NBER WORKING PAPERS SERIES

ENVIRONMENTAL IMPACTS OF A NORTH AMERICAN FREE TRADE AGREEMENT

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Working Paper No. 3914

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
November 1991

This paper was prepared for the conference on the U.S.- Mexico Free Trade Agreement, sponsored by SECOFI. We are grateful to the Industrial Relations Section and International Finance Section of Princeton University, and the National Science Foundation for partial financial support. We thank Loren Baker, Kainan Tang, and Guillermo Frias for research assistance, and Drusilla Brown, Gardener Evans, and Greg Schoepfle for sharing their unpublished data. Joanne Gowa, Howard Gruenspecht, and Jeff Mackie-Mason provided helpful comments and discussion. This paper is part of NBER's research program in International Studies.

NBER Working Paper #3914
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ABSTRACT

A reduction in trade barriers generally will affect the environment by expanding the scale of economic activity, by altering the composition of economic activity, and by bringing about a change in the techniques of production. We present empirical evidence to assess the relative magnitudes of these three effects as they apply to further trade liberalization in Mexico.

In Section 1, we use comparable measures of three air pollutants in a cross-section of urban areas located in 42 countries to study the relationship between air quality and economic growth. We find for two pollutants (sulfur dioxide and "smoke") that concentrations increase with per capita GDP at low levels of national income, but decrease with GDP growth at higher levels of income. Section 2 studies the determinants of the industry pattern of U.S. imports from Mexico and of value added by Mexico's maquiladora sector. We investigate whether the size of pollution abatement costs in the U.S. industry influences the pattern of international trade and investment. Finally, in Section 3, we use the results from a computable general equilibrium model to study the likely compositional effect of a NAFTA on pollution in Mexico.

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Environmental advocacy groups in the United States have voiced their concerns about a potential North American Free Trade Agreement (NAFTA). Some went so far as to oppose the Congressional granting of fast-track negotiating authority to the President to enable American negotiators to enter into talks with their Mexican counterparts. The reservations of the lobbying groups mirror a growing perception on the part of environmentalists worldwide that an open world trading system may be inimical to the goal of preserving a clean, healthy, and sustainable global commons.

The arguments linking trade liberalization with environmental degradation have not been fully articulated.[1] With regard to a NAFTA, the environmentalists have expressed a number of reasons for fearing that freer trade and direct investment flows between the United States and Mexico may aggravate pollution problems in Mexico and in the border region.[2] At the least discerning level, some have argued simply that any expansion of markets and economic activity inevitably leads to more pollution and faster depletion of scarce natural resources. A more pointed argument recognizes that pollution already is a severe problem in Mexico and that the country's weak regulatory infrastructure is strained to the breaking point. Under these conditions, it is feared that any further industrialization that results from the liberalization of trade and investment will exacerbate an already grave situation.

Other environmentalists draw their conclusions by extrapolating the experience of the maquiladora sector in Mexico. The maquiladoras are

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[1] See Low and Safedi (1991), who cite several examples of writings that view open trade as detrimental to environmental protection.

[2] See, for example, Gregory (1991), Kelly and Kamp (1991), National Wildlife Foundation (1990), Leonard and Christensen (1991), and Ortman (1991).

predominantly foreign-owned firms that produce largely for export to the United States under a Mexican policy that allows duty-free imports of foreign components for further processing and re-export. Originally, maquiladoras were required to locate within a 20-kilometer strip along the U.S.- Mexico border in order to qualify for special customs treatment. The sector grew quite rapidly and with little governmental oversight, and now is widely regarded as being a major contributor to the perilous environmental and social conditions in the border region. Environmental groups point to this sector as a prime example of how unregulated expansion in response to trade opportunities can create risks to worker safety and public health. They argue that investments in this sector have been encouraged by the lax enforcement of environment and labor protection laws in Mexico and fear that any further expansion in trade and investment flows between the United States and Mexico will be motivated by firms' desires to avoid the high costs of meeting U.S. regulations.

A further concern of some environmental groups is that a NAFTA may undercut regulatory standards in the United States. Spokespersons have made the political-economic argument that, with freer trade, industry groups in the United States will demand less stringent pollution controls in order to preserve their international competitiveness, so that environmental standards will tend toward a lowest common denominator. The environmentalists worry, moreover, that existing environmental protection laws in the United States may be seen as nontariff barriers to trade in the context of a regional trade agreement.

While the environmental groups have raised a host of valid questions, they have so far been unable to provide convincing and well supported answers to these questions. Many of their arguments fail to recognize all of the implications of trade liberalization for resource allocation and natural resource use in each of the trade partner countries. Moreover, the empirical claims that have been made rely mostly on anecdotal evidence and on extrapolation of the experience in one region or industry to the entirety of economic activity in Mexico. Indeed, relatively little is known at any level of generality about the relationship between a country's trade regime and its rate of environmental degradation, or even about the relationship between a country's stage of economic development and its output of pollution. Theoretical investigation of these topics has been limited, and empirical studies are virtually non-existent.

It is useful to distinguish three separate mechanisms by which a change in trade and foreign investment policy can affect the level of pollution and the rate of depletion of scarce environmental resources.[3] First, there is a scale effect, capturing the simple intuition espoused by the environmental advocates. That is, if trade and investment liberalization causes an expansion of economic activity, and if the nature of that activity remains unchanged, then the total amount of pollution generated must increase. The environmental groups point, for example, to the deleterious environmental consequences of the combustion of fossil fuels and to the air pollution that is generated by the trucking industry. To the extent that economic growth gives rise to an increased demand for energy, which then is generated by means similar to the prevailing methods, there will be an increased output of harmful pollutants that attends an increase in economic output. Similarly, to

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[3] A similar decomposition of the effects of economic growth on the output of pollution has been proposed by the Task Force on the Environment and the Internal Market (1990).

the extent that expanded trade gives rise to an increased demand for cross-border transportation services without there being any change in trucking practices, increased trade will contribute to a deterioration in air quality.

Second, there is a composition effect that results from any change in trade policy. When trade is liberalized, countries specialize to a greater extent in the sectors in which they enjoy competitive advantage. If competitive advantage derives largely from differences in environmental regulation, then the composition effect of trade liberalization will be damaging to the environment. Each country then will tend to specialize more completely in the activities that its government does not regulate strictly, and will shift out of production in industries where the local costs of pollution abatement are relatively great. On the other hand, if the sources of international comparative advantage are the more traditional ones, namely cross-country differences in factor abundance and technology, then the implications of the composition effect for the state of the environment are ambiguous. Trade liberalization will lead each country to shift resources into the sectors that make intensive use of its abundant factors. The net effect of this on the level of pollution in each location will depend upon whether pollution-intensive activities expand or contract in the country that on average has the more stringent pollution controls.

Finally, there is a technique effect. That is, output need not be produced by exactly the same methods subsequent to a liberalization of trade and foreign investment as it has been prior to the change in regime. In particular, the output of pollution per unit of economic product need not remain the same. There are at least two reasons to believe that pollution per unit of output might fall, especially in a less developed country. First, foreign producers may transfer modern technologies to the local economy when restrictions on foreign investment are relaxed. More modern technologies typically are cleaner than older technologies due to the growing global awareness of the urgency of environmental concerns. Second, and perhaps more importantly, if trade liberalization generates an increase in income levels, then the body politic may demand a cleaner environment as an expression of their increased national wealth. Thus, more stringent pollution standards and stricter enforcement of existing laws may be a natural political response to economic growth.

In this paper we explore some of the empirical evidence that bears on the likely environmental impacts of a NAFTA. In Section 1, we shed some light on the relative magnitudes of the scale and technique effects. We use a cross-country sample of comparable measures of pollution in various urban areas to explore the relationship between economic growth and air quality. After holding constant the identifiable geographic characteristics of different cities, a common global time trend in the levels of pollution, and the location and type of the pollution measurement device, we find that ambient levels of both sulphur dioxide and dark matter suspended in the air increase with per capita GDP at low levels of national income, but decrease with per capita GDP at higher levels of income. The turning point comes somewhere between $4,000 and $5,000, measured in 1985 U.S. dollars. For a third measure of air quality, namely the mass of suspended particles found in a given volume of air, the relationship between pollution and GDP is monotonically decreasing.

Sections 2 and 3 address different aspects of the composition effect. In section 2 we ask whether and to what extent the sectoral patterns of U.S.

foreign investment in Mexico and of Mexican exports to the United States are affected by the laxity of environmental regulations in Mexico as compared to the stricter enforcement of controls in the United States. We relate the sectoral pattern of maquiladora activity, of U.S. imports from Mexico under the offshore assembly provisions of the U.S. tariff codes, and of total U.S. imports from Mexico to industry factor intensities, U.S. tariff rates, and the size of pollution abatement costs in the U.S. industry. We find that the traditional determinants of trade and investment patterns are significant here, but that the alleged competitive advantages created by lax pollution controls in Mexico play no substantial role in motivating trade and investment flows.

Finally, in Section 3, we begin with the premise that resource allocations in the United States, Mexico, and Canada have been guided by competitive advantages generated by differences in factor endowments. We borrow from Brown, Deardorff and Stern (1991) their estimates of the change in resource allocation that might result from a NAFTA, and discuss the implications of these predicted changes in the structure of production for levels of pollution in each country.

1 Economic Growth and Urban Air Pollution

As we noted in the introduction, economic growth has offsetting implications for the anthropogenic generation of air pollution. On the one hand, some pollutants are a natural byproduct of economic activities such as electricity generation and the operation of motor vehicles. As economic activity expands, emissions of these pollutants tend to grow. On the other hand, firms and households can control their pollution to some degree by their choice of technology. Cleaner technologies produce less pollution per unit of output. As a society becomes richer its members may intensify their demands for a more healthy and sustainable environment, in which case the government may be called upon to impose more stringent environmental controls.

Little is known about the empirical relationship between national income and concentrations of various pollutants. Investigation of this issue has been hampered by the paucity of data on air pollution that is available on a comparable basis for a representative sample of countries. However, since 1976 the World Health Organization (WHO) has collaborated with the United Nations Environment Programme in operating the Global Environmental Monitoring System (GEMS). The goal of this project has been to monitor closely the concentrations of several pollutants in a cross-section of urban areas using standardized methods of measurement. This data set, which to our knowledge has not previously been analyzed by economists, provides us with an opportunity to examine how air quality varies with economic growth.[4]

In the next subsection we describe the GEMS project, the types of pollution that it monitors, and the data that it has generated. Section 1.2 gives the details of the statistical analysis that we have performed. Our findings are presented in Section 1.3 and the implications for Mexico are discussed in Section 1.4.

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[4] The GEMS data have been statistically analyzed by some environmental scientists (see World Health Organization [1984]), but they have neglected to use any economic variables in their exclusively bivariate analyses.

1.1 The GEMS Data[5]

The GEMS monitors air quality in urban areas throughout the world. Daily (or, in some cases, weekly or less frequent) measurements are taken of concentrations of sulphur dioxide (SO_2) and suspended particulate matter. Data on particulates, which are gases and liquids suspended in the air, are collected by different methods (described further below) that alternatively measure the mass of materials in a given volume of air and the concentration of finer, darker matter, sometimes referred to as "smoke".

Sulfur dioxide is a corrosive gas that has been linked to respiratory disease and other health problems.[6] It is emitted naturally by volcanoes, decaying organic matter, and sea spray. The major anthropogenic sources of SO_2 are the burning of fossil fuels in electricity generation and domestic heating, and the smelting of non-ferrous ores (World Resource Institute, 1988). Other sources in some countries include automobile exhaust and the chemicals industry (Kormondy, 1989). Sulfur dioxide emissions can be controlled by the installation of flue gas desulfurization equipment (scrubbers) on polluting facilities, and by switching electricity-generating and home-heating capacity to lower sulfur grades of coal or away from coal altogether.

