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Pollution Control and Foreign Direct Investment in Mexico: An Industry-Level Analysis

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Abstract Foreign direct investment (FDI) flows into developing countries have been increasing dramatically over the past decade. At the same time, there has been widespread concern that lax environmental standards are in part responsible for this surge. This paper revisits the question of the existence of a pollution haven effect by examining the extent to which the pollution intensity of production helps explain FDI in Mexico. We focus on pollution intensities, which are directly related to emission regulations, rather than unobservable pollution taxes and allow for substitution between capital and pollution. Examining several different pollutants, we find a positive correlation between FDI and pollution that is statistically and economically significant in the case of the highly regulated sulfur dioxide emissions. Industries for which the estimated relationship between FDI and pollution is positive receive up to 30% of total FDI and 30% of manufacturing output. Although we confirm the importance of Mexico's comparative advantage in labor-intensive production processes, consistent with the previous literature, our results suggest that environmental considerations may matter as well for firms' investment decisions.

Keywords Foreign direct investment · Pollution haven · Mexico

JEL Classification F21 · F23 · Q38

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1 Introduction

Concerns about the effects of environmental standards on trade and investment flows abound. There is much talk about a "race to the bottom", where developing countries in particular are said to be increasing their competitive advantage in the world economy due to lower labor and environmental standards. Some in the developed world view the lower standards as "unfair" cost advantages and have suggested ways to limit or eliminate them. For instance, the labor and environmental side agreements to the North American Free Trade Agreement (NAFTA) sought to level the "standards" between the United States and Mexico. The side agreements hoped to prevent Mexico, which has lower environmental standards, from becoming a pollution haven for US and Canadian firms trying to avoid the costs associated with more stringent domestic environmental standards.[1] However, the academic literature has reported very mixed results. Many studies fail to find empirical support for environmental standards to affect either trade or firms' investment decisions, with only a select few reporting significant effects.

A review of the literature is given by Jaffe et al. (1995) and Wheeler (2001), who conclude that there is hardly any empirical support for the existence of a pollution haven effect. More recently, Eskeland and Harrison (2003) find that abatement cost and pollution intensity do not affect foreign direct investment (FDI) into Morocco, Côte d'Ivoire, Venezuela, and Mexico. Smarzynska and Wei (2004) for a sample of 24 transition countries and Dean et al. (2005) in a study of China find some, though relatively weak evidence of a pollution haven effect, the latter only for investors from Hong Kong, Taiwan, and Macao. An exception is Ederington and Minier's (2003) study, which finds that environmental regulations significantly affect trade flows.[2]

There are a variety of factors, theoretical as well as empirical, that must be considered in a study of pollution haven effects. On the theoretical side, as a country develops and incomes rise, several forces are at work simultaneously. Low environmental standards during the early stages of industrial development should attract a disproportionate amount of polluting industries, which is a composition effect. Moreover, the increased scale of production should give rise to more pollution. On the other hand, as new factories replace their older and more polluting counterparts, pollution will decrease due to this "technique effect". In particular, as multinational firms locate new plants in developing countries, they generally do so using state-of-the-art technology. Thus, the net effect of pollution standards on investment and trade flows depends on the relative strength of composition, scale and technique effects (see Copeland and Taylor 2003).

On the empirical side, many studies face problems such as unobserved heterogeneity, aggregation bias or possible endogeneity of proxies for environmental stringency (Levinson and Taylor 2004). Since decisions on output, inputs, and pollution abatement are made simultaneously, regressions of trade or FDI on pollution abatement costs have produced counter-intuitive results, e.g., significant pollution haven effects for less pollution-intensive industries (Kalt 1998; Grossman and Krueger 1993). Compounding these problems is the use of US data on pollution intensities and abatement costs to represent environmental

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[1] Environmental regulations and their enforcement in Mexico were very low until well into the 1980s. The scope of environmental regulation has picked up only recently. The agency in charge of enforcement of regulations is Procuraduría Federal de Protección al Ambiente (PROFEPA), whose factory inspections expanded during the 1990s from only a few per year to several thousand (Dasgupta et al. 2000). As far as compliance is concerned, in a confidential survey of 236 Mexican plants in the fall of 1995, Dasgupta et al. (2000) found that 52% of survey respondents admitted only occasional or no compliance with environmental regulations.

[2] See also Lucas et al. (1992), Hettige et al. (1996), and Mani and Wheeler (1998).

regulations of both developed and developing countries (Eskeland and Harrison 2003). When economy-wide data are used, the composition of GDP may change over time, thus attributing changes in pollution output to changes in environmental stringency instead of this composition effect. Finally, when many unobserved characteristics of industry, such as the labor intensity of production, are not controlled for in empirical analyses, the resulting estimates are likely to be biased.

Another reason why developing countries do not tend to become pollution havens may be that the stringency of a country's environmental standards is only one, and perhaps not the most important, factor determining comparative advantage among countries (Ederington et al. 2005). In particular, endowment of factors such as skilled labor and capital largely determine where industry is located and which goods a country will export. To the extent that heavily polluting industries also tend to be capital-intensive, the relative paucity of capital in developing countries may outweigh their abatement cost advantage (Antweiler et al. 2001; Cole and Elliott 2005).

This study contributes to the literature on the existence of pollution havens in several ways. First, we use pollution intensities, which follow directly from emission control, as a measure of the stringency of environmental standards (Xing and Kolstad 2002). The focus on pollution intensity is useful since it allows for substitution between capital and pollution and does not require data on unobservable pollution taxes. It is also consistent with actual US policy, which does not impose taxes but rather regulates emissions directly by setting distinct limits that plants must attain (Kunce and Shogren 2002).[3] Second, we focus on FDI rather than trade since we consider a developing host country, Mexico, which tests the hypothesis that firms invest there to take advantage of environmental standards which are less strict.[4] This is in contrast to studies that focus on trade flows which can help assess whether stricter environmental standards harm domestic industry, which is a more appropriate approach when studying developed countries. Third, by looking at one developing host country for which we have detailed information on industry-specific pollution by type of pollutant, we avoid some of the measurement problems of earlier studies. Fourth, we have industry level information on FDI and can identify the source country of investment, allowing us to control for a range of determinants of FDI known to matter, which greatly reduces the likelihood of spurious correlations.

In our empirical work, we focus on three distinct pollutants, sulfur dioxide (SO_2), nitrogen oxide (NO_x), and particulates (PT), which were chosen on the conditions that make them relevant for a study of the effects of pollution concentration on economic activity (Antweiler et al. 2001). These three pollutants are largely regulated at stationary sources. Others, notably carbon monoxide, are regulated at mobile sources, i.e. regulations are imposed on engine design rather than the production process. Still, the scope of regulation varies among the pollutants we focus on. For instance, the US Environmental Protection Agency (EPA) has imposed NO_x limitations mostly on coal-based power plants, whereas SO_2 regulations affect metal and cement processing, petroleum refineries and others in addition to power plants. It thus seems plausible that the correlation between FDI and pollution varies across pollutants and in fact may only be positive for the most regulated pollutants.

