-75 growth in the sector.

(iv) As (iii), but by the 1975 distribution of the state totals between the areas.

(v) Follows (iii), but using the 1977-79 totals for Greater Sao Paulo only, shared on the 1970-75 growth.

(vi) Following (iv) and (v), using Greater Sao Paulo totals shared on the 1975 distribution.

There are some negative figures in Table Five under criteria (iii) and (v), indicating a contraction of activity in the 1970-75 period, predating the pollution control policy. These occur principally in the textiles sector, for which the relative advantages of locations outside Greater Sao Paulo had been improving since the mid-sixties. Leaving
aside the negative figures, in the 28 areas x sector cells in only 5 were the expected figures on any of the six criteria lower than the actual figures for the number of plants. (Three of these were in Diadema). For employment, this was true in only 6 of the cells of the Table. In the city of Sao Paulo in particular the actual numbers were way below the expected values. While it is obviously true that the differences may reflect many other causal factors than the pollution policy (rising land and property prices and rents, increasing congestion, difficulties with utilities, some scarcity of skilled labor, etc.), the turnaround between the two periods is striking.

There are a number of problems with the procedure used here to generate the expected values. Because it is taken from the results of two Industrial Census, the 1970 to 1975 growth is a net change in plants and employment, whereas the 1977 to 79 figure is a gross change. If there is a high birth rate and death rate of plants, the second figure would show an increasing share of growth when this may not be the case. However, this problem would reduce the actual to expected difference, not increase it. Although a gross figure, the 1977 to 79 additions do include new firms going into old or existing buildings, not therefore adding to the total stock of plants. They do not include in situ expansions. This may bias the employment figures. The employment figures for the latter period are estimates, of "planned" employment, by the firm applying for the investment licence. It is likely if anything to be an overestimate, given the relative slow down of the rate of growth of the Brazilian economy in the second half of the seventies relative to the first.
Calculation of expected values for Greater Sao Paulo as a whole provides some reassurance that the estimates are not degrees of magnitude out of line. Methods (iii) and (iv) in particular give good approximation of the actual, (the textiles employment estimate by method (iii) being a significant exception). The values for Greater Sao Paulo do however suggest a redistribution of these four sectors away from the seven listed municipalities to the remaining 31 municipalities of the greater metropolitan area, rather than to areas outside, in the hinterland of the state. The proportion of the state total of new plants locating in Greater Sao Paulo 1977-79 closely follows the 1975 distribution. Across the four sectors, in terms of number of plants (1975 first) the percentages go: 33.8, 29.0; 68.3, 88.4; 59.1, 62.6; and 56.6, 53.9. In terms of the employees the two percentage shares in each sector are (1975 first again): 55.2, 47.7; 78.2, 71.5; 63.6, 64.8; and 56.5, 42.9. Textiles is the sector which shows a marked drop in the metro area share in the second period.

F. Conclusions

This paper has made a small contribution to the issue of subsidizing or forcing firms to relocate to mitigate pollution damage from emissions from those firms by analyzing and illustrating the impact of such policies. The issue is complicated by the non-pollution related social costs and benefits of firm relocation. In very large metropolitan areas there is frequently an assumption that more industrial decentralization is a good thing, and in many countries this assumption has been translated into a set of relevant policy instruments. Both the need
for and the effectiveness of these policy instruments in economic terms still remains an open question in most of these countries. The relative weighting of pollution benefits is therefore difficult to establish.

The São Paulo experience demonstrates that the introduction of a fairly strict and discriminatory industrial pollution policy may be expected to have fairly immediate spatial consequences on the geographical pattern of industrial growth, even though very few industrial managers recognize the policy as an important factor leading them to consider a new location, and even fewer cited the policy as an influence on their choice between alternative new locations. In this paper we have not been able to fully quantify the responses of firm locations to policies, although the earlier parts of the paper set out key factors affecting the magnitudes. The paper has also shown the overall output of industrial pollutants is dominated by very few sectors and plants. The arguments for a discriminatory policy are therefore very strong on both theoretical and administrative grounds. Within an administrative area like metro São Paulo there are also strong arguments for discrimination by area between polluters. Any such discrimination on benefit grounds has of course to be justified politically and/or in the courts for the differential burden that is placed on the costs of competing firms.