Particulates arise from dust, sea spray, forest fires, and volcanoes. Most of these naturally produced particles are relatively large. Finer

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[5] The GEMS data for 1977-1984 are published by the World Health Organization in the series Air Quality in Selected Urban Areas. Unpublished data for 1985-1988 have been kindly provided to us by Gardener Evans of the U.S. EPA.

[6] Lave and Seskin (1970) find, for example, that variation in SO_2 and population density together explain two-thirds of the variation in death from bronchitis in a sample of U.S. cities.

particles are emitted by industry and from domestic fuel combustion (World Resources Institute, 1988). Larger particles reduce visibility but have a relatively minor health impact, whereas the finer particles can cause eye and lung damage and can aggravate existing respiratory conditions (U.S. EPA, 1982). Particulate emissions from anthropogenic processes can be reduced via the installation of control equipment and by switching to fuels that, when burned, emit fewer particles.

The GEMS sample of cities has been changing over time. Sulfur dioxide was monitored in 47 cities spread over 28 different countries in 1977, 52 cities in 32 countries in 1982, and 27 cities in 14 countries in 1988. Measurements of suspended particles were taken in 21 cities in 11 countries in 1977, 36 cities in 17 countries in 1982, and 26 cities in 13 countries in 1988, while data for darker matter (smoke) are available for 18 cities in 13 countries for 1977, 13 cities in nine countries for 1982, and seven cities in four countries for 1988. In all, there are 42 countries represented in our sample for SO_2, 19 countries in our sample for dark matter, and 29 countries in our sample for suspended particles. The participating cities are located in a variety of developing and developed countries and have been chosen to be fairly representative of the geographic conditions that exist in different regions of the world (Bennett et al., 1985). In most of the cities included in the project, air quality measurements are taken at two or three different sites, which are classified either as center city or suburban, and as commercial, industrial, or residential. Multiple sites in the same city are monitored in recognition of the fact that pollutant concentrations can vary dramatically with local conditions that depend in part upon land use. Observations at most sites are made on a daily basis and the data set includes measures of the mean, median, 80th, 95th, and 98th percentile of daily observations in a given site for a given year.

Sulfur dioxide concentrations have been determined by a number of well accepted methods (see WHO, 1984). The reliability of these methods has been checked in independent studies, and an intercomparison exercise was performed using one particular method as a reference point (Bennett et al., 1985). It was concluded that the measurements by alternative methods are roughly comparable, although particular meteorological conditions can affect the various methods differently. With these results in mind, we have chosen to pool our sample of observations of SO_2 concentration, but to allow for a dummy variable to reflect the method of measurement at each site.

Suspended particles are measured by two main methods. High volume gravimetric sampling determines the mass of particulates in a given volume of air while the smoke-shade method assesses the reflectance of the stain left on a filter paper that ambient air has been drawn through. The former method measures the total weight of suspended particles while the latter is predominantly an indication of dark material in the air. Since the two methods yield incomparable measures that capture different aspects of particulate air pollution, we treat the data generated by gravimetric and smoke-shade methods separately in our analysis.[7]

Table 1 provides the mean, median and standard deviation for the 50th and 95th percentiles of daily observations in our sample of cities for each of

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[7] A few sites used nephelometric methods to measure suspended particles; i.e., they measured the light loss due to scattering when a light beam is passed through a sample of particle-laden air. This method gauges the mass of suspended particles, much as does the high volume gravimetric method. Since the estimates are comparable in many cases, we pooled the observations from these two types of instruments, but included a dummy variable to allow for device-specific measurement differences.

the three types of pollution. Figure 1 displays the corresponding histograms. The median of daily observations on SO_2 range from a minimum of zero to a maximum of 291 micrograms per cubic meter ($\mu g\ m^{-3}$) of air, whereas the 95th percentile of daily measures range from zero to 1022 $\mu g\ m^{-3}$.[8] These numbers can be compared with the World Health Organization recommendation that annual average SO_2 concentrations ought not to exceed 40-60 $\mu g\ m^{-3}$ and that 98th percentile concentrations ought not to exceed 100-150 $\mu g\ m^{-3}$. The median of daily observations for suspended particles varied from zero to 715 $\mu g\ m^{-3}$, while that for the 95th percentile observation ranged from 15 to 1580 $\mu g\ m^{-3}$. The WHO guidelines for suspended particles list 60-90 $\mu g\ m^{-3}$ as the safe limit for the annual mean and 150-230 $\mu g\ m^{-3}$ as the safe limit for the 98th percentile. Finally, the median of daily observations of dark matter (or smoke) in the sample of sites varied from zero to 312 $\mu g\ m^{-3}$, while the 95th percentile observation varied from two to 582 $\mu g\ m^{-3}$. The WHO recommends that dark matter not exceed 50-60 $\mu g\ m^{-3}$ in annual average and 100-150 $\mu g\ m^{-3}$ in the 98th percentile of daily observations.

1.2 Estimation

Concentrations of pollutants in the air depend upon the amounts that are emitted by natural and anthropogenic sources and on the ability of the atmosphere to absorb and disburse the gases or particles. Thus, our analysis of the relationship between growth and air quality must allow for an influence of city and site characteristics on the observed concentrations of the various pollutants in addition to the dependence on national product.

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[8] Actually, SO_2 concentrations are never literally zero, but the machines are unable to detect very low levels of the gas.

We have sought to explain the median and 95th percentile of daily observations for SO_2, suspended particles (gravimetric and nephelometric methods) and dark matter (smoke-shade method). As explanatory variables, we have included functions of per capita GDP in the country where the site is located, characteristics of the site and city, and a time trend. We used the Summers and Heston (1991) data for per capita GDP, which attempt to measure output in relation to a common set of international prices. Initially, we allowed the coefficient on per capita GDP to vary across income ranges by including a dummy variable in our regressions for each $2,000 interval of per capita GDP. These relatively unrestricted regressions suggested that a cubic function of per capita GDP would fit the data fairly well. The cubic equations are the main focus of our subsequent analysis.[9]

In the equation for concentrations of SO_2, we included dummy variables for the location within the city (central city or suburban) and for the land use of the area near the testing site (industrial, commercial, or residential). We also included a dummy variable for the method of measurement (gas bubbler or otherwise). Another dummy indicated whether the city was located along a coastline or not (reflecting the disbursement properties of the local atmosphere). We included a variable for the population density of the city and a dummy variable for whether the city was located in a country ruled by a Communist government.[10] Finally, a linear time trend was included to allow for the possibility that pollution has been abating (or worsening)

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[9] We also estimated equations in which we entered per capita GDP in quadratic form. In general, the quadratic equations do not fit quite as well as the cubic equations, though in many cases the shape of the estimated relationship between income and pollution is found to be roughly the same.

[10] Population densities were collected from several different sources. These sources and other details of our data set are available upon request.

worldwide, in response to increased global awareness or for other reasons.[11]

The regressions for suspended particles and dark matter included a similar set of right-hand-side variables, except that we did not include a dummy variable for the method of monitoring dark matter, because all measurements were taken in the same way. Since dust is an important natural source of particulate matter, we included as an additional explanatory variable a dummy that indicates whether the measurement site is located within 100 miles of a desert.[12]

Some commentators have argued that a country's level of pollution might be directly related to its openness to international trade, perhaps because environmental regulations tend to a least common denominator. To test this hypothesis, we estimated one set of regressions in which we included the trade intensity of the country in which the site is located (ratio of the sum of exports and imports to GDP) as a separate determinant of the concentration of the air pollutants.[13]

For each pollutant, we estimated a random effects model, allowing for a component of the error term that is common to a given year's observations at different sites located in the same city.[14] We find that the variance of the

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[11] We began our analysis with separate dummy variables for each year in our sample, but the estimates of this model strongly suggested a simple, linear time trend.

[12] However, we coded the desert dummy variable as zero for Cordoba, Argentina, in view of the fact that a mountain range lies between this city and the nearby desert. The regressions fit somewhat better with Cordoba treated this way, although none of our conclusions about the relationship of particulate pollution to GDP depends upon this designation.

[13] The data on trade intensities were taken from the World Bank database.

[14] That is, if μ_{ijt} is the total residual in the equation for some pollutant at site i in city j at time t, we assume that $\mu_{ijt} = \alpha_{jt} + \epsilon_{ijt}$, where α_{jt} is the common-to-the-city component, ϵ_{ijt} is the idiosyncratic component, and

common-to-the-city component of the estimated residuals is relatively large in comparison to the idiosyncratic (site-by-time) component, so that ordinary least squares would give an inconsistent estimate of the standard errors of the regression. We also calculated one set of estimates that allowed for fixed site effects. In other words, we included a separate dummy variable for each of the different sites in our various samples. The fixed effects were intended to capture the unobservable topographical and meteorological conditions at a site that might contribute to its ability to absorb or disburse pollution. Of course, when we included the fixed site effects we dropped the dummy variables reflecting the location of the site within the city and the location of the city on a coastline or near a desert, since these influences were no longer separately identified. The model with fixed site effects provides an especially stringent test of the relationship between national income and pollution, inasmuch as it ignores all information contained in the cross-country variation in pollution levels and relies instead only on the variation in air quality that resulted at the various sites from changes in GDP during the twelve years of GEMS observations (and then only that part of the variation that cannot be explained by a common linear time trend).

1.3 Findings

The results of our various estimates of the random effects models for the three pollutants are given in Tables 2-4. These regressions do not include the model with fixed site effects, which we discuss separately below.

$E(\alpha_{jt}\epsilon_{ijt}) = 0$. Our estimation takes into account the unbalanced nature of this panel data set.

Figure 2 displays, for the median of daily observations on each pollutant, the estimated coefficients on the dummy variables indicating whether a country's per capita GDP falls in the range from \$2,000 to \$3,999, from \$4,000 to \$5,999, and so on. The coefficient estimates have been plotted above the midpoint in the range; e.g., above \$3,000 for GDP in the range from \$2,000 to \$3,999. These coefficients should be interpreted as indicating the amount of extra pollution a country with a per capita GDP in a given range is likely to have, holding constant the values of other explanatory variables (site location, city population density, etc.), relative to a country with a per capita GDP in the range from zero to \$2,000. The figure also shows the estimated amount of extra pollution that is associated with a given level of per capita GDP (relative to a country with a per capita GDP of \$1,000) that comes from regressing the pollution concentrations on per capita GDP, per capita GDP-squared, per capita GDP-cubed, and the remaining explanatory variables. The figure shows that, in each case, the cubic functional form approximates well the shape of the relationship between pollution and GDP that is indicated by the less restrictive regressions.

Figure 3 depicts the estimated relationship between per capita GDP and SO_2, derived form the cubic equations, for both the 50th and 95th percentile of daily observations. For both measures, the concentration of SO_2 rises with per capita GDP at low levels of national income, falls with per capita GDP in the broad range between \$5,000 and \$14,000 (1985 U.S. dollars), and then levels off or perhaps begins to rise again.[15] The turning point in the

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[15] There are only two countries in our sample (the United States and Canada) with per capita incomes in excess of \$16,000, so the fact that the estimated curves turn upward in this range probably should not be viewed as strong evidence for a renewed positive relationship between national product and SO_2 pollution at high income levels.

predicted relationship for the median of daily observations comes at \$4,119, while that for the 95th percentile observation occurs at \$4,630. We estimate that a country with per capita GDP of \$5,000 will have a 20 $\mu g\ m^{-3}$ greater concentration of SO_2 for the 95th percentile of its daily observations, as compared to a country with a per capita GDP of \$1,000, all else equal. Table 2 indicates that the hypothesis that SO_2 pollution is unrelated to the level of GDP can be rejected at the 1/100th of one percent significance level in the regression for the median observation and at the seven percent level in the regression for the 95th percentile observation (see columns 2 and 5).