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[3] Pollution intensities have also been used by Eskeland and Harrison (2003) and Smarzynska and Wei (2004), among others, although usually in a complementary fashion to other pollution control measures. The disadvantage from using pollution intensities is that they could also depend on a plant's age and management practices, which can be controlled for only in plant-level studies.

[4] It could also be the case that standards are enforced less strictly. However, compliance with pollution regulations tends to be considerably higher for multinationals than for domestic firms. E.g., in a survey of industrial plants in Indonesia 80% of multinationals reported good or superior compliance (Dasgupta et al. 2000).

Indeed, we find a significantly positive relationship between pollution intensity and FDI in Mexico only in the case of sulfur dioxide, whose primary source is industrial production, and then only in industries with large firms. However, these Mexican industries receive as much as 30% of total inward FDI and account for as much as 30% of total manufacturing output, but results do vary considerably depending on the empirical specification. At the same time, there are a number of industries for which the FDI-pollution relationship is negative, suggesting that environmental regulations enforcing a lower emission intensity may not necessarily deter FDI inflows, ceteris paribus. Consistent with the previous literature on the determinants of FDI, we also find that firms invest in Mexico in accordance with its comparative advantage in labor-intensive production.

The remainder of the paper is organized as follows. The next section builds a simple theoretical model that derives the demand for foreign capital as a function of inputs, pollution levels and other economic variables. Section 3 lays out the empirical framework employed and discusses some econometric issues as well as the data used. This is followed by a discussion of results and conclusions.

2 A Theoretical Model of FDI and Emissions

Following Copeland and Taylor (2003), we consider a firm that jointly produces two outputs, good X and emissions Z, using variable inputs of labor and capital. Abatement of emissions is a choice for the firm, and we assume that the firm allocates an endogenous fraction, θ, of its inputs to abatement activity. The production technology is therefore given by:

$$X = (1 - \theta)F(K, L), \tag{1}$$

where K and L denote capital and labor inputs, respectively. Pollution emitted is a function of total output and the abatement intensity, θ:

$$Z = \phi(\theta)F(K, L), \tag{2}$$

where $\phi(\theta)$ is a decreasing function of θ. With no abatement, $\theta = 0$, $\phi(\theta) = 1$ and pollution emitted is proportional to output: $Z = F(K, L)$. When abatement intensity $\theta > 0$, $\phi(\theta) < 1$ and pollution is reduced. Note that abatement and production use factors in the same proportion.

Rather than model the choice on abatement intensity (θ) explicitly, we transform the problem to choose the level of Z. To see this, let $\phi(\theta) = (1 - \theta)^{\frac{1}{\alpha}}$, $\alpha \in (0, 1)$ and $F(L, K) = TK^a L^b$(Cobb–Douglas). Then,

$$X = Z^{\alpha} T^{1-\alpha} K^{\beta} L^{\delta} \tag{3}$$

where $\beta = a(1 - \alpha)$, $\delta = b(1 - \alpha)$, and T is an indicator of the level of technology.

Prior studies on the pollution haven hypothesis have assumed that emissions, Z, are controlled using taxes, which are represented by abatement costs, and/or industry-specific (fixed) effects (Keller and Levinson 2002; Eskeland and Harrison 2003). The environmental policy literature has addressed the choice of policy instruments, taxes or permits, to control pollution (Weitzman 1974; Baumol and Oates 1988; Cropper and Oates 1992). Weitzman (1974) argued that permits often prove to be preferable over taxes in pollution control since they provide greater assurance against excessive emissions of harmful pollutants. Baumol and Oates (1988) suggested that marginal social benefits of emission reduction are likely to be steep for harmful pollutants, necessitating a quantity control over a pollution tax.

Cropper and Oates (1992) observed that environmental policies are often based on standards or quality targets along with a regulatory mechanism to achieve the standards. The 1990 US Clean Air Act requires companies to obtain a production permit, which limits their emissions of harmful pollutants (EPA; see also List et al. 2003). Mexico has also emphasized command-and-control regulation, where firms are required to comply with various permits and licenses (Dasgupta et al. 2000). Until recently, pollution control was largely a problem of enforcement, which increased dramatically in intensity since the early 1990s. Annual factory inspections rose from virtually zero to well over 8,000 per year for every year since 1993 (Procuraduría Federal de Protección al Ambiente (PROFEPA)). In summary, we feel justified in modeling emissions in the form of a quantity control or input constraint.

Firms minimize costs as follows:

$$\min_{L,K,Z} \; wL + rK$$

$$\text{s.t.} \;\; Z^{\alpha} T^{1-\alpha} K^{\beta} L^{\delta} \geq \overline{X}, \tag{4}$$

$$Z \leq \overline{Z},$$

where w and r denote the wage and capital rental rate, respectively.[5] The first constraint is the usual (given) output level, while the second constraint represents a ceiling on emissions (Xing and Kolstad 2002). The solution to the problem in Eq. 4 represents a long-run equilibrium, where we treat any slack in the emission constraint as a temporary perturbation. Profit-maximizing firms are expected to eliminate any slack, i.e. buy a permit with lower emission limits, lower costs and return to the long-run equilibrium path. Note that the predetermined limit on emission control is the result of political or regulatory competition within or across countries/regions, which is outside the scope of our model (Kunce and Shogren 2002).[6] With substitution possibilities among L, K and Z, and explicit prices for L and K, we anticipate that the second constraint holds under equality, i.e., full utilization of allowed pollution limits. The solution is expressed in the form of optimal L and K, denoted as L^o and K^o:

$$\begin{aligned} L^o &= \left[\overline{Z}^{-\alpha} T^{\alpha-1} \overline{X} \left(\tfrac{r}{w}\right)^{\beta} \left(\tfrac{\delta}{\beta}\right)^{\beta}\right]^{\frac{1}{\beta+\delta}} \\ K^o &= \left[\overline{Z}^{-\alpha} T^{\alpha-1} \overline{X} \left(\tfrac{w}{r}\right)^{\delta} \left(\tfrac{\beta}{\delta}\right)^{\delta}\right]^{\frac{1}{\beta+\delta}}. \end{aligned} \tag{5}$$

Note that

$$\frac{\partial K^o}{\partial \overline{Z}} = -\frac{\alpha}{\beta+\delta} \overline{Z}^{\frac{-(\alpha+\beta+\delta)}{\beta+\delta}} \left[T^{\alpha-1} \overline{X} \left(\frac{w}{r}\right)^{\delta} \left(\frac{\beta}{\delta}\right)^{\delta}\right]^{\frac{1}{\beta+\delta}} < 0, \tag{6}$$

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[5] Note that in the derivation of the cost function, we have allowed for constant, increasing or decreasing returns to scale. The value of $\beta + \delta$ determines the degree of returns to scale, where $\beta + \delta = 1$ implies constant returns.