Balance of payments problems and a slow down in the rate of industrial growth have led to something of a slow down in the enthusiasm with which the industrial pollution policy is being prosecuted in Brazil.
The threat of closing down a plant which fails to meet standards has yet to be followed through upon in São Paulo. The policy is therefore working much more effectively for new plants than it is for old units. Now, two new major pollution issues in the state arise from the efforts the federal government is making to move Brazil away from its dependence upon imported oil. Firstly, the complete population of road vehicles is being moved from the use of gasoline and diesel as fuels to alcohol, manufactured from sugar cane. Unfortunately, each litre of fuel alcohol produces 18 litres of organically polluted water as a byproduct in its manufacture. Secondly, Brazil's reserves of coal, although large, are of low calorific value, producing large amounts of ash and sulfur dioxide when burnt. Although this new air pollution will be partly offset by the reduction in particulates and hydrocarbons from vehicle emissions in the switch to alcohol, both policies are presenting new problems for the administration of the pollution control legislation.
Table One: Pollution Controls as a Factor Encouraging Industrial Mobility, by Plant Type and Origin (percentages)

<table>
<thead>
<tr>
<th>Questionnaire Responses</th>
<th>Transfer Moves (2)</th>
<th>Branch Plants (1)</th>
<th>Total (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inner Metro Area</td>
<td>Inner Rest of State</td>
<td></td>
</tr>
<tr>
<td>&quot;No Importance&quot;</td>
<td>73</td>
<td>92</td>
<td>77</td>
</tr>
<tr>
<td>&quot;Little Importance&quot;</td>
<td>13</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>&quot;Major Importance&quot;</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>&quot;A Decisive Importance&quot;</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Total firms in weighted sample (= 100)</td>
<td>872</td>
<td>237</td>
<td>1108</td>
</tr>
<tr>
<td></td>
<td>190</td>
<td>50</td>
<td>240</td>
</tr>
</tbody>
</table>

(1) 16 no responses.
(2) For definition of these groups, see text.

SOURCE: 1980 Survey
Table Two: Pollution Controls as a Factor Encouraging Industrial Mobility, by Origin/Destination Group for Transfers (=T) and Branches (=B) (percentages)

<table>
<thead>
<tr>
<th>Questionnaire Responses</th>
<th>Across (1)</th>
<th>Suburban-ising</th>
<th>Exurban-ising</th>
<th>Other Moves in State</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City</td>
<td>T</td>
<td>B</td>
<td>T</td>
<td>B</td>
</tr>
<tr>
<td>&quot;No Importance&quot;</td>
<td>81 100</td>
<td>70</td>
<td>82</td>
<td>69</td>
<td>(63)</td>
</tr>
<tr>
<td>&quot;Little Importance&quot;</td>
<td>10 -</td>
<td>14</td>
<td>-</td>
<td>13</td>
<td>(9 )</td>
</tr>
<tr>
<td>&quot;Major Importance&quot;</td>
<td>4 -</td>
<td>6</td>
<td>-</td>
<td>2</td>
<td>(15)</td>
</tr>
<tr>
<td>&quot;A Decisive Importance&quot;</td>
<td>5 -</td>
<td>9</td>
<td>18</td>
<td>16</td>
<td>(13)</td>
</tr>
</tbody>
</table>

Total firms in weighted sample (= 100)

277 158 427 52 172 27 198 63 1074 299 (2)

(1) For definition of these groups, see text.
(2) 16 no responses.

SOURCE: 1980 Survey
Table Three: Pollution Controls as a Factor Encouraging Industrial Mobility, by Industrial Sector