Table 2 reveals that several other variables contribute significantly to the cross-city variation in concentrations of SO_2. For example, cities located on a coastline are estimated to have lesser concentrations of SO_2: 6.68 $\mu g\ m^{-3}$ lower for the median of daily observations and 46.79 $\mu g\ m^{-3}$ lower for the 95th percentile observation. Concentrations of SO_2 are higher in the center city than in the suburbs, lower in residential areas than in commercial areas, and higher in industrial areas than in commercial areas (although this effect is not statistically significant at conventional significance levels). More densely populated cities suffer greater concentrations of SO_2, all else equal. We also find that SO_2 pollution has been significantly greater in cities located in Communist-ruled countries. Finally, we note that SO_2 levels have been trending downward in our sample of cities even after controlling for the effects of income and other variables. The downward trend may reflect an increasing global awareness of the health problems associated with SO_2, and the expanding efforts that are being made worldwide to limit sulfur emissions.

Columns 3 and 6 of Table 2 present estimates of a model for SO_2 determination that includes trade intensity as an additional explanatory variable. Contrary to the fears of some environmentalists, we find that SO_2 levels are significantly <u>lower</u> in cities located in countries that conduct a great deal of trade (relative to their GDP). We have no good economic explanation for this finding.

Figure 4 depicts the estimated (cubic) relationship between dark matter and per capita GDP for the median and 95th percentile of daily observations. Apparently, the nature of the relationship is much the same as for SO_2. The concentration of smoke in the air rises with per capita GDP at low levels of income, peaks at around $5,000 (1985 U.S. dollars), and falls with GDP at higher income levels until it eventually levels off. We see in columns 2 and 5 of Table 3 that the three GDP variables are jointly significant in the determination of dark matter pollution at the 1/100th of one percent significance level. Moreover, the size of the estimated effects are quite large. We estimate that a country with a per capita GDP of $5,000 will have a higher concentration of smoke by about 90 $\mu g\ m^{-3}$ in its median of daily observations and 220 $\mu g\ m^{-3}$ in its 95th percentile observation, compared to one with a per capita GDP of $1,000. Recall that the WHO recommends that concentrations of smoke not exceed 50-60 $\mu g\ m^{-3}$ for the mean observation and 100-150 $\mu g\ m^{-3}$ for the 98th percentile observation.

Not surprisingly, the dummy variable indicating proximity to a desert has a positive and significant coefficient in the regressions explaining concentrations of dark matter. A location on a coast reduces a city's concentration of this type of pollution, and again the effect is statistically significant. We find that smoke pollution levels are greater in center cities than in suburbs, and smaller in residential areas than in commercial areas. Also, dark matter, like SO_2, rises with population density, although this effect is significant only in the regression for the median of daily observations. Finally, there appears to be neither a global trend in this type of pollution (once the upward movement in world incomes has been accounted for) nor a significant association with trade intensity.

Unlike the other two pollutants, the mass of suspended particles in the air appears to fall in response to increases in per capita GDP at low levels of economic development (see Figure 5). This relationship continues until per capita GDP reaches about $9,000, whereupon economic growth has no further effect on the concentration of suspended particles. Again, the estimated effects are large in comparison to the WHO guidelines, and again the three GDP variables are jointly significant in the determination of this measure of air quality.

As with dark matter, cities situated near to a desert are likely to experience higher concentrations of suspended particles than cities located elsewhere. This effect is both quantitatively large and highly significant. The coefficients on the Communist dummy, the center-city dummy and the industrial area dummy all are positive and statistically significant in the regressions for both the median and 95th percentile of daily observations. The global trend in suspended particle pollution apparently has been downward, although the coefficient on the year variable is statistically significant only in the regressions for the median of daily observations. Finally, a country's trade intensity has a small and statistically insignificant effect on this form of pollution.

Table 5 reports the estimated coefficients from a random effects model for each type of pollutant that also allows for fixed site effects. The numbers of site dummy variables that were included in the various regressions are shown in the table. These estimates of the relationship between per capita GDP and the various measures of air quality rely only on the covariation between GDP and concentrations of the pollutants over time within the individual sites, and not on the cross-country variation in pollution and GDP at a given moment in time. The estimated relationships for the median of daily observations of SO_2 and dark matter hold up remarkably well (see Figure 6). In each case, the data continue to indicate an inverted-U shaped relationship between pollution and national income, with peak levels of pollution occurring for per capita incomes in the range from $4,000 to $5,000. Only the estimated coefficients from the fixed site effects model for suspended particles suggest a different relationship between per capita GDP and concentrations of the pollutant than is found in the regressions without site effects. In this case, the estimation indicates a monotonically increasing relationship between particulate pollution and national output in the sample range of output levels.

1.4 Implications for Mexico

Unfortunately, Mexíco has not participated in the GEMS project and reliable measures of its air pollution are not available (US GAO, 1991b). Thus, predictions for Mexico must be inferred from relationships that hold in other countries at similar stages of development. Surely the available evidence suggests that air quality has deteriorated with economic growth in Mexico (US GAO, 1991b). Our estimates indicate that this experience is common in poor countries, but that the positive association between two pollutants and economic output ceases when the typical country reaches a per capita income level of about $5,000 (1985 U.S. dollars). We note that Summers and

Heston (1991) put Mexico's per capita GDP in 1988 at $4,996. Thus, we might expect that further growth in Mexico, as may result from a free trade agreement with the United States and Canada, will lead the country to intensify its efforts to alleviate its environmental problems.

Recent measures taken by the government of Mexico suggest that the country already may have reached the turning point in terms of air pollution. In the last year, the Salinas government has reduced the lead content of petrol, ordered several power stations to burn natural gas instead of sulfur-generating fuel oil, and shut down oil refineries and private firms that were found to be major sources of air pollution (The Economist, May 18, 1991). Also, new cars are being fitted with catalytic convertors, a new fleet of cleaner buses has been introduced, and drivers have been banned from using their cars in Mexico City one day each week. To beef up enforcement, the budget of the environmental protection ministry has been increased sevenfold (New York Times, Sept. 22, 1991). Further growth may enable the government to implement fully its planned $2.5 billion, four-year program to clean up Mexico City.

2 Pollution Abatement Costs and the Pattern of U.S.- Mexico Investment and Trade

A main source of concern about a NAFTA is that it will enable firms to circumvent U.S. environmental protection laws. If the costs of meeting pollution controls are high in the United States and low or negligible in Mexico, then the asymmetry in standards or enforcement efforts can create a competitive advantage for Mexican producers and can motivate U.S. firms to relocate their production facilities south of the border. In these circumstances, liberalization of trade and investment flows can strengthen the incentives for "environmental dumping."

A number of authors, including for example Pethig (1976), Siebert (1977), Yohe (1979) and McGuire (1982), have studied the theoretical relationship between environmental regulations and the pattern of trade. They find that strict environmental standards or costly controls weaken a country's competitive position in pollution-intensive industries and diminish its exports (or increase its imports) of the product of such sectors. Countries that fail to regulate industrial pollution increase their specialization in activities that damage the environment. McGuire has extended these results to include direct foreign investment: controls cause firms active in the pollution-intensive industry to relocate their activities to the less regulated countries.

While these theoretical predictions are plausible and intuitive, they have found little support in previous empirical studies of trade and investment patterns. For example, Tobey (1990) has tested the hypothesis that environmental regulations have altered the pattern of trade in goods produced by "dirty" industries. He finds that a qualitative variable describing the stringency of environmental controls in 23 countries fails to contribute to the determination of their net exports of the five most pollution-intensive commodities. Similarly, Walter (1982) and Leonard (1988) conclude that there is little evidence that pollution abatement costs have influenced the location decisions of multinational firms. Apparently, the cross-country variation in the costs of meeting environmental controls is not so large as to be a major factor in the determination of nations' comparative advantages.

Our purpose in this section is to address this issue in connection with the pattern of U.S. imports from Mexico and the pattern of U.S. foreign investments in Mexico. There is some evidence from a GAO survey suggesting that a few American furniture manufacturers may have moved their operations to Mexico in response to the State of California's tightening of air pollution control standards for paint coatings and solvents (US GAO, 1991c). But the question remains open as to whether the overall sectoral pattern of U.S. economic relations with Mexico has been meaningfully affected by the higher costs of pollution abatement in the United States. If the pattern of specialization has been so influenced, then the composition effect of a further liberalization of trade and investment may be damaging to the environment.

Using data from the Bureau of Census' 1988 survey of pollution abatement costs in American industries (U.S. DOC, 1988), we have conducted three sets of tests. We have studied the 1987 pattern of U.S. imports from Mexico in 3-digit SIC manufacturing industries, the pattern of 1987 U.S. imports from Mexico that have entered the country under the offshore assembly provisions (again at the 3-digit SIC level), and the sectoral pattern of value added by maquiladora plants in (approximately) 2-digit industry categories. In each case we have investigated whether pollution abatement costs in the United States help to explain the pattern of Mexican specialization and trade.

Our estimates of the determinants of the pattern of manufactured imports from Mexico are recorded in the first two columns of Table 6. We use the ratio of 1987 U.S. imports from Mexico to total U.S. shipments in the same industry as the dependent variable. The explanatory variables include factor shares (reflecting the intensity of use of the various factors by the different industries; see Harkness [1978]), the U.S. effective tariff rate on imports of goods in the industry, and the ratio of pollution abatement costs (operating expenses) to total value added in the U.S. industry.[16] We also report another regression that includes the average injury rate in the industry as an additional independent variable. Since firm outlays for worker compensation insurance are roughly proportional to injury rates (Krueger and Burton, 1990), the injury variable proxies for one (large) component of the cost to American manufacturing firms of U.S. labor protection laws.

We computed the factor shares as follows. We took the payroll expenses in an industry to represent a combined compensation for unskilled or "raw" labor and human capital. Payments to unskilled labor were defined as the product of the number of workers in the industry and the economy-wide average yearly income of workers in manufacturing with less than a high school education. We formed a share by dividing this amount by value added, and considered the remaining part of the total labor share to represent the payment to human capital.[17] Finally, we calculated the share of capital in value added as the difference between one and the total payroll share.[18,19]

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[16] The Census survey did not include the apparel industry (SIC category 23). For these observations and four others with missing data, we inserted the average ratio of pollution abatement costs to value added for all manufacturing sectors included in the survey.

[17] For twelve industries, this method gives a negative number as the estimate of the share of human capital. To ensure that our results were not sensitive to the choice of income for an unskilled worker, we also computed factor shares using the income level for unskilled workers ($10,819) that made the minimum share of human capital our sample of industries equal to zero. The estimated import equations with these measures of factor shares look much the same as for our original measures.

[18] The import figures and the effective tariff rates were provided to us by Greg Schoepfle of the U.S. Department of Labor. The tariff rates were estimated by dividing the total duties collected on imports from Mexico in a two digit SIC industry by the total value of imports in the industry. Data on shipments, value added, employment, and payroll were taken from the N.B.E.R. trade and immigration data set (see Abowd, 1987). Since the trade data are classified

Factor intensities figure prominently in the determination of the pattern of U.S. imports from Mexico. The ratio of imports to total U.S. shipments is smaller in industries that are highly intensive in their use of human or physical capital. This means, of course, that Mexico exports to the United States goods that have a relatively high share of unskilled labor in total factor cost. The coefficients on the physical and human capital variables both are statistically significant at the five percent level, but the latter coefficient is quantitatively much larger. We estimate that a ten percentage point increase in the share of human capital reduces the ratio of imports to shipments by 0.52 percentage points, while a ten percentage point increase in the share of physical capital lowers the import ratio by only 0.24 percentage points. Note that the mean ratio of imports to shipments across all manufacturing industries is 0.69 percent.