[6] We therefore treat emission ceilings as exogenous. While some recent work has documented that these may be endogenously determined (Fredriksson et al. 2003; Ederington and Minier 2003), our partial equilibrium set-up focuses on location of production given an enviromental policy. Endogenizing pollution policy would require a general equilibrium framework as in Copeland and Taylor (2003) and cross-country information on political economy variables and disutility from pollution. An additional justification for assuming an exogenous pollution policy is the fact that most of our pollution data precede the FDI data (see Sect. 3.3).

which suggests a negative relationship (substitution) between optimal capital and emissions, given an output level $(\overline{X})$.

Then, the cost function is given by:

$$C(w, r; \overline{X}, \overline{Z}) = \omega \overline{Z}^{-\frac{\alpha}{\beta+\delta}} T^{\frac{\alpha-1}{\beta+\delta}} \overline{X}^{\frac{1}{\beta+\delta}} w^{\frac{\delta}{\beta+\delta}} r^{\frac{\beta}{\beta+\delta}} \tag{7}$$

where $\omega = \left[\left(\frac{\delta}{\beta}\right)^{\frac{\beta}{\beta+\delta}} + \left(\frac{\beta}{\delta}\right)^{\frac{\delta}{\beta+\delta}} \right]$.

The effect of emissions on cost of production is given by:

$$\frac{\partial C}{\partial \overline{Z}} = -\left(\frac{\alpha}{\beta+\delta}\right) \overline{Z}^{\frac{-(\alpha+\beta+\delta)}{\beta+\delta}} \left[\omega T^{\frac{\alpha-1}{\beta+\delta}} \overline{X}^{\frac{1}{\beta+\delta}} w^{\frac{\delta}{\beta+\delta}} r^{\frac{\beta}{\beta+\delta}} \right] < 0, \tag{8}$$

i.e., if $\overline{Z}$ increases, costs decline. If a country allows greater emissions either by lower taxes or lax regulations, it would lower the cost of producing $\overline{X}$.

Given the cost function above, consider a representative multinational firm that produces and sells in two markets: home and foreign.[7] The cost function for overseas production carries the * superscript for X, Z, K, L, T, w, r, α, β, and δ and is written in general form as $C^*(\overline{X}^*) = C^*(w^*, r^*; \overline{X}^*, \overline{Z}^*)$. Profit maximization in this context involves choosing both sales (S and S^*) and output ($\overline{X}$ and $\overline{X}^*$) in both markets:[8]

$$\pi = \max_{S, S^*, \overline{X}, \overline{X}^*} P_S(S, \eta)S + P_{S^*}(S^*, \eta^*)S^* - C(\overline{X}) - C^*(\overline{X}^*), \tag{9}$$

$$\text{s.t. } S + S^* = \overline{X} + \overline{X}^*,$$

where $P_S(.)$ and $P_{S^*}(.)$ are inverse demand functions with shifters η and η^* respectively, which represent other factors affecting demand such as aggregate market size. The solution to this multinational problem is one where the endogenous variables (S, S^*, $\overline{X}$, $\overline{X}^*$) are derived as functions of all exogenous variables. For instance, foreign production, $\overline{X}^*$, is given by:

$$\overline{X}^* = \overline{X}^*(\overline{Z}, \overline{Z}^*, T, T^*, \eta, \eta^*, w, w^*, r, r^*), \tag{10}$$

which implies:

$$\frac{\partial \overline{X}^*}{\partial \overline{Z}^*} = \frac{\partial \overline{X}^*}{\partial C^*} \frac{\partial C^*}{\partial \overline{Z}^*} > 0, \tag{11}$$

i.e., as $\overline{Z}^*$ is relaxed, the lower foreign production cost $\left(\frac{\partial C^*}{\partial \overline{Z}^*} < 0\right)$ leads to increased foreign production $\left(\frac{\partial \overline{X}^*}{\partial C^*} < 0\right)$.

The foreign investment demand, an optimal input demand function, is obtained from the cost function using Shephard's lemma:

$$\frac{\partial C^*}{\partial r^*} = K^* = K^*(w^*, r^*; \overline{X}^*, \overline{Z}^*). \tag{12}$$

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[7] While we do not include intermediate goods, it would be straightforward to extend the model to include multiple production stages. For instance, the cost function can be modified such that the locations of intermediate and final goods production are endogenous.

[8] With the modeling of output levels and consumption in each market, trade in goods ($S^* - \overline{X}^*$ or $S - \overline{X}$) becomes a redundant choice.

In the multinational problem, note that the foreign production level ($\overline{X}^*$) is endogenous in the foreign investment demand function. Therefore, the effect of emissions on foreign capital flows has two components:

$$\frac{dK^*}{d\overline{Z}^*} = \frac{\partial K^*}{\partial \overline{Z}^*} + \frac{\partial K^*}{\partial \overline{X}^*}\frac{\partial \overline{X}^*}{\partial \overline{Z}^*}, \tag{13}$$

where we showed earlier that $\frac{\partial K^*}{\partial \overline{Z}^*} < 0$ (substitution effect, Eq. 6). Since we optimize over $\overline{X}^*$ there is a second effect, which we refer to as the "output effect" (Eq. 11). An increase in emission substitutes for capital in foreign production, but the lower costs abroad increase foreign output as well. As foreign output increases, so does the demand for foreign capital. In general, the derivatives, $\frac{\partial K^*}{\partial \overline{X}^*}$ and $\frac{\partial \overline{X}^*}{\partial \overline{Z}^*}$, are both positive. The derivative $\frac{\partial K^*}{\partial \overline{X}^*}$ denotes the increase in foreign capital demand due to a unit increase in foreign output, while $\frac{\partial \overline{X}^*}{\partial \overline{Z}^*}$ depends on the pollution intensity of foreign production. Therefore, the net effect of emissions on foreign capital flows depends on the relative strength of the substitution and the output effects, which are presumably empirical questions. For instance, if the latter effect dominates, a higher ceiling on emissions would encourage foreign capital flows, despite K^* and $\overline{Z}^*$ substitutability.

3 Empirical Framework

The foreign investment demand function (12) from the theoretical framework is our FDI equation for the empirical analysis. To test the presence or absence of a pollution haven, we must identify the substitution as well as the output effect. For this purpose, we include home and host-country pollution controls, but interact the latter with host-country output. Other independent variables (controls) in the FDI equation are home and host country factor endowments (prices), and demand and supply shifters. Prior empirical FDI studies also guide us in the choice and specification of the conditioning variables (e.g., Markusen 2002; Brainard 1997; Carr et al. 2001; Yeaple 2003). The investigation of the output effect (13) requires us to explore functional forms, in particular those that allow for interaction between output and pollution. In this section, we outline our basic FDI specification as well as variations to ensure the robustness of our results. In addition, we discuss some econometric issues that arise from the data structure and describe the data, their sources and limitations, in more detail.