<table>
<thead>
<tr>
<th>Sector Description</th>
<th>I.P.I 2-Digit Code</th>
<th>&quot;No Importance&quot;</th>
<th>&quot;Little Importance&quot;</th>
<th>&quot;Major Importance&quot;</th>
<th>&quot;Decisive Factor&quot;</th>
<th>Total (n=100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural and mineral products</td>
<td>0-27, 68-70</td>
<td>76</td>
<td>12</td>
<td>1</td>
<td>12</td>
<td>140</td>
</tr>
<tr>
<td>Chemicals, including pharmaceuticals</td>
<td>28-38</td>
<td>41</td>
<td>24</td>
<td>9</td>
<td>26</td>
<td>110</td>
</tr>
<tr>
<td>Plastics and rubber</td>
<td>39-40</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td>118</td>
</tr>
<tr>
<td>Textiles</td>
<td>50-60</td>
<td>65</td>
<td>9</td>
<td>16</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>Clothing and leather goods</td>
<td>41-43, 61-67</td>
<td>98</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>86</td>
</tr>
<tr>
<td>Iron and steel including iron foundries</td>
<td>73</td>
<td>82</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>167</td>
</tr>
<tr>
<td>Other metal working</td>
<td>74-83</td>
<td>59</td>
<td>12</td>
<td>7</td>
<td>22</td>
<td>93</td>
</tr>
<tr>
<td>Machinery, apparatus and instruments</td>
<td>84</td>
<td>70</td>
<td>20</td>
<td>4</td>
<td>5</td>
<td>173</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>85, 90-93</td>
<td>83</td>
<td>1</td>
<td>5</td>
<td>11</td>
<td>166</td>
</tr>
<tr>
<td>Transport products</td>
<td>86-89</td>
<td>96</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>107</td>
</tr>
<tr>
<td>Other, to include wood and paper, furniture, toys, printing</td>
<td>44-49, 71-72, 94-98</td>
<td>92</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>148</td>
</tr>
<tr>
<td>All Sectors</td>
<td>78</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>1373</td>
<td></td>
</tr>
</tbody>
</table>

SOURCE: 1980 Survey
<table>
<thead>
<tr>
<th>Sectors</th>
<th>Pariculates</th>
<th>Sulfur Dioxide</th>
<th>Carbon Monoxide</th>
<th>Nitrogen Oxide</th>
<th>Hydrocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallurgy</td>
<td>17</td>
<td>22</td>
<td>76</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Non-metallic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minerals</td>
<td>48</td>
<td>18</td>
<td>1</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Chemicals</td>
<td>18</td>
<td>19</td>
<td>1</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Textiles</td>
<td>1</td>
<td>17</td>
<td>1</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>24</td>
<td>21</td>
<td>31</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total (=100%)</strong></td>
<td><strong>376</strong></td>
<td><strong>835</strong></td>
<td><strong>153</strong></td>
<td><strong>85</strong></td>
<td><strong>140</strong></td>
</tr>
</tbody>
</table>