We estimate that the import ratio rises with the share of pollution abatement costs in U.S. industry value added, as would be predicted by a model of environmental dumping. However, the impact of these regulatory costs is

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according to the old (1972) SIC categories, we used manufacturing census data that were bridged to this classification scheme. The average income for a worker in the manufacturing sector with less than a high school education was calculated from the 1987 Current Population Survey by the authors. Injury rates by industry were taken from the Bureau of Labor Statistics publication, Occupational Injuries and Illness in the United States by Industry. In the few cases where an injury rate was not available for a three digit industry, we used instead the average injury rate for the applicable 2-digit industry.

[19] We are also experimenting with a second procedure for dividing the labor share into component parts representing the shares of unskilled labor and human capital. In this, we form factor share for different skill groups (workers with a high school education, workers with some college education, and workers with a college degree) by taking the product of the industry labor force, the fraction of the industry's workers in the skill group in question, and the economy-wide average income of workers in that skill group, and then dividing by value added. If this procedure yields substantially different conclusions, we will report on the results in a future draft of this paper.

both quantitatively small and statistically insignificant. Consider for example an industry that has the mean ratio of pollution abatement costs to industry value added and another that has a ratio that is two standard deviations higher. We estimate that the latter industry will have a greater ratio of imports to U.S. shipments by about 0.05 percent, which is less than 1/20th of a standard deviation in the import variable. This finding can be understood from the fact that pollution abatement costs average only 1.38 percent of value added across all manufacturing industries and rise to only 4.85 percent in an industry that is two standard deviations above the mean. The implied variation in competitiveness is small in comparison with that which arises from cross industry variations in labor costs, for example.

We note that the injury rate has a positive coefficient when it is included in the import equation, but this variable too has a very small and statistically insignificant effect. Finally, the coefficient on the tariff variable has the theoretically predicted negative sign (imports are smaller in industries with high effective tariff rates), but also is not significant.[20]

We turn next to the determinants of the pattern of U.S. imports from Mexico under the offshore assembly provision (i.e., import category 807.00 in the old TSUSA tariff schedule). U.S. trade law provides for duty free re-entry of American-made components embodied in imported final goods. In cases where intermediate products are exported for further processing or assembly abroad, the applicable tariff rate applies only to the foreign value added. Nearly 44 percent of the value of Mexican exports to the United States qualified for this customs treatment in 1987 (Schoepfle, 1991). We study

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[20] A simultaneity bias may exist here, insofar as many political-economic theories of tariff formation predict that high tariff rates will endogenously emerge in industries in which import penetration is great.

these imports separately, because much of the output by maquiladora plants enters the United States in this manner, and maquiladoras are the source of most of the item 807.00 U.S. imports from Mexico (Schoepfle, 1991). Thus, the sectoral pattern of item 807.00 imports gives us an idea as to the pattern of maquiladora activity.

The middle two columns of Table 6 reports estimates of an equation for the ratio of the Mexican value added in imports entering under the 807.00 code in 1987 to the total value added by the U.S. industry. We would expect this variable to be high in industries where maquiladoras are especially active; i.e., those in which Mexico enjoys a competitive advantage. The independent variables in these equations are the same as before, namely the factor shares, the share of pollution abatement costs in U.S. industry value added, and in one set of estimates, the industry injury rate. The tariff variable was omitted from these regressions because our effective tariff rate applies to all imports from Mexico, and does not reflect the average tariff paid on imports that entered under the offshore assembly provision. We use a Tobit model to estimate these equations in view of the fact that item 807.00 imports are zero in 58 of the 136 industry categories. Since the import share cannot be negative, a censored regression model is appropriate.

The foreign content of U.S. item 807.00 imports from Mexico is highest in relation to total value added in the corresponding U.S. industry in sectors that make relatively intensive use of unskilled labor. This is not surprising, since many U.S. manufacturers attempt to outsource to maquiladora operations the most unskilled labor intensive phases of the production process. We find a negative association between the Mexican content of item 807.00 imports as a fraction of total U.S. industry value added and both the human capital share and the physical capital share in U.S. industry costs. The coefficient on the physical capital variable is estimated to be nearly twice as large in absolute value as that on the human capital variable (reversing the ordering found for total imports from Mexico), and the former coefficient is statistically significant at the five percent level whereas the latter is statistically significant at only the ten percent level.

Again, we fail to find a significant positive relationship between the size of pollution abatement costs (as a fraction of value added) in the U.S. manufacturing industry and the scale of sectoral activity in Mexico. In fact, the foreign content of item 807.00 imports from Mexico appears to be lower in relation to the size of the U.S. industry in sectors where U.S. pollution abatement costs are relatively high. The negative coefficient on the abatement cost variable is found to be statistically significant at the five percent level, although this may of course reflect a spurious correlation between these costs and some omitted variable. When the U.S. injury rate is included in the equation for item 807.00 imports, the estimated coefficient on this variable is also negative. This would imply that relatively little Mexican assembly activity takes place in those industries where the cost to U.S. employers of workers' compensation insurance and other accident-related costs are especially high. However, in this case, the estimated coefficient is not significantly different from zero, so we cannot reject the hypothesis that the association between injury rates and the pattern of Mexican assembly operations is nil.

The final set of estimates recorded in Table 6 relate to the activity of Mexican maquiladoras. The Instituto Nacional de Estadistica Geografia E Informatica (INEGA), a private Mexican research institute, has surveyed all maquiladoras on the government's list of in-bond producers. Their publication, Estadistica de la Industria Maquiladora de Exportacion, 1978-1988, provides data on value added by maquiladoras in eleven different manufacturing industries. We developed a concordance of the available data to a 2-digit SIC basis and sought to explain the ratio in 1987 of value added by maquiladoras to value added in the corresponding U.S. industry.[21] The explanatory variables are defined as before, except that now we calculate factor shares and pollution abatement costs as a fraction of value added at the 2-digit SIC level.

The estimated coefficients from the models of maquiladora activity confirm our findings for total U.S. imports from Mexico and for imports under tariff item 807.00. Again we find that Mexican competitive advantage derives from an abundance of unskilled labor, and that value added by maquiladoras declines in relation to value added in the United States the greater are the shares of human and physical capital in industry cost. Although neither coefficient has been estimated precisely enough to allow for a clear rejection of the hypothesis that the associations are zero, the magnitudes of the coefficients are very much in line with what we have found before. Also, we find no evidence in support of the hypothesis that U.S. regulatory costs contribute to the explanation of the pattern of maquiladora activity. Neither the coefficient on the abatement cost variable nor that on the injury rate variable has the (positive) sign that one would expect if American firms are investing in maquiladora plants primarily to avoid the high costs of

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[21] We note that INEGA withheld industry-level data for industries with sixteen or fewer maquiladora establishments. Thus, our analysis treats as zero the maquiladora activity in sectors where some small amount of production may have taken place.

environmental and labor protection laws at home. Evidently, the costs involved in complying with these laws are small in relation to the other components of total cost that determine whether it is profitable to operate in the United States or Mexico.

3 Resource Reallocation: Implications for Pollution

Our findings in Section 2 suggest that relative factor supplies govern the pattern of trade between Mexico and its neighbors to the North. We might expect, therefore, that trade liberalization will stimulate Mexican production in unskilled labor-intensive industries, while the United States and Canada will shift resources into sectors that make relatively heavy use of capital and skilled labor. The removal by Mexico of barriers to direct foreign investment can have the opposite effect on international patterns of specialization, if foreign firms bring with them the factors that are scarce in Mexico. Then local production may expand in (moderately) capital and skilled-labor intensive sectors. The question that arises is, what are the environmental implications of these potential resource reallocations?

To answer this question fully, we need several pieces of information. First, we need to know which sectors will expand in each country, and to what extent. Second, we need to know the pollution-intensities of the various industries. Finally, we must know how NAFTA will affect the production technologies used in each location, so as to gauge any changes in pollution generated per unit of output. Estimates of NAFTA impacts on the production structure in each country are available from computational modeling exercises. Brown, Deardorff, and Stern (1991), for example, have predicted resource movements for several different scenarios of policy change under a NAFTA.

Unfortunately, the remaining informational requirements pose more serious difficulties. Concerning the pollution generated by different industries, the United States collects data only on releases of toxic waste (and that of questionable quality), while Mexico collects no such data whatsoever. And although our findings in Section 1 suggest that production techniques might well change in response to a trade agreement that generates economic growth in Mexico, it is difficult to assess how these changes will be distributed across industries.

In this section we draw upon the detailed estimates of Brown, Deardorff, and Stern (BDS) to derive some possible environmental implications of the resource reallocations that would result from a NAFTA. After describing the BDS modeling exercise, we turn to two issues. First, we discuss the model's predictions about each country's demand for the services of utilities. Second, we use the information available in the U.S. EPA's Toxic Resources Inventory to analyze how a NAFTA might affect releases of hazardous waste by the manufacturing sectors in the three partner countries.

The BDS estimates are based on a computable general equilibrium model of the economic interactions between the United States, Canada, Mexico, a group of 31 other major trading nations, and an abbreviated fifth region comprising the rest of the world. The model aggregates production into 23 categories of tradable goods and six categories of non-tradable goods and services. The industries are treated either as perfectly competitive or monopolistically competitive, with the latter set exhibiting economies of scale. Output in each sector is produced from intermediate inputs and an aggregate of capital and labor. The authors allow for varying degrees of substitution between capital and labor in the different sectors, but treat labor as a homogeneous input. The latter assumption is unfortunate in view of our finding in Section 2 that human capital endowments play a central role in determining the bilateral trade pattern between the United States and Mexico.

Since it is not clear what policy measures will be included in a NAFTA, BDS explore a number of alternatives. In one scenario they assume the removal of all bilateral tariffs between the United States, Canada and Mexico, and an easing of U.S. quantitative restrictions that generates a twenty five percent increase in U.S. imports of agricultural products, food, textiles, and apparel from Mexico. In a second scenario they allow for these same forms of trade liberalization and also a relaxation of restrictions on direct foreign investment in Mexico. The liberalization of investment is assumed to result in an (exogenous) ten percent increase in Mexico's capital stock. It should be noted that in both of these cases, the estimated impacts include not only the removal of existing barriers between Mexico and its trade partners, but also the ultimate implementation of the policy changes that comprise the already concluded Canada-U.S. free trade agreement.

It is well known that many pollutants, such as sulfur dioxide, nitric oxide, nitrogen dioxide, and carbon dioxide, are byproducts of electricity generation, especially when fossil fuels are burned in the process. Thus, an important determinant of the net effect of trade liberalization on air pollution will be the induced change in the demand for electricity. Unfortunately, the disaggregation in the BDS model does not allow us to identify the likely impacts of a NAFTA on electricity use, inasmuch as the model treats electricity as a component of the broader category of utilities. It is interesting to note, nonetheless, that BDS predict a <u>decline</u> of 0.56 percent in output by the Mexican utilities sector in response to a hypothetical agreement involving an elimination of tariffs and an increase in U.S. import quotas. This prediction can be understood from the fact that the scenario generates output contractions in ten of twenty one Mexican manufacturing sectors, and expansions are anticipated primarily in labor-intensive industries such as food, textiles, apparel, leather products, and footwear, which presumably are not the sectors that use energy most intensively. But just as Mexico will shift resources into activities that require relatively little energy input, the United States and Canada may be expected to do the opposite. The model predicts modest increases of 0.07 percent and 0.09 percent, respectively, in production by utilities in the United States and Canada.