3.1 The Empirical Model

Our basic empirical FDI specification is:

$$\begin{aligned} FDI_{ijt} = {} & \beta_0 + \beta_1 pollutionmex_i + \beta_2 \left(pollutionmex_i * output_i\right) \\ & + \beta_3 pollutionsrc_{ij} + \beta_4 skillabundancemex_t + \beta_5 skillabundance_{jt} \\ & + \beta_6 capintensitymex_i + \beta_7 capintensity_{ij,t-1} + \beta_8 skillintensity_{it} \\ & + \beta_9 numplants_i + \beta_{10} MexGDP_t + \beta_{11} GDP_{jt} + \beta_{12} FDIaglom_{it} \\ & + \beta_{13} invcostmex_t + \beta_{14} tradeopenmex_t \\ & + \beta_{15} tradeopenpar_{jt} + \beta_{16} distance_j + \varepsilon_{ijt} \end{aligned} \tag{14}$$

The subscripts indicate each regressor's variation over time (t), across industries (i) and source countries (j). In the following, we discuss the sets of included variables in detail and relate them to the theoretical model of Sect. 2.

3.1.1 Pollution Variables

The variables $pollutionmex$ and $pollutionsrc$ denote Mexican and source country pollution intensities, respectively. Both are measured as tons per \$1 million in constant (1995) output for each industry i.

Emissions have a direct substitution effect on FDI flows, but there is an indirect effect that is a combination of the emissions effect on foreign production (pollution intensity) and output of foreign production. To capture these two effects, therefore, we include both pollution intensity and its interaction with plant output.[9] Applying the derivative in (13) to our empirical specification in (14) shows that:

$$\frac{\partial FDI_{ijt}}{\partial pollutionmex_i} = \beta_1 + \beta_2\ output_i \tag{15}$$

The expected sign of β_1 is negative, the substitution effect. The expected sign of β_2 is generally positive and for the pollution haven hypothesis to hold, the entire derivative in (15) would need to be positive.[10] Note the lack of time series variation in our pollution measure. While this is in part due to data limitations, where we explain the details in the next section, we emphasize that what we seek to investigate here is the presence or absence of a pollution effect in the determinants of FDI in Mexico. This is a static question which only requires a cross-section of data. Nonetheless, we utilize all available FDI observations and run a simple cross-section regression as a robustness check.

In our empirical work, we focus on three distinct pollutants, sulfur dioxide (SO_2), nitrogen oxide (NO_x), and particulate matter (PT). Antweiler et al. (2001) outline a number of conditions that make a pollutant relevant in a study of the effects of pollution concentration on economic activity. Similarly, we claim that for a pollutant to be useful for us, it should (a) be a by-product of goods production, (b) vary in emission intensity across industries, (c) be subject to regulations because of its noxious effect on the population, and (d) have abatement technologies available for implementation. The potential harm of a pollutant together with the possibility to avoid at least some of its effect through abatement gives rise to regulation which, in turn, affects the cost of production in different locales. In addition, for practical purposes, the choice of pollutants is driven by data availability. Antweiler et al. (2001) use only sulfur dioxide which they claim satisfies essentially all of the above properties. Others, e.g. Cole and Elliott (2003), use a number of pollutants to check the robustness of results to the choice of pollutant.

The scope of regulation and the source of emissions varies widely across pollutants and thus, we expect the results of our analysis to differ across pollutants. All three pollutants are regulated at stationary sources. This is not true for other pollutants, notably carbon monoxide,

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[9] In line with the theory, this should only be output of foreign-owned plants. Since the output data are not differentiated by ownership, total industry output must be used to calculate plant output. Note, however, that foreign-owned plants tend to be larger than domestically-owned ones and thus our results, if anything, will be biased against finding a pollution haven effect, which critically depends on the scale effect.

[10] One might expect to find a positive output effect as simply a scale effect: more FDI flows into industries with larger plant size. However, the correlation between average plant size and the share of FDI received by that industry is positive, but not statistically significant (the correlation is 0.18, p-value 0.24). If the automotive industry, which received the largest share of FDI, is excluded, the correlation is 0.12 with a p-value of 0.43.

which is largely regulated at mobile sources, making the location of production less relevant. The SO_2 regulations affect a much wider range of industries than regulations of NO_x or PT, which are largely imposed on coal-based power plants. Finally, the extent of industrial production processes being the source of emissions should be a rough indicator of the relevance of a particular pollutant to industry. OECD (2002) provides information on emission sources for pollutants for a number of countries and years. In 1999 US data, the main source of SO_2 emissions were industry and energy transformation, while the main source of NO_x (and to an even greater extent carbon monoxide) emissions was transportation.

3.1.2 Factor Prices and Endowments

Equations 10 and 12 suggest that there are a number of other determinants of foreign capital. To avoid omitted variable bias, we make use of the literature on the determinants of FDI to specify Eq. 14. If countries are in different cones of diversification, endowment differences reflect factor price differences. Following Markusen (1997, 2002), Carr et al. (2001), Blonigen et al. (2003) and Markusen and Maskus (2002), we use parent country and Mexican measures of skilled-labor endowments ($skillabundance$ and $skillabundancemex$) to capture such differences, rather than data on factor prices.[11] If FDI is, in addition to environmental considerations, determined by comparative advantage stemming from factor endowments, FDI should originate in countries that are skilled-labor abundant relative to Mexico. Skill abundance is measured as the endowment share of skilled labor in the source country and Mexico, respectively. As a robustness check, we also include aggregate measures of capital abundance (*capitalabundance* and *capitalbundancemex*).

In addition, FDI should flow into industries that are relatively unskilled-labor intensive. *Skillintensity* is measured as the share of skilled workers in an industry. This is consistent, e.g., with the definition used by Feenstra and Hanson (1997). Skill intensities exhibit substantial heterogeneity across sectors, ranging from 11 to 63% skilled labor (see the summary statistics in Table 1).

Similarly, Mexican and source country capital intensities are represented by *capintensitymex* and *capintensity*, which are measured as the ratio of the capital stock and total employment for each industry i. The source country's capital intensity variable is lagged by one period to avoid contemporaneous determination of FDI and capital stock in an industry.

3.1.3 Other Controls

Additional factors affecting industry-level FDI are plant and corporate scale economies and the degree of concentration.[12] Markusen (1997, 2002) and Brainard (1997) emphasize the

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[11] Markusen's (2002) "knowledge-capital model" assumes that headquarter services of a multinational firm (e.g. R&D) can be geographically separated from production activities and supplied simultaneously to several production facilities at low cost. The ordering of skill-intensities in the economy is such that headquarter services are more skilled-labor intensive than production, which in turn is more skilled-labor intensive than the rest of the economy. Then, if countries differ sufficiently with respect to their endowments such that they are in different cones of diversification, the skilled-labor abundant country will be the headquarter site, while the unskilled-labor abundant country will have a comparative advantage in hosting the production facility. Consequently, foreign investment in unskilled-labor abundant countries should flow into industries that are relatively unskilled-labor intensive.