*Source: CETESB*
<table>
<thead>
<tr>
<th>Local Government Areas</th>
<th>Non-Metallic Minerals</th>
<th>Metallurgy</th>
<th>Chemicals</th>
<th>Textiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plants</td>
<td>Employees</td>
<td>Plants</td>
<td>Employees</td>
</tr>
<tr>
<td><strong>City of Sao Paulo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>302</td>
<td>52</td>
<td>3636</td>
<td>7</td>
</tr>
<tr>
<td>Expected 1</td>
<td>1064</td>
<td>192</td>
<td>20238</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>124</td>
<td>21</td>
<td>17756</td>
<td>47</td>
</tr>
<tr>
<td>3</td>
<td>153</td>
<td>25</td>
<td>15067</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>77</td>
<td>1307</td>
<td>106</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>87</td>
<td>19929</td>
<td>78</td>
</tr>
<tr>
<td>6</td>
<td>77</td>
<td>112</td>
<td>18120</td>
<td>112</td>
</tr>
<tr>
<td><strong>Santo Andre</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>0</td>
<td>0</td>
<td>58</td>
<td>1</td>
</tr>
<tr>
<td>Expected 1</td>
<td>6</td>
<td>92</td>
<td>31</td>
<td>1977</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>108</td>
<td>43</td>
<td>2714</td>
</tr>
<tr>
<td>3</td>
<td>-3</td>
<td>-2</td>
<td>-44</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>71</td>
<td>101</td>
<td>1961</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>-19</td>
<td>113</td>
<td>744</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>63</td>
<td>131</td>
<td>1775</td>
</tr>
<tr>
<td><strong>Sao Bernardo do Campo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>188</td>
<td>17</td>
<td>1304</td>
<td>5</td>
</tr>
<tr>
<td>Expected 1</td>
<td>9</td>
<td>31</td>
<td>3128</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>31</td>
<td>4295</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
<td>121</td>
<td>4842</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>264</td>
<td>577</td>
<td>2041</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>158</td>
<td>6609</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>233</td>
<td>95</td>
<td>2805</td>
</tr>
<tr>
<td><strong>Sao Caetano do Sul</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>202</td>
</tr>
<tr>
<td>Expected 1</td>
<td>4</td>
<td>604</td>
<td>18</td>
<td>1320</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>706</td>
<td>24</td>
<td>1688</td>
</tr>
<tr>
<td>3</td>
<td>-8</td>
<td>-142</td>
<td>67</td>
<td>520</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>457</td>
<td>57</td>
<td>1201</td>
</tr>
<tr>
<td>5</td>
<td>-2</td>
<td>-141</td>
<td>86</td>
<td>515</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>197</td>
<td>74</td>
<td>1088</td>
</tr>
<tr>
<td><strong>Diadema</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>3</td>
<td>34</td>
<td>44</td>
<td>5240</td>
</tr>
<tr>
<td>Expected 1</td>
<td>4</td>
<td>346</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>604</td>
<td>6</td>
<td>640</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>173</td>
<td>24</td>
<td>600</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>264</td>
<td>7</td>
<td>320</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>170</td>
<td>10</td>
<td>573</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>128</td>
<td>21</td>
<td>286</td>
</tr>
<tr>
<td><strong>Maua</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>Expected 1</td>
<td>4</td>
<td>346</td>
<td>5</td>
<td>322</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>604</td>
<td>6</td>
<td>640</td>
</tr>
<tr>
<td>3</td>
<td>48</td>
<td>173</td>
<td>24</td>
<td>600</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>264</td>
<td>7</td>
<td>320</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>170</td>
<td>10</td>
<td>573</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>128</td>
<td>21</td>
<td>286</td>
</tr>
<tr>
<td><strong>Osasco</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>3192</td>
</tr>
<tr>
<td>Expected 1</td>
<td>4</td>
<td>260</td>
<td>11</td>
<td>884</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>303</td>
<td>15</td>
<td>1213</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>508</td>
<td>67</td>
<td>1212</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>203</td>
<td>34</td>
<td>880</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>504</td>
<td>62</td>
<td>1088</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>170</td>
<td>45</td>
<td>802</td>
</tr>
<tr>
<td><strong>Greater Sao Paulo</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td>185</td>
<td>4846</td>
<td>2973</td>
<td>28624</td>
</tr>
<tr>
<td>Expected 1</td>
<td>256</td>
<td>7336</td>
<td>713</td>
<td>31996</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>8580</td>
<td>980</td>
<td>43928</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>4906</td>
<td>2248</td>
<td>20894</td>
</tr>
<tr>
<td>4</td>
<td>215</td>
<td>5607</td>
<td>2298</td>
<td>31495</td>
</tr>
</tbody>
</table>
Bibliography


DEWEES, D.N., C.K. EVERSON and W.A. SIMS (1975), *Economic Analysis of Environmental Policies*, University of Toronto Press, Toronto.


THOMAS, V., A.E. Comune and V. Faiva (1981), "Air Pollution Control in São Paulo", *FIPE, University of São Paulo, São Paulo, Brazil.*

Annex: The Marginal cost criterion and Pollution control in two regions

Encouraging existing pollutors to relocate to environments which are unsaturated is one way of increasing the assimilative capacity of the natural environment of a region or a nation. An individual polluter who faces an effluent change or standard based on total waste discharge alone will continue to discharge into the previous medium, albeit at a lower level than before the policy. The stringency of the standard or the charge may be able to be lowered, if one or few dominant polluters are subsidized to fully relocate their operations, taking advantage of an environmental assimilation capacity elsewhere. From society's point of view there may be a net advantage.

Consider the objective of an environmental protection authority to minimize the social costs of pollution in a river or an air quality area. The goal is to maximize

\[ \text{NB} = B - C \]

where NB is the net social benefit, B is the social benefit of the improved environmental quality and C is the total cost of the control.