Quite different conclusions emerge from the scenario that attempts to capture the effects of a potential liberalization of investment flows. The exogenous ten percent increase in the Mexican capital stock that is taken to be the outgrowth of an easing of restrictions on foreign investment effects an expansion of every manufacturing industry there, with the implication that demand for utilities must rise. The experiment generates an increase in utilities output in Mexico of 9.31 percent. Presumably, air quality would deteriorate in this case, unless the associated income growth gave rise to political demands for more stringent standards and tougher enforcement.

We turn next to toxic waste. Our focus on this form of pollution is primarily a reflection of data availability. As far as we know, this is the only type of pollution for which data on releases are collected at the firm level. U.S. law requires all manufacturing firms with ten or more employees that use at least 10,000 pounds of one or more of over 300 chemicals to report their annual chemical releases to the EPA. Lines of business are recorded along with information on releases, enabling aggregation of the data to the industry level.

Several pitfalls in the use of the data contained in the Toxic Release Inventory (TRI) should be noted.[22] First, since the report reflects releases rather than exposures, it cannot reflect the great differences that exist in the rates at which different chemicals are dispersed or transformed. Second, releases are measured only in terms of weight, and no effort is made to account for the fact that some high volume releases are relatively benign, while other lower volume releases may create great health risks. Third, many toxic chemicals are omitted entirely from the inventory. Fourth, the inventory does not reflect emissions by firms outside the manufacturing sector or by federal facilities. Fifth, the EPA conducts relatively little verification of the information it receives and makes relatively little effort to ensure compliance with the reporting requirements. Finally, there is no way to know whether the relationships between toxic waste and industry outputs in Canada and Mexico mirror those in the United States, or whether there are great differences across countries in the industry-specific relationships between hazardous waste and quantities of output.

We have used the predictions of the BDS model and the data on the industry breakdown of toxic releases by U.S. manufacturing firms contained in the TRI to generate Table 7. The table contains estimated impacts on total toxic releases by the manufacturing industries of Mexico, United States, and Canada in response to two scenarios for a NAFTA. As before, the scenarios distinguish a NAFTA that effects only trade liberalization and one that also includes investment liberalization measures in Mexico. In constructing the table we have assumed that an industry-specific fixed coefficient characterizes the relationship between the amount of toxic release and the quantity of output produced. We have

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[22] The following discussion is based on U.S. GAO (1991a).

calculated this coefficient using output and total release data for the United States in 1989.[23] To the extent that releases per unit of output are uniformly higher or lower in Mexico or Canada than they are in the United States, the estimates in Table 7 for these countries can be adjusted upward or downward to reflect these percentage differences. But lacking data for Canada and Mexico, we cannot address the possibility that these countries have higher or lower pollution coefficients than the United States in some industries but not in others.

The table tells a similar story to the one told by the utilities sector. A liberalization of trade in the absence of increased capital flows causes Mexico to shift resources toward industries that, on average, generate less pollution than its current producers. In particular, the BDS model predicts contraction by the industries producing chemical products and rubber and plastics products, both of which generate great quantities of waste per unit of output. The beneficial environmental effects of these resource flows are largely offset by an expansion of the electrical equipment industry, but a small positive net impact remains. The reallocation of resources in the United States and Canada differ from those in Mexico, as these countries enjoy comparative advantage in a complementary set of activities. The model predicts an expansion of the chemical products industry in the United States, and of the primary metals industry in Mexico, with the implication that aggregate chemical releases by manufacturing enterprises will rise in both of these countries.

Again, the scenario that assumes a ten percent increase in Mexico's capital

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[23] The output data, which were provided to us by Drusilla Brown, are those that were used in the calibration of the BDS model. Since these data are reported on an ISIC basis, we were forced to reclassify some industries in order to make them compatible with the SIC-based TRI data.

stock has quite different implications for Mexico. As noted before, such growth in the capital stock causes output to expand in every Mexican manufacturing industry. If the relationship between waste and output remains unchanged, then total chemical releases must rise.

While our estimates in this section must be taken with a large grain of salt, they suggest conclusions that accord well with intuition. Since Mexico enjoys comparative advantage in a set of activities (agriculture and labor-intensive manufactures) that on the whole are "cleaner" than the average, the composition effect of trade liberalization may well reduce pollution there. On the other hand, a NAFTA will cause the United States and Canada to specialize more in physical and human capital-intensive activities, to the possible (slight) detriment of their local environments. On the global level, a net benefit may derive from the movement of the dirtier economic activities to the more highly regulated production environments.

4 Conclusions

Environmental advocacy groups have pointed to several risks that might be associated with further liberalization of trade between the United States and Mexico. While they raise a number of valid concerns, our findings suggest that some potential benefits, especially for Mexico, may have been overlooked. First, a more liberal trade regime and greater access to the large U.S. market is likely to generate income growth in Mexico. Brown, Deardorff and Stern (1991), for example, estimate potential short run welfare gains to Mexico of between 0.6 and 1.9 percent of GDP. We have found, through an examination of air quality measures in a cross-section of countries, that economic growth tends to alleviate pollution problems once a country's per capita income reaches about $4,000 to

$5,000 U.S. dollars. Mexico, with a per capita GDP of $5,000, now is at the critical juncture in its development process where further growth should generate increased political pressures for environmental protection and perhaps a change in private consumption behavior. Second, trade liberalization may well increase Mexican specialization in sectors that cause less than average amounts of environmental damage. Our investigation of the determinants of Mexico's trade pattern strongly suggests that the country draws comparative advantage from its large number of relatively unskilled workers and that it imports goods whose production requires intensive use of physical and human capital. The asymmetries in environmental regulations and enforcement between the United States and Mexico play at most a minor role in guiding intersectoral resource allocations. But since it would appear that labor-intensive and agricultural activities require less energy input and generate less hazardous waste per unit of output than more capital and human capital-intensive sectors, a reduction in pollution may well be a side-benefit of increased Mexican specialization and trade.

Our findings must remain tentative until better data become available. We have been unable to use any information about the pollution situation as it currently stands in Mexico, since environmental monitoring there has been unsystematic at best. Furthermore, the kinds of pollutants that we can examine are limited by data availability (e.g., there are no reliable data on emissions of carbon dioxide in different countries). Still, one lesson from our study seems quite general and important. The environmental impacts of trade liberalization in any country will depend not only upon the effect of policy change on the overall scale of economic activity, but also upon the induced changes in the intersectoral composition of economic activity and in the technologies that are used to produce goods and services.

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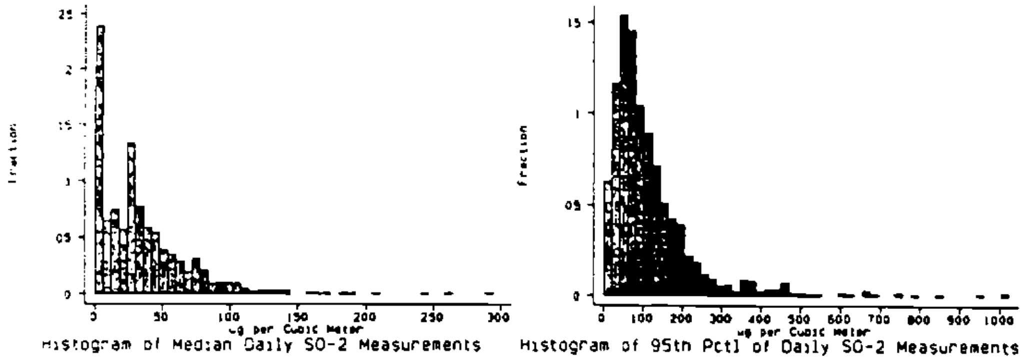
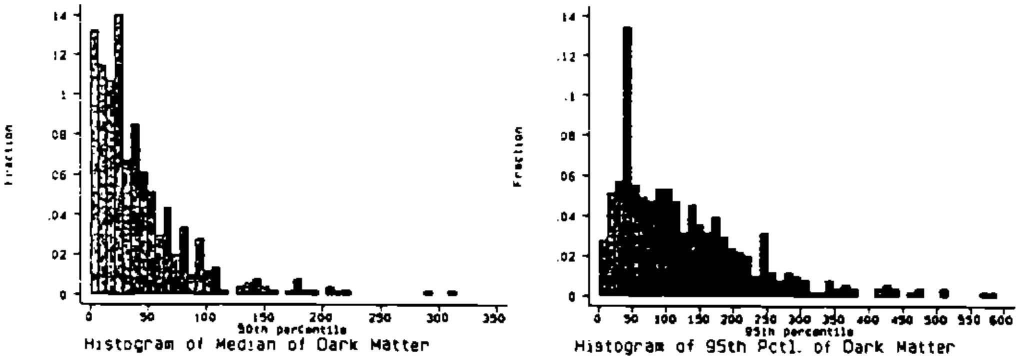
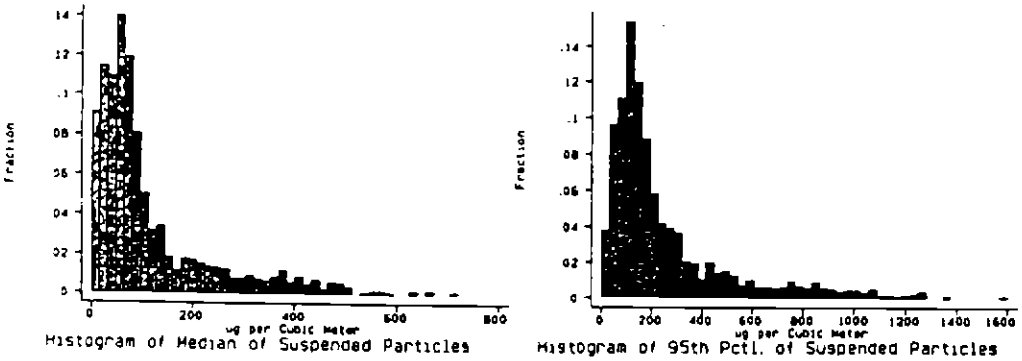
Figure 1: Histograms of Air Pollutants



Histogram of Median Daily SO-2 Measurements
Histogram of 95th Pctl of Daily SO-2 Measurements



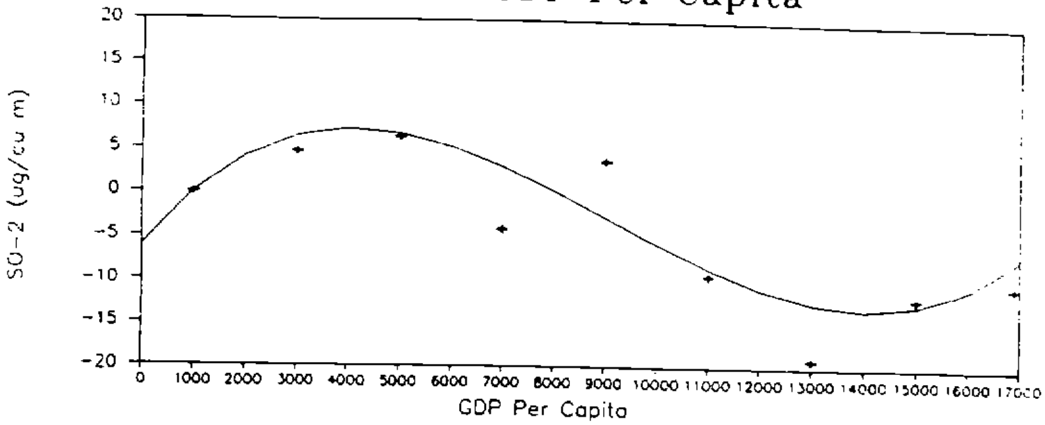
Histogram of Median of Dark Matter
Histogram of 95th Pctl. of Dark Matter