[12] Recall that we allow for increasing returns to scale in the derivation of the cost function and the FDI demand equation.

Table 1 Summary statistics base sample

Variable	Unit	Median	Mean	Standard deviation	Minimum	Maximum
Real FDI	$1,000	0	5,141	42,733	−355,271	870,290
SO_2 Mexico	*	1,151	2,549	3,964	27.42	22,236
SO_2 source	*	433.9	1,279	2,608	5.727	14,096
NO_x Mexico	*	1,241	1,631	1,613	28.95	7,897
NO_x source	*	389.9	751.2	1,147	0.657	4,735
PT Mexico	*	917.2	2,038	2,769	13.40	11,871
PT source	*	111.6	440.2	833.6	0.328	4,779
capintensitymex	#	23.51	45.78	58.91	3.740	318.2
capintensity	#	75.58	104.0	107.5	8.697	756.9
skillabundancemex	Share	15.05	15.11	0.484	14.56	15.81
skillabundance	Share	34.77	33.11	7.077	15.70	46.09
skilldifferences		20.21	18.00	7.039	0.499	30.27
capitalabundancemex	#	67.24	67.81	3.025	65.29	74.79
capitalabundance	#	93.87	94.35	10.66	78.81	112.1
skillintensity	Share	25.52	28.62	10.89	11.23	62.77
industrysize	$million	1,892	2,946	3,543	93.44	23,366
numplants		1,892	5,600	8,470	27	38,029
output per plant	$million	0.993	5.797	11.54	0.015	53.21
MexGDP	$billion	321.6	324.0	27.79	286.6	375.2
GDP	$billion	460.6	1,674	2,382	141.2	9,049
SumGDP	$billion	804.3	1,998	2,384	433.3	9,424
FDIaglom	$1,000	13,809	269,909	692,964	−9,994	5,588,123
invcostmex	Index	62	62	3.038	57	66
tradeopenmex	Share	62.26	59.09	8.167	38.48	65.33
tradeopenpar	Share	68.67	68.96	32.16	16.44	172.8
distance	km	9,442	8,648	2,425	3,039	11,311

* All pollution intensities are measured as tons per $1 million in real output (base year = 1995)
Capital intensity and capital abundance are measured in $1,000 per employee
All dollars are real values with base year 1995

positive effect of firm level scale economies on FDI as headquarter services can be spread across many plants. However, FDI is negatively affected by plant scale economies, which encourage concentration of production. Finally, multinationals tend to operate in imperfectly competitive industries with positive profits and hence a high degree of concentration in an industry would also encourage FDI. Data availability precludes the use of the same measures used in Brainard (1997), so we use the number of plants (*numplants*) as a proxy for plant level scale economies. The advantage of our measure is that we use information from industries that FDI is actually flowing into. Both Brainard (1997) and Yeaple (2003) use US measures of scale economies, which may not be applicable to developing (host) economies.

For Mexico, output, the number of plants, and capital intensity is taken from the Industrial Census, which is conducted every 5 years. We use 1998 data, which is about the middle of our sample period. Industry-level data is also available from annual industry surveys, but a careful comparison of the two sources reveals that the data are not comparable. Since we expect e.g. capital intensities to change little over the 7 years of our sample, we do not think that the lack of time series variation in these variables affects the results. Also, our pollution variables lack time series variation, as explained above.

The inclusion of a number of additional controls follows the standard empirical FDI literature and is meant to ensure that we control for as many known determinants of FDI as possible in order to minimize spurious correlations due to omitted variable bias. Aggregate US and Mexican GDP, representing shifters η and η^* in the inverse demand functions, are also included in our empirical model. Parent country GDP is expected to be positive as larger countries tend to have more outward FDI in absolute terms. A positive coefficient on Mexican GDP would indicate the importance of host country market size.

The final elements that impact FDI in this framework are transport and more generally trade and investment costs.[13] If transport costs are low, a firm might substitute exports for foreign production. Parent country trade costs should have a negative effect on multinational activity of all types since exporting back to the home country would be more costly relative to home production. Host country trade costs, on the other hand, should encourage multinational activity, the well-known tariff-jumping argument. Host country investment costs should have a negative effect. The measure of Mexican investment cost accounts for both formal investment barriers as well as the overall economic climate that affects the decision where to invest. Source country and host country (Mexican) trade costs are measured by the ratio of exports plus imports to GDP, an often used measure of the trade openness of a country. This measure is used over others since it is available for the entire sample period. Since greater openness corresponds to lower trade costs, a positive sign is expected for parent country, but a negative sign for host country trade costs. Distance is measured as the distance between country capitals. Its sign is theoretically ambiguous since it can proxy for both trade and investment costs.

Finally, the inclusion of accumulated FDI, $FDIaglom$, recognizes the fact that more FDI tends to flow into industries with a previous presence of foreign investors, due to positive spillover effects or the availability of specialized inputs. Wheeler and Mody (1992), for example, find strong evidence that agglomeration economies positively affect FDI.

3.2 Econometric Issues

The theoretical model derives an expression for the demand of foreign capital, that is the foreign capital stock, K^*. However, we observe capital flows F^* in the data. A partial adjustment model describes flows as

$$F_t^* = (1-\alpha)\left(K_t^* - K_{t-1}^*\right) \tag{16}$$

where α is an adjustment parameter. Substituting Eq. 12 into 16 relates capital flows to all the determinants of the model. Additionally, the lagged capital stock is included, which we proxy with accumulated FDI, by industry. To the extent that reported capital stock data are compiled from historical flows, this should be a good approximation. Still, we do construct a proxy for industry level FDI stocks from aggregate stock and our flow data, using the perpetual inventory method, and re-estimate the model with this dependent variable.

Since there are many source country-industry pairs with no FDI in a given year, there is a prevalence of zeros in the data. Hence, we estimate a tobit model. While FDI flows can

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[13] We do not include these in our model in order to keep it tractable and focus on the pollution control issue. Markusen's (2002) model, which cannot be solved analytically, provides an in-depth treatment.

be positive or negative for a given industry in a given year (they are negative for disinvestments), their negative value cannot exceed the stock of FDI. Specifically, let F^{desired} be a latent variable signifying the amount of the desired foreign investment flow. We observe

$$\begin{array}{ll} F = F^{\text{desired}} & \text{if } F^{\text{desired}} \geq 0 \\ F = F^{\text{desired}} & \text{if } F^{\text{desired}} < 0 \text{ and } \left|F^{\text{desired}}\right| \leq K^* \\ F = -K^* & \text{if } F^{\text{desired}} < 0 \text{ and } \left|F^{\text{desired}}\right| > K^* \end{array}$$

Again, since no stocks are observed, observations are treated as censored if an industry-year-source country observation is zero and there has not been a positive flow in that industry in a previous time period. If anything, this treats too many observations as censored and results are biased against finding significant effects.