The pollution control authority knows the following relationships:

\[ B = B(Q) \]
\[ Q = Q(e,r) \]
\[ C = C_e(e) + C_r(r) \]

(i)
where $Q$ is the present air or water quality and is a function of the firm's emissions $e$, and of the emissions of other firms $r$. $C_e$ is the total cost of abating emissions of the firm to emission rate $e$, and $C_r$ is the total cost of relocating activity to hold other emissions to $r$.

The system is optimised by maximising

$$NB = B[Q(e,r)] - C_e(e) - C_r(r)$$

Giving the first order cooditions

$$\frac{dB}{dQ} \frac{\partial Q}{\partial e} = \frac{dC_e}{de}$$

$$\frac{dB}{dQ} \frac{\partial Q}{\partial r} = \frac{dC_r}{dr}$$

These indicate that: (i) the marginal benefit of reducing emissions to level $e$ must equal the marginal cost of reducing emissions, and (ii) the marginal benefit of relocating other firms must equal the marginal costs involved.

Now since,

$$\frac{dB}{dQ} = \frac{dC_e}{de} / \frac{\partial Q}{\partial e} = \frac{dC_r}{dr} / \frac{\partial Q}{\partial r}$$

then the relocation cost (or subsidy) can be raised at the margin until it equals the cost of reducing emissions at the firm.

This result ignores however, the impact of relocation on the hinterland region. It assumes that pollution levels in the hinterland are below the proscribed standard.
To include the effects on the other region, we assume that the pollution control authority knows

\[ B_M = B_M(Q_M) \]
\[ B_H = B_H(Q_H) \]

where \( B_M \) is the benefit of environmental quality \( Q_M \) in the metro area
and \( B_H \) is the benefit of environmental quality \( Q_H \) in the hinterland area.

and

\[ Q_M = Q_M(e,r) \]
\[ Q_H = Q_H(e,r) \]

where \( e \) is the emission from the firm and \( r \) is the output moved of other firms.

and

\[ C = C(e,p) \]

where \( C \) is the cost of the overall policy.

Our maximand is the sum of the benefits of lower pollution in both regions minus the costs of the policy.

\[ NB = B_M [Q_M(e,p)] + B_H [Q_H(e,p)] - C(e,p) \]

Giving

\[ \frac{d B_M}{d Q_M} \frac{\partial Q_M}{\partial e} + \frac{d B_H}{d Q_H} \frac{\partial Q_H}{\partial e} = \frac{\partial C}{\partial e} \]
\[ \frac{d B_M}{d Q_M} \frac{\partial Q_M}{\partial r} + \frac{d B_H}{d Q_H} \frac{\partial Q_H}{\partial r} = \frac{\partial C}{\partial r} \]
Maximum net benefits come therefore when the combined marginal benefits for both regions of a movement in production and the combined marginal benefits for both regions of a decline in emissions equal the marginal cost of doing so. The first condition here gives an optimal effluent charge by the authority but for the most efficient solution, the second condition must also be simultaneously fulfilled.

In general,

\[
\frac{\partial Q_M}{\partial r} > 0, \quad \frac{\partial Q_H}{\partial r} < 0, \quad \frac{\partial Q_M}{\partial e} < 0, \quad \text{and} \quad \frac{\partial Q_H}{\partial e} < 0
\]

Further, the magnitudes of \( \frac{\partial Q_M}{\partial e} \) and \( \frac{\partial Q_H}{\partial e} \) are affected by \( r \).

So,

\[
\frac{d B_H}{d Q_H} \frac{\partial Q_H}{\partial r}
\]

conditions may be rewritten as

\[
\frac{d B_M}{d Q_M} = \left( \frac{\partial C}{\partial e} \cdot \frac{d B_H}{d Q} \cdot \frac{\partial Q_H}{\partial e} \right) / \frac{\partial Q_M}{\partial e}
\]

\[
= \left( \frac{\partial C}{\partial e} - \frac{d B_H}{d Q_H} \cdot \frac{\partial Q_H}{\partial r} \right) / \frac{\partial Q_M}{\partial r}
\]

This implies that relocation expenditures should be increased until the incremental cost of improving environmental quality in the metropolitan area in this way, including damages in the hinterland, equals the incremental cost, including benefits in the hinterland (if any), of improving the environment of the metropolitan area by reducing emissions at the polluting firm. These relocation expenditures must also simultaneously equal the incremental benefits of improving environmental quality in the metropolitan area.