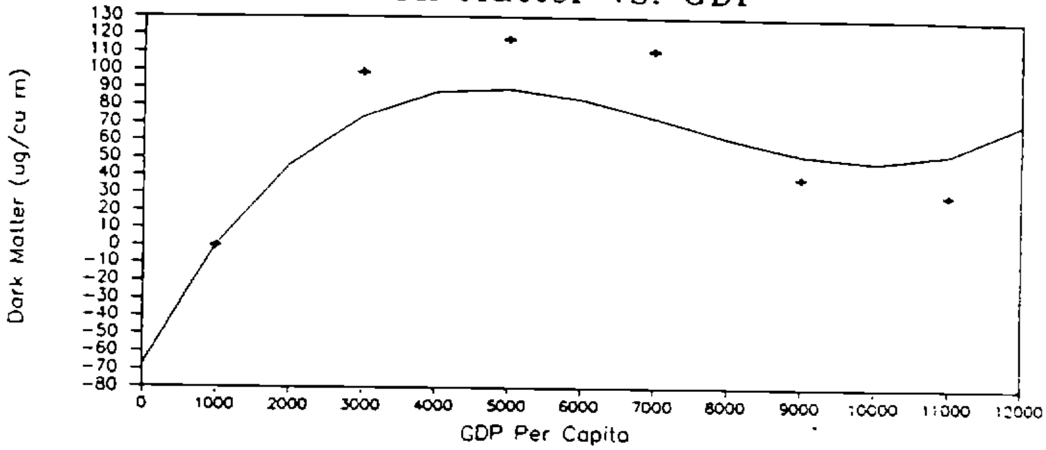
Histogram of Median of Suspended Particles
Histogram of 95th Pctl. of Suspended Particles