Since not all regressors vary along all dimensions, disturbances may be correlated within groups. While the coefficients would still be unbiased, they are inefficient and variances and hence standard errors could be biased. We employ the correction suggested by Moulton (1986). Note that this takes care econometrically of the lack of time series variation in the pollution data. Finally, industry size varies substantially, implying potential heteroscedasticity in the error structure. We deal with this issue by using (the inverse of) industry size as weights and estimating robust standard errors.

3.3 Data

FDI data come from the Mexican National Statistical Institute (INEGI). These are nominal FDI inflows into Mexico in US dollars from 1994 to 2000.[14] The data are at the 4-digit industry level, using the Mexican Industrial Classification System (CMAP), which is very similar to the 1968 International Standard of Industrial Classification. We focus on manufacturing only. Within this sector, the bulk of FDI goes into production of metal products, including automobiles. Thus not surprisingly, many automobile manufacturers, such as General Motors, Ford, DaimlerChrysler and Volkswagen, are among the largest foreign investors.

For the entire sample period, FDI inflows fluctuate around $10 billion per year. This is considerably more than Mexico received on an annual basis prior to 1994. Foreign investment flows were low for much of the 1980s. The first substantial increase in FDI in the late 1980s and early 1990s coincided with a major overhaul of Mexico's investment laws in 1989. Many obstacles to foreign investors, such as licensing requirements and restrictions pertaining to majority ownership, were removed. This change reversed Mexico's long-standing policy of reserving ownership in many sectors to Mexican nationals or the Mexican state and encouraging foreign investment only in sectors that were deemed crucial to the pursuit of import substitution policies. At the same time, and earlier than in many other countries in the region, substantial privatizations occurred. By 1994, the number of state-owned enterprises had decreased to only 80, down from 1,155. However, foreign investors participated in this sale only to a small degree. FDI from privatization constituted only 7.9% of total FDI between 1990 and 1995 (Franko 1999, pp. 158–161). Yet, during the first half of the 1990s, Mexico was the major recipient of FDI in Latin America, with a big surge occurring in 1994 after the inception of NAFTA.

During the sample period, most FDI comes from the United States (about 60%), followed by European Union countries (about 20%). The only other major source countries of FDI are Japan and South Korea. Not surprisingly, investments from developed countries

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[14] These are converted to real flows in the estimation below. Note that the detailed information on FDI is not available prior to 1994 when Mexico started complying with World Bank standards for data collection.

vastly dominate Mexican inward FDI with negligible amounts from developing countries. Altogether, OECD countries account for over 95% of all FDI flows.

Data on pollution intensities are available for only a small number of countries and industries. For the purpose of this paper, we have data on US and Mexican pollution intensities. Since we are using the US data for all source countries of FDI, we restrict our base sample to a set of developed countries which are most likely to have similar pollution restrictions and include all countries for which we have information only as a robustness check.[15] The novel point is that we use different pollution intensity data for the FDI host country, Mexico. The data on pollution intensities for the US come from the World Bank's Industrial Pollution Projection System (IPPS). This comprehensive data set was developed in coordination with the US Environmental Protection Agency (EPA) and the US Census Bureau. The information is based on surveys of more than 200,000 US factories in 1987. While we would rather have more recent data, they are not available.[16] The data for Mexico have also been produced by the World Bank, in collaboration with Mexico's Instituto Nacional de Ecologia (INE). They derive from surveys of a total of 5,799 small, medium, and large firms, conducted from 1993 to 1995, thus largely preceding the FDI data. US pollutants are originally in pounds per $1 million in (1987) output and were converted to tons per $1 million in (1995) output. Mexican pollution intensities were originally in tons per employee, but were also converted to tons per $1 million in (1995) output, using employment and output information for each industry from the Mexican Industrial Census. As can be seen from the summary statistics in Table 1, average pollution intensities are higher in Mexico for any pollutant. Table 2, which provides more details on a 2-digit industry level, reveals that this is true for most, although not all sectors. Measured pollution intensity in the iron and steel industry in particular is higher in the US than in Mexico, which could be a reflection of the stock of plants being much older in the former compared to the latter.

Note that we cannot run a fixed effects model, since our measure of pollution is not time-varying and thus would be perfectly correlated with industry fixed effects. However, we do include a variety of other industry-specific variables such as skill- and capital intensity, unlike previous studies. In addition, we stress the advantage of using actual pollution intensity rather than abatement cost data and using host country, not US data, for Mexico.

For source countries, we take information on capital from the OECD's STAN database, where capital flows are converted to stocks using the perpetual inventory method. Unfortunately, there are a large number of missing values, leading to a dramatic drop in the number of observations. We therefore assume that technologies outside of Mexico are identical and can be represented by US technologies, where we have information on all the industries that we also have pollution information for.[17] A common source of skill data is the International Labor Organization (ILO). The ILO data measure the number of workers in a particular occupation and characterize some as skilled, some as unskilled, employing the skill definitions from Carr et al. (2001). A country's skill level then is represented by the share of skilled workers. Finally, GDP and exchange rate data come from *International Financial Statistics (IFS)*. For further details, see the summary statistics in Tables 1 and 2.

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[15] Specifically, our base sample consists of countries with an *International Financial Statistics* code below 160, accounting for about 90% of all FDI into Mexico during the sample period. See Table A1 for a list of countries and years of FDI data.

[16] Note that pollution intensities and FDI data are not contemporaneous.

[17] Again, since we limit our basic sample to developed countries, we do not think of this as an overly restrictive assumption.

Table 2 Summary statistics Mexican 2-digit industries

	SO_2 Mexico	SO_2 Source	NO_x Mexico	NO_x Source	PT Mexico	PT Source
31: Food, Beverages	3,683	473.3	1,865	426.9	4,274	324.3
32: Textiles, Apparel	3,407	305.5	2,236	354.9	772.3	78.04
33: Wood products	1,163	308.5	294.3	560.2	6,189	851.7
34: Paper, Printing	5,295	2,161	1,589	1,193	533.8	422.9
35: Chemicals, Pharma.	4,960	2,789	1,648	2,149	997.7	770.4
36: Glass, Clay	1,955	2,595	3,163	2,049	650.0	1,799
37: Iron, Steel	1,193	10,307	701.2	1,645	396.0	1,347
38: Metals, Machinery	344.6	121.5	1,222	108.0	1,325	26.69

	Cap. int. Mexico	Cap. int. Source	Skill int. Mexico	Numplants	Industrysize
31: Food, Beverages	45.20	98.71	34.08	55,519	25,498
32: Textiles, Apparel	13.24	35.24	19.07	54,500	12,159
33: Wood products	9.33	32.56	15.60	42,512	2,523
34: Paper, Printing	52.24	108.2	41.21	18,906	7,451
35: Chemicals, Pharma.	70.63	299.2	39.28	5,466	19,994
36: Glass, Clay	67.85	69.74	24.58	21,480	6,683
37: Iron, Steel	265.1	112.0	28.40	270	9,696
38: Metals, Machinery	20.86	78.58	26.71	58,952	51,523

Units as in Table 1
Everything except numplants and industrysize (which are totals) are averages

4 Results

Results are shown in Tables 3 through 5. We first focus our discussion on the most important pollutant, sulfur dioxide (Tables 3a and 3b). Our basic specification, an estimation of Eq. 14 in levels, is contained in the first column of Table 3a. The remaining four columns present specification checks on the included variables, the sample and alternative specifications of the dependent variable. Table 3b presents the estimated effect of pollution on FDI for the sample of all countries as well as a subset of the base sample, focusing on the US and excluding the automotive industry, which has received more FDI than any other industry during our sample period.

Recall from Eq. 15 that the coefficient on Mexican pollution intensity ($pollutionmex$) represents the substitution effect, which is expected to be negative. The coefficient on the interaction with output ($pollutionmex^*output$) reflects the output effect, which should be positive according to our framework. Looking at the basic specification in column (1), note that these two coefficients are indeed significantly negative and positive, respectively. A Wald test reveals that the two coefficients are jointly significant.[18] The negative coefficient on $pollutionmex$ shows that industries with lower emission intensities appear to attract larger

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[18] All three coefficients involving pollution intensity (including the source country one) are jointly significant as well.

Table 3a Estimation results for sulfur dioxide

Regressors	Dependent variable: inward FDI				
	(1)	(2)	(3)	(4) Cross section	(5) Dep. Var FDI stocks
pollutionmex	−8.233**	−8.264**	−8.129**	−5.525**	−59.83
	(3.836)	(3.830)	(3.832)	(2.864)	(39.24)
pollutionmex ∗ *output*	0.526**	0.529**	0.514**	0.814***	−0.237
	(0.230)	(0.231)	(0.216)	(0.185)	(2.281)
pollutionsrc	−8.168**	−8.145**	−8.238**	−4.142	−109.2**
	(3.999)	(3.984)	(3.995)	(2.680)	(52.56)
capintensitymex	−253.3*	−252.9*	−253.6*	−317.8**	11.56
	(135.7)	(135.5)	(134.3)	(122.9)	(1,602)
capintensity	−3.918	−5.162	4.504	21.02	1,198
	(88.61)	(88.77)	(85.54)	(69.52)	(1,214)
skillabundancemex	1,417	−22,213			14,151
	(8,382)	(18,042)			(17,549)
skillabundance	1,537	1,504		1,283*	8,465
	(1,319)	(1,310)		(725.6)	(9,305)
skilldifferences			1,634		
			(1,269)		
capitalabundancemex		−3,403*			
		(1,992)			
capitalabundance		−842.5			
		(1,530)			
skillintensity	601.9	608.7	575.8	572.3	6,854
	(563.7)	(564.9)	(532.5)	(446.6)	(5,156)
numplants	−1.316*	−1.312*	−1.319*	−1.024*	−8.606
	(0.708)	(0.705)	(0.704)	(0.540)	(5.568)
MexGDP	141.8	430.2			−2,560
	(158.5)	(389.6)			(2,023)
GDP	2.182	2.083		5.811	21.00
	(5.211)	(5.207)		(3.868)	(35.18)
SumGDP			9.147		
			(12.67)		
(*GDP differences*)^2			−0.001		
			(0.002)		
FDIaglom	0.036***	0.036***	0.037***		
	(0.007)	(0.007)	(0.007)		
invcostmex	1,477	2,050	1,044		−2,334
	(2,825)	(3,383)	(1,174)		(4,339)
tradeopenmex	153.3	1,493	550.2**		−3,814
	(475.7)	(1,222)	(276.0)		(4,779)

Table 3a continued

Regressors	Dependent variable: inward FDI				
	(1)	(2)	(3)	(4) Cross section	(5) Dep. Var FDI stocks
tradeopenpar	−492.9*	−500.1*	−397.8	−71.80	−2,913
	(265.9)	(266.3)	(272.9)	(202.0)	(2,970)
distance	−1.844	−1.932	−2.386	−0.380	−2.941
	(4.435)	(4.425)	(4.673)	(2.898)	(26.96)
Observations	3,956	3,956	3,956	598	3,841
Log likelihood	−7,993	−7,992	−7,993	−1,304	−8,516
Wald χ^2	655.2	713.3	298.4	218.3	40.57
Prob > χ^2, p-value	0.00	0.00	0.00	0.00	0.00
Joint significance of all pollution coeff., p-value	0.02	0.02	0.02	0.00	0.07
Joint significance of all Mex. pollution coeff., p-value	0.02	0.02	0.02	0.00	0.30
Share of FDI into industries with $\frac{dFDI}{dpollutionmex} > 0$	0.021	0.021	0.021	0.322	0
Share of output of industries with $\frac{dFDI}{dpollutionmex} > 0$	0.048	0.048	0.048	0.293	0
Beta coefficient *pollutionmex*	−0.76	−0.77	−0.75	−0.67	−0.69
Beta coefficient *pollutionmex* ∗ *output*	0.27	0.28	0.27	0.55	−0.02

Notes: All results from estimating a censored regression model as described in the text
Robust standard errors are in parentheses; ***, **, * denote significance at the 1, 5, and 10% level, respectively; all regressions include a constant (not reported)
Share calculations only include observations for which the derivative is significantly different from zero

FDI flows. This result suggests that environmental regulations enforcing a lower emission intensity may not necessarily deter FDI inflows, ceteris paribus. However, we need to consider the scale effect for a complete evaluation of the impact of environmental regulations. The total effect of Mexican pollution on FDI flows can be computed according to (15). It is negative for 84% of source country-industry pairs, suggesting that for the most part, the substitution effect dominates the output effect. However, larger firms also receive more FDI. Those industries where average output is large enough that the correlation between pollution intensity and FDI is positive account for close to 40% of total FDI flows during the sample period. Their share of total output is nearly 30%. Using the delta method, we can calculate which of these positive values are significantly different from zero. Doing this lowers the estimate of the share of FDI and output accounted for by these industries to 2.1 and 4.8%, respectively (shown at the bottom of Table 3a).[19] Note, however, that since SO_2 intensity is measured in terms of output, the total amount of pollution generated by these firms is not as small as these numbers might suggest at first. There is thus evidence of a pollution haven effect in the case of SO_2, although it is not too large.[20] Another way of illustrating the magnitude of the coefficients is to compute the effect of a one standard deviation change in an independent variable on the dependent variable (in standard deviations). These beta coefficients are shown for the pollution variable and the interaction term on the bottom of Table 3a. They are reasonable in magnitude and confirm that the substitution effect dominates the output effect for all but the largest industries.