Figure 2: Fitted Cubic and Unrestricted Dummies

SO-2 vs. GDP Per Capita



Dark Matter vs. GDP



Suspended Particles vs. GDP

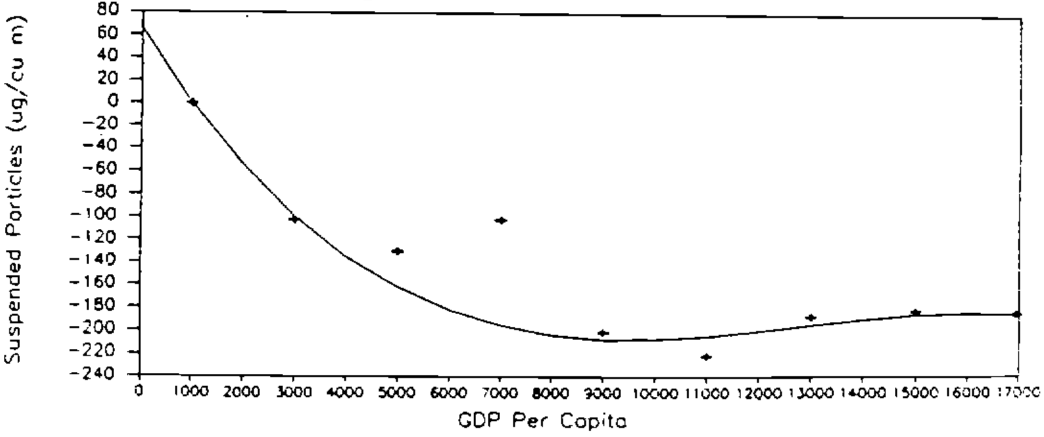


Figure 3
SO-2 vs. GDP Per Capita

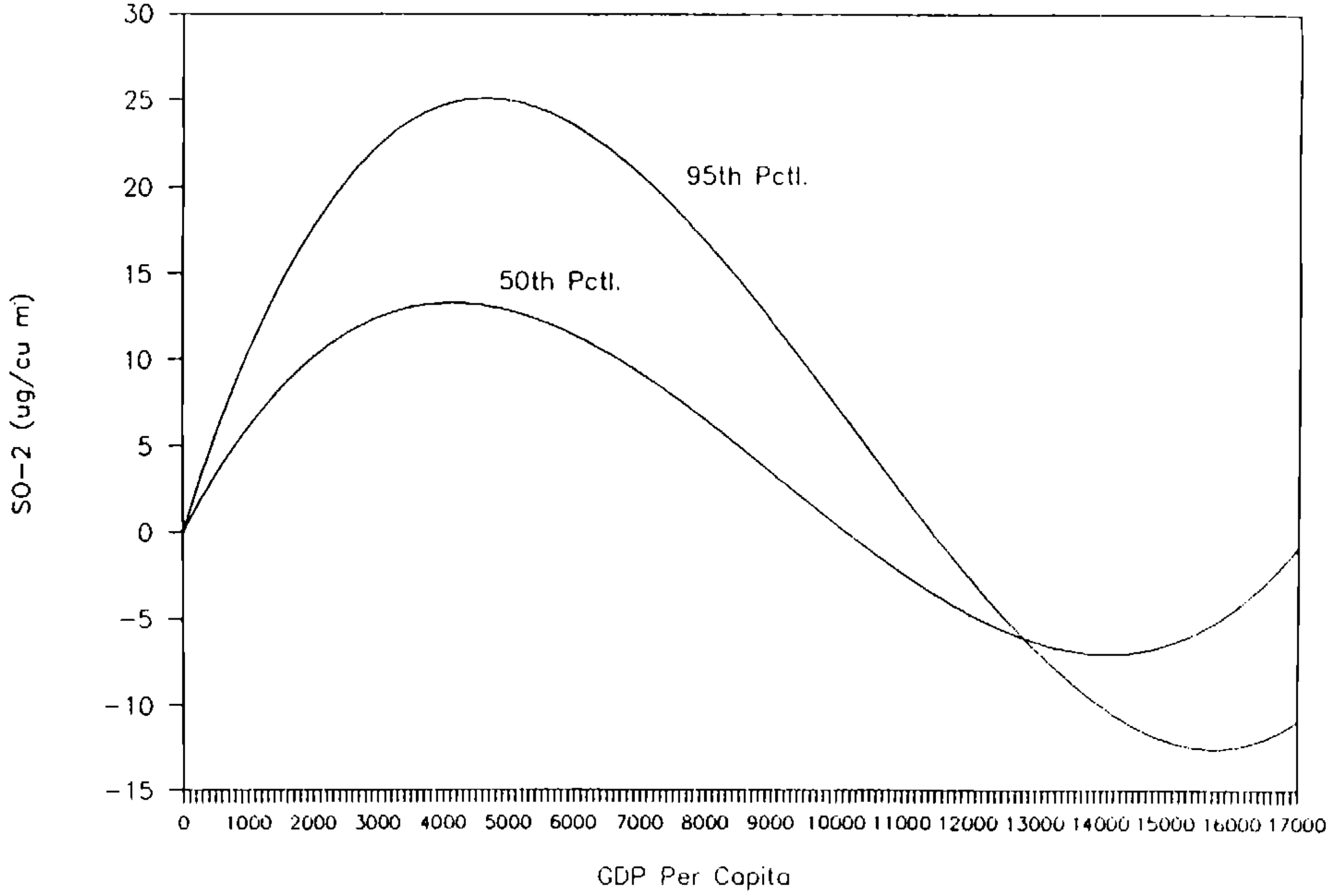


Figure 4
Dark Matter vs. GDP Per Capita

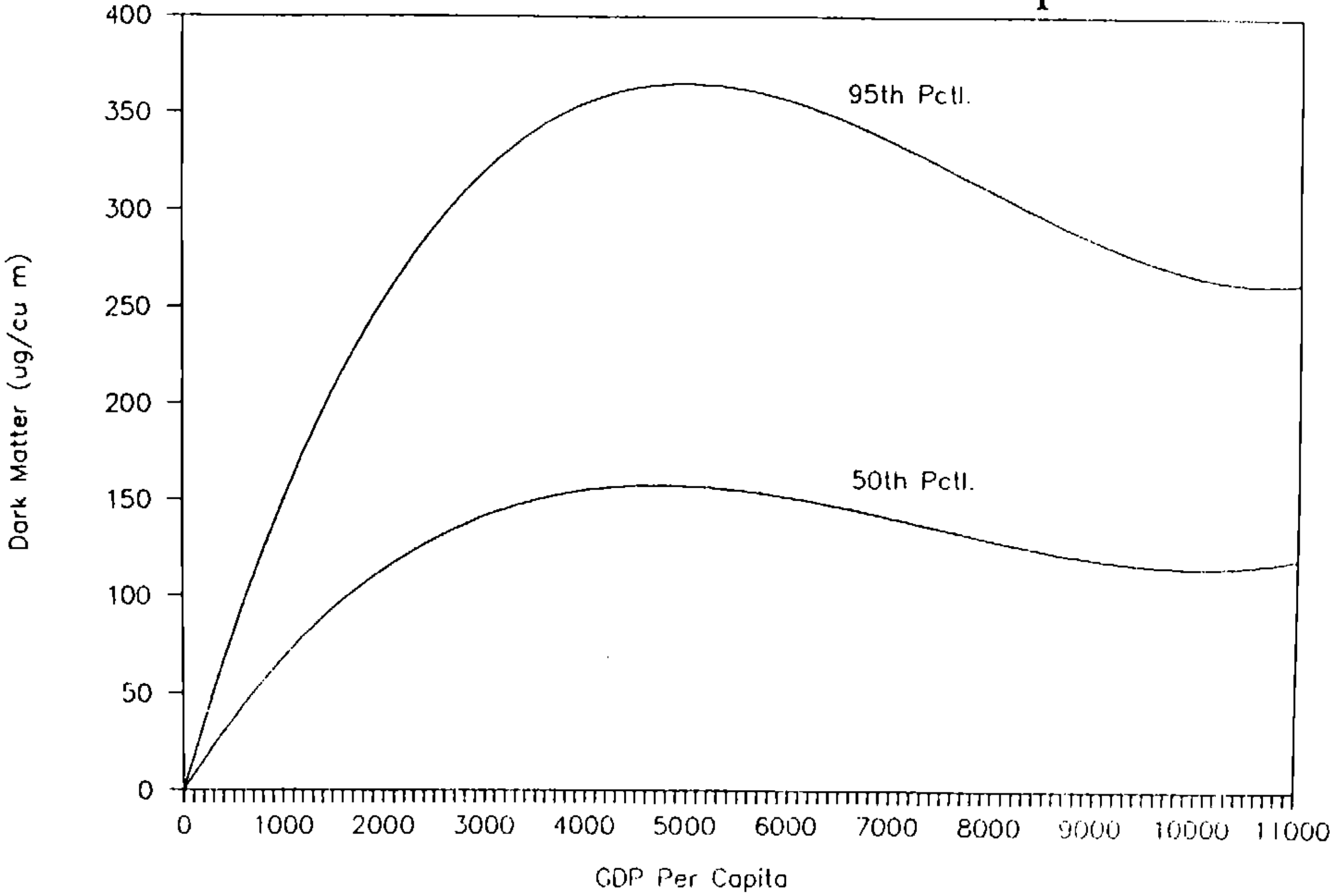


Figure 5

Suspended Particles vs. GDP Per Capita

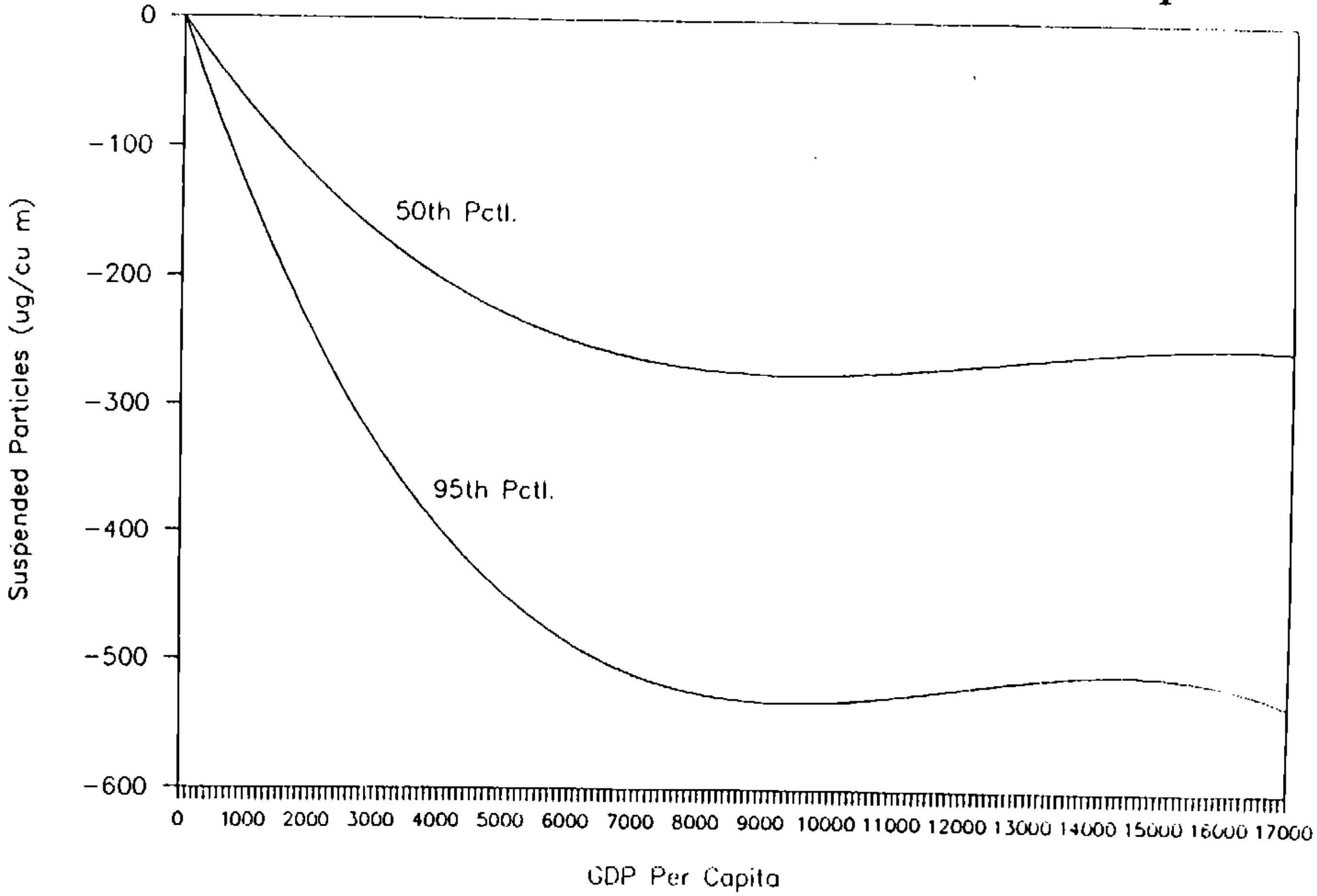


Figure 6: Fixed Effects Estimates - 50th Percentile

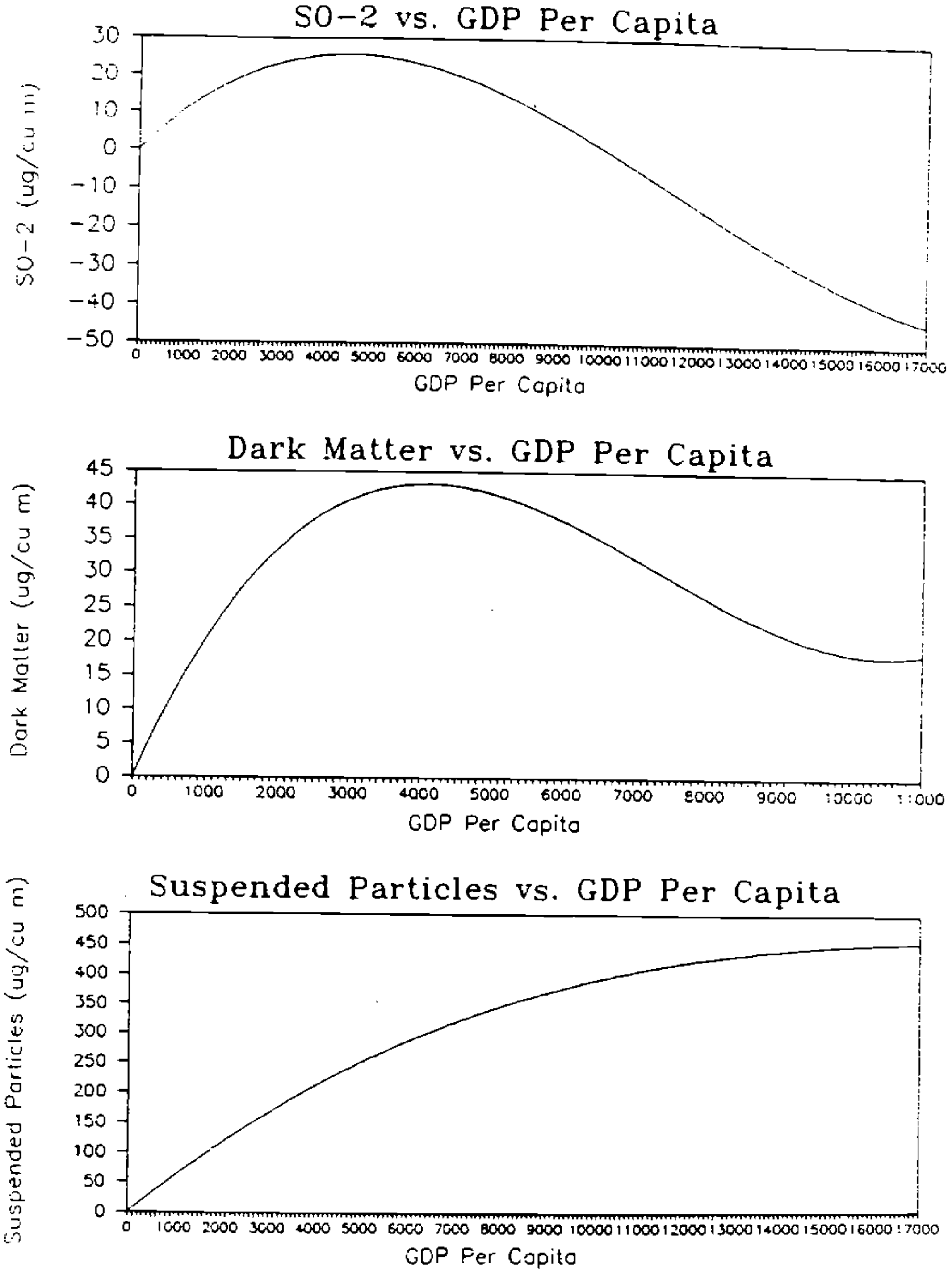


Table 1

Descriptive Statistics on Air Pollution in Urban Areas

Pollutant	Mean	Std. Dev.	Median	WHO Standard
Sulphur Dioxide 50th Percentile	33.08	33.11	26.2	40-60
Sulphur Dioxide 95th Percentile	117.17	112.71	87.0	100-150
Dark Matter 50th Percentile	42.22	41.92	29.5	50-60
Dark Matter 95th Percentile	127.47	101.45	102.0	100-150
Suspended Particles 50th Percentile	146.62	126.79	91.0	60-90
Suspended Particles 95th Percentile	301.01	268.01	187.0	150-230

Notes: Pollutants are measured in μg per cubic meter. World Health Organization standards listed for the 50th percentile are for the annual average measure, and those listed for the 95th percentile are for the 98th percentile of daily measures. Sample size is 1,370 for sulphur dioxide, 1,021 for suspended particles, and 506 for dark matter.

TABLE 2
The Determinants of Sulphur Dioxide Air Pollution
Random Effects Estimates
(Standard errors in parentheses)

Variable	50th Percentile			95th Percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Per Capita GDP $2,000 - $3,999	4.70	--	--	3.28	--	--
	(3.94)			(13.67)		
Per Capita GDP $4,000 - $5,999	6.43	--	--	23.45	--	--
	(4.19)			(14.57)		
Per Capita GDP $6,000 - $7,999	-4.15	--	--	-15.00	--	--
	(5.31)			(18.42)		
Per Capita GDP $8,000 - $9,999	3.91	--	--	20.80	--	--
	(4.55)			(15.79)		
Per Capita GDP $10,000 - $11,999	-9.33*	--	--	-3.58	--	--
	(4.40)			(15.26)		
Per Capita GDP $12,000 - $13,999	-19.07*	--	--	-3.58	--	--
	(5.74)			(19.82)		
Per Capita GDP $14,000 - $15,999	-11.82*	--	--	-24.62	--	--
	(5.11)			(17.61)		
Per Capita GDP $16,000 - $17,999	-10.28	--	--	-11.35	--	--
	(6.63)			(22.34)		
Per Capital GDP ($1,000s)	--	7.14*	11.22*	--	12.02	22.18*
		(2.50)	(2.64)		(8.66)	(9.22)
Per Capita GDP - squared	--	-1.12*	-1.44*	--	-1.68	-2.42*
		(0.34)	(0.34)		(1.53)	(1.18)
Per Capita GDP - cubed	--	0.041*	0.047*	--	0.055	0.068
		(0.013)	(0.013)		(0.043)	(0.044)
Coast	-8.68*	-6.68*	-5.73*	-52.62*	-46.79*	-45.27*
	(2.39)	(2.32)	(2.32)	(8.17)	(7.94)	(8.03)
Central City	9.45*	8.94*	8.94*	35.42*	34.33*	35.31*
	(1.83)	(1.82)	(1.86)	(5.76)	(5.73)	(5.77)
Industrial	1.58	1.32	1.74	10.95	10.39	9.65
	(1.95)	(1.94)	(2.01)	(6.06)	(6.04)	(6.12)

Residential	-5.30*	-5.71*	-4.97*	-4.08	-5.45	-3.23
	(1.96)	(1.95)	(2.01)	(6.10)	(6.08)	(6.14)
Pop. density (10,000/sq. mi.)	5.54*	4.09	10.31*	41.74*	35.43*	49.81*
	(2.65)	(2.57)	(4.64)	(9.27)	(8.97)	(16.30)
Year	-1.69*	-1.79*	-1.77*	-5.38*	-5.32*	-5.12*
	(0.36)	(0.34)	(0.35)	(1.21)	(1.18)	(1.22)
Communist	11.59*	11.47*	12.64*	88.05*	88.04*	90.77*
	(3.88)	(3.83)	(3.86)	(13.47)	(13.32)	(13.61)
Trade Intensity	--	--	-15.47*	--	--	-40.96*
			(4.38)			(15.36)
p-value for all GDP variables	.0001	.0001	.0001	.06	.07	.007
Per Capita GDP at which pollution reaches peak	--	$4,107	$5,257	--	$4,635	$6,182
		(1,327)	(1,179)		(3,309)	(2,963)
σ_ϵ^2	556	554	579	5,593	5,575	5,555
σ_a^2	368	378	323	5,431	5,541	5,232
R^2	.158	.150	.166	.132	.125	.138

Notes: Equations also include an intercept, a dummy to indicate that the type of area is unknown, and a dummy to indicate that the measurement device is a gas bubbler. σ_a^2 is the estimated variance of the common-to city component of the residuals and σ_ϵ^2 is the estimated variance of the idiosyncratic component of the residual. Sample size is 1,370 for columns 1, 2, 4 and 5; sample size is 1,301 for columns 3 and 6.

*Statistically significant at .05 level for a two-tailed t-test.