The signs of other determinants of FDI are in line with the theory. Both source country and Mexican GDP coefficients are positive, although statistically not significant. The negative coefficient on the number of plants suggests that industries that receive more FDI are characterized by scale economies. Mexican skill intensity has the expected negative sign, but it is not significant. This might be because we already control for aggregate skill differences between source countries and Mexico, leaving no independent effect for sector-level skill differences. Mexican capital intensity of production, on the other hand, is significantly negative, confirming that Mexico has a comparative advantage in labor-intensive production.

To gauge the robustness of our results, we make various modifications to the basic specification. In column (2), we add economy-wide measures of the capital-labor ratio, separately for Mexico and the source countries. These can be viewed as proxies for aggregate factor price differences between Mexico and the source countries of FDI, to the extent that endowment differences reflect factor price differences. None of the results are affected. Note in particular the persistence of the quantitative importance of those investors for whom the correlation between pollution intensity and FDI is estimated to be positive.

Empirical FDI studies based on the knowledge-capital model usually include a measure of total (host and source country) market size, market size differences and focus on skill endowment differences, rather than skill endowments separately (e.g. Carr et al. 2001; Markusen 2002). Accordingly, column (3) replaces the separate measures of source and Mexican GDP and source and Mexican skill endowments with the sum of GDP, squared GDP differences and skill differences. All new variables have the expected signs, but are not significant. The pollution results are extremely similar, both qualitatively and quantitatively.

In column (4), we estimate (14) as a cross-section since, as pointed out earlier, ours is a static model and our time dimension is short in any case. Moreover, some of our variables have no time variation. We chose 1998 since this is the Census year from which we draw much of our industry information. Note that the signs and significance levels of our central variables of interest are virtually unchanged. Most notably, the direct pollution effect is significantly negative at the five percent level and a bit smaller, while the interaction term (the output effect) is now significantly positive at the one percent level and a bit larger. Thus, the estimated quantitative significance of industries for which the total pollution effect on FDI is positive is larger. Industries for which the total effect is positive account of about 30% of total FDI and output. The signs and significance levels of other variables are largely comparable.

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[19] This represents the iron and steel industry. Other industries with positive values (some signficantly so in other specifications discussed below) include artificial and synthetic fibers, nonferrous metals, oils and fats, and tobacco.

[20] Using either US abatement cost or pollution intensities, Eskeland and Harrison (2003) find no effect of environmental regulation on FDI in Mexico. Xing and Kolstad (2002), who use aggregate sulfur dioxide emissions and find some effects for two of the most polluting industries, chemicals and primary metals, do not include Mexico in their cross-country sample.

Table 3b Further estimation results for sulfur dioxide

Regressors	Dependent variable: inward FDI				
	(6) Extended sample	(7) U.S. only	(8) U.S. only stocks	(9) No auto.	(10) U.S. only no auto.
pollutionmex	−4.714**	−73.55***	−613.8***	−8.497**	−77.79***
	(2.117)	(21.74)	(184.6)	(3.971)	(13.78)
pollutionmex ∗ output	0.355**	7.759***	64.73***	0.537**	12.13***
	(0.140)	(1.929)	(15.46)	(0.246)	(2.436)
pollutionsrc	−3.452	59.63*	491.8*	−8.628**	132.1***
	(2.169)	(30.52)	(254.2)	(4.318)	(37.32)
capintensitymex	−303.0***	−7,460***	−61,637***	−256.3*	−12,645***
	(88.86)	(2,232)	(18,418)	(144.0)	(2,807)
capintensity	−56.35	527.1	4,032	−5.014	−101.1
	(59.25)	(570.6)	(5,205)	(92.49)	(614.7)
skillabundancemex	−937.9			1,740	
	(3,503)			(8,343)	
skillabundance	1,155**	−132,627	39,988	1,582	−131,013
	(501.1)	(86,089)	(116,519)	(1,368)	(98,903)
skillintensity	−117.3	5,912*	52,183*	584.4	11,835***
	(229.8)	(3,381)	(28,901)	(592.8)	(3,580)
numplants	−1.015**	−13.31**	−115.1**	−1.365*	−15.95**
	(0.394)	(5.792)	(49.38)	(0.731)	(7.196)
MexGDP	269.7**	−28,158	8,857	148.2	−27,499
	(129.5)	(17,787)	(27,543)	(156.7)	(20,635)
GDP	6.236***	1,854	−397.2	1.743	1,837
	(1.832)	(1,173)	(1,767)	(5.323)	(1,363)
FDIaglom	0.003			0.039***	
	(0.003)			(0.008)	
invcostmex	977.6	57,780	−6,958	1,479	58,803
	(1,278)	(38,210)	(49,781)	(2,809)	(43,683)
tradeopenmex	211.3	−46,691	11,741	181.2	−46,036
	(192.6)	(30,020)	(46,432)	(468.0)	(34,744)
tradeopenpar	51.99	−69,310	12,443	−522.5*	−69,709
	(74.51)	(50,851)	(46,892)	(275.7)	(56,078)
distance	−1.269			−1.911	
	(0.952)			(4.565)	
Observations	12,926	322	318	3,870	315
Log likelihood	−15,805	−816.8	−875.9	−7,152	−707.2
Wald χ^2	120.65	239.2	117.8	632.2	186.3
Prob > χ^2, *p*-value	0.00	0.00	0.00	0.00	0.00

Table 3b continued

Regressors	Dependent variable: inward FDI				
	(6) Extended sample	(7) U.S. only	(8) U.S. only stocks	(9) No auto.	(10) U.S. only no auto.
Joint significance of all pollution coeff., *p*-value	0.00	0.00	0.00	0.02	0.00
Joint significance of all Mex. pollution coeff., *p*-value	0.00	0.00	0.00	0.02	0.00
Share of FDI into industries with $\frac{dFDI}{dpollutionmex} > 0$	0.052	0.303	0.063	0	0.128
Share of output of industries with $\frac{dFDI}{dpollutionmex} > 0$	0.057	0.307	0.109	0	0.219
Beta coefficient *pollutionmex*	−0.78	−2.56	−2.48	−0.94	−3.01
Beta coefficient $pollutionmex * output$	0.33	1.52	1.31	0.33	2.65

Notes: All results from estimating a censored regression model as described in the text
Robust standard errors are in parentheses; ***, **, * denote significance at the 1, 5, and 10% level, respectively; all regressions include a constant (not reported)
Share calculations only include observations for which the derivative is significantly different from zero

Thus far, the results confirm the findings of