TABLE 3

The Determinants of Dark Matter Pollution
Random Effects Estimates
(Standard errors in parentheses)

Variable	50th Percentile			95th Percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Per Capita GDP $2,000 - $3,999	50.50* (11.77)	–	–	99.21* (31.77)	--	--
Per Capita GDP $4,000 - $5,999	58.25* (12.63)	–	--	118.05* (33.99)	--	–
Per Capita GDP $6,000 - $7,999	43.49* (13.10)	–	–	111.74* (35.23)	--	--
Per Capita GDP $8,000 - $9,999	21.26 (13.07)	–	–	39.85 (35.12)	–	–
Per Capita GDP $10,000 - $11,999	22.27 (13.04)	–	–	30.27 (35.17)	--	–
Per Capita GDP $12,000 - $13,999	27.29 (28.64)	–	–	16.01 (74.95)	–	–
Per Capital GDP ($1,000s)	–	79.33* (13.04)	30.52 (16.79)	–	173.84* (34.32)	113.19* (47.45)
Per Capita GDP - squared	--	-12.38* (2.05)	-5.08* (2.54)	--	-25.62* (5.38)	-16.45* (7.16)
Per Capita GDP - cubed	–	0.56* (0.10)	0.233 (0.121)	–	1.09* (0.26)	0.68* (0.34)
Desert	40.19* (8.61)	42.11* (8.49)	-10.12 (14.21)	113.03* (23.24)	118.14* (22.67)	44.27* (41.85)
Coast	-21.29 (4.94)	-21.75* (4.55)	-17.68* (4.52)	-35.85* (13.00)	-41.44* (11.87)	-33.46* (12.50)
Central City	9.55* (4.05)	8.26* (3.96)	10.95* (3.86)	32.41* (9.38)	20.32* (9.18)	21.44* (9.50)
Industrial	0.25 (4.23)	-0.55 (4.18)	-0.13 (4.06)	-5.95 (9.62)	-6.37 (9.51)	-5.92 (9.74)
Residential	-10.60* (3.98)	-11.56* (3.93)	-7.09* (3.87)	-21.64* (9.12)	-22.51* (9.01)	-15.20 (9.34)

Pop. density (10,000/sq. mi.)	1.32* (0.37)	1.35* (0.36)	2.92* (1.17)	0.70 (0.98)	0.94 (0.95)	4.75 (3.17)
Year	-0.26 (0.58)	-0.60 (0.56)	-0.59 (0.58)	0.41 (1.51)	-0.15 (1.45)	1.27 (1.59)
Communist	-20.44* (7.91)	-20.93* (7.54)	-14.44 (8.51)	-0.98 (20.87)	-9.73 (19.78)	7.56 (23.39)
Trade Intensity	--	--	-6.57 (6.35)	--	--	-12.05 (17.84)
p-value for all GDP variables	.0001	.0001	.0001	.0001	.0001	.0001
Per Capita GDP at which pollution reaches peak	--	$4,721 (771)	$4.240 (2,180)	--	$4,970 (973)	$4,971 (2,105)
σ_{α}^{2}	598	953	864	4,865	4,828	4,772
σ_{ϵ}^{2}	192	186	166	2,183	2,040	2,108
R^2	.345	.352	.210	.315	.315	.221

Notes: Equations also include an intercept and a dummy to indicate that the type of area is unknown. Sample size is 506 for columns 1, 2, 4 and 5; sample size is 457 for columns 3 and 6.

*Statistically significant at .05 level for a two-tailed t-test.

TABLE 4

The Determinants for Suspended Particles Pollution
Random Effects Estimates
(Standard errors in parentheses)

Variable	50th Percentile			95th Percentile		
	(1)	(2)	(3)	(4)	(5)	(6)
Per Capita GDP $2,000 - $3,999	-102.4*	–	–	-191.4*	–	–
	(11.9)			(25.4)		
Per Capita GDP $4,000 - $5,999	-129.7*	–	–	-247.4*	–	–
	(13.5)			(29.0)		
Per Capita GDP $5,000 - $7,999	-101.9*	–	–	-134.2	–	–
	(31.8)			(69.2)		
Per Capita GDP $8,000 - $9,999	-201.2*	–	–	-348.8*	–	–
	(22.4)			(47.1)		
Per Capita GDP $10,000 - $11,999	-221.1*	–	–	-425.0*	–	–
	(13.0)			(27.7)		
Per Capita GDP $12,000 - $13,999	-187.9*	–	–	-368.1*	–	–
	(14.6)			(31.6)		
Per Capita GDP $14,000 - $15,999	-183.1*	–	–	-366.2*	–	–
	(12.5)			(27.1)		
Per Capita GDP $16,000 - $17,999	-184.5	–	–	-381.2*	–	–
	(15.5)			(32.9)		
Per Capita GDP ($1,000s)	–	-71.97*	-72.54*	–	-144.31*	-146.48*
		(8.02)	(8.49)		(17.81)	(17.74)
Per Capita GDP - squared	–	6.03*	5.81*	–	12.65*	12.31*
		(1.08)	(1.10)		(2.28)	(2.28)
Per Capita GDP - cubed	–	-0.157*	-0.143*	–	-0.353*	-0.328*
		(0.043)	(0.040)		(0.085)	(0.084)
Desert	189.6*	213.3*	289.4*	354.7*	409.8*	489.5*
	(19.0)	(18.6)	(34.3)	(40.7)	(39.6)	(68.9)
Coast	0.42	4.47	2.90	-9.78	0.22	-4.39
	(7.73)	(7.58)	(7.41)	(16.41)	(16.01)	(15.43)
Central City	11.11*	12.99*	14.76*	32.52*	36.31*	39.11*
	(5.24)	(5.20)	(4.28)	(10.47)	(10.40)	(10.46)

Industrial	13.73*	15.23*	11.15	44.28*	47.55*	40.48*
	(5.79)	(5.77)	(5.91)	(11.55)	(11.49)	(11.66)
Residential	-12.17*	-9.67*	-9.45	-1.19	3.83	2.02
	(5.83)	(4.78)	(5.90)	(11.62)	(11.51)	(11.66)
Pop. density (10,000/sq. mi.)	5.20	-4.64	-17.55	-41.38	-43.97*	-74.43*
	(9.99)	(9.64)	(12.63)	(21.84)	(20.95)	(26.92)
Year	-2.06	-2.27*	-2.26*	-1.41	-1.65	-1.27
	(1.20)	(1.14)	(1.15)	(2.58)	(2.43)	(2.41)
Communist	90.52*	108.37*	107.81*	221.51*	256.46*	251.12*
	(13.21)	(12.65)	(12.54)	(28.68)	(27.28)	(26.52)
Trade Intensity	–	–	12.39	–	–	6.49
			(15.17)			(31.23)
p-value for all GDP variables	.0001	.0001	.0001	.0001	.0001	.0001
σ_a^2	3,379	3,350	3,482	12,950	12,793	13,085
σ_e^2	3,353	3,754	3,073	18,043	17,218	14,894
R^2	.581	.577	.574	.569	.582	.590

Notes: Equations also include an intercept, a dummy to indicate the type of area unknown, and two dummies to indicate the kind of instrument used to measure suspended particulate matter. Sample size is 1,021 for columns 1, 2, 4 and 5; sample size is 971 for columns 3 and 6.

*Statistically significant at .05 level for a two-tailed t-test.

TABLE 5

Random Effects Estimates of the Determinants of Air Pollution Including Fixed Site Effects (Standard errors in parentheses)

	SO_2		Dark Matter		Suspended Particles	
Variable	50 pctl	95 pctl	50 pctl	95 pctl	50 pctl	95 pctl
Per Capita GDP ($1,000s)	12.54* (4.69)	-8.28 (15.11)	24.35 (17.70)	77.89 (49.71)	63.44* (13.94)	142.18* (30.30)
Per Capita GDP - squared	-1.74* (0.52)	0.10 (1.67)	-4.15 (2.73)	-12.10 (7.66)	-2.84 (1.49)	-6.21 (3.23)
Per Capita GDP - cubed	0.05* (.02)	-0.00 (.06)	0.19 (0.13)	0.51 (0.36)	0.04 (0.05)	0.07 (0.11)
Year	-1.05* (0.28)	-3.51* (0.90)	-0.91* (0.42)	-1.12 (1.17)	-3.60* (0.82)	-5.58* (1.77)
No. of site dummies	239	239	87	87	161	161
p-value for GDP variables	0.0001	0.118	0.479	0.250	0.0001	0.0001
σ_a^2	161	1,951	141	1,070	919	3679
σ_e^2	97	982	93	755	512	2473
R^2	0.76	0.77	0.87	0.82	0.91	0.91

Notes: Sample size is 1,370 for SO_2, 506 for dark matter and 1,021 for suspended particles. The SO_2 equations also include a dummy for the measuring device, and the suspended particles equations include two dummies for measuring device.

*Statistically significant at .05 level for a two-tailed t-test.

TABLE 6

The Determinants of the Pattern of U.S. Imports from Mexico and of Value Added by Maquiladora

Independent Variables	Total US Imports from Mexico as Fraction of US shipments		Mexican Value Added in 807 Imports as Fraction of US Value Added		Maquiladora Value Added as Fraction of US Value Added	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	.028*	-.027*	.019*	.021*	.010	.015*
	(.008)	(.009)	(.006)	(.007)	(.007)	(.007)
Human Capital Share	-.053*	-.053*	-.016	-.015	-.015	-.016
	(.016)	(.016)	(.010)	(.010)	(.012)	(.011)
Physical Capital Share	-.024*	-.023*	-.026*	-.027*	-.011	-.016
	(.010)	(.011)	(.009)	(.010)	(.010)	(.011)
Pollution Abatement Costs as Fraction of US Industry Value Added	.014	.012	-.165*	-.151*	-.085	-.077
	(.060)	(.061)	(.073)	(.074)	(.098)	(.090)
Tariff Rate	-.002	-.001	--	--	--	--
	(.028)	(.029)				
Injury Rate	--	.005	--	-.011	--	-.028
		(.020)		(.016)		(.020)
R^2	.127	.127	.095	.095	.236	.392
Sample Size	135	135	136	136	19	19
Mean of Dependent Variable	.0069	.0069	.0022	.0022	.0012	.0012

Notes: Standard errors are in parenthesis. Columns (1) and (2) are OLS estimates. Columns (3), (4), (5) and (6) are maximum likelihood estimates of Tobit models.

*Indicates statistically significant at .05 level.

TABLE 7

Estimated Impacts of NAFTA on Toxic Releases by Manufacturing Enterprises
(Pounds in Thousands)

Industry	Trade Liberalization Only			Trade & Investment Liberalization		
	Mexico	U.S.	Canada	Mexico	U.S.	Canada
Food & Tobacco Products	5	17	40	129	10	39
Textile Products	22	499	39	169	487	42
Apparel	6	18	28	15	57	28
Lumber & Wood Products	-13	86	-88	76	74	-88
Furniture	128	210	176	257	148	178
Paper Products	55	1,198	-953	611	1,198	-971
Printing & Publishing	-10	52	-49	56	40	-48
Chemical Products	-1,430	12,198	-1,178	4,047	12,408	-1,180
Petroleum & Coal Products	62	93	19	29	70	19
Rubber & Plastic Products	-484	693	2,072	289	636	2,062
Leather Products	37	-26	181	158	-38	182
Stone, Clay, Glass & Concrete	0	124	152	107	112	152
Primary Metals	-15	-1,591	5,437	2,166	-1,452	5,494
Fabricated Metals	-1	558	254	259	530	254
Nonelectrical Equipment	-61	587	-103	62	569	-104
Electrical Equipment	1,445	-1,101	217	1,490	-1,091	217
Transportation Equipment	-178	-594	1,435	354	-594	1,424
Misc. Manufacturing	171	32	338	192	97	332
Total	-261	13,053	8,017	10,466	13,261	8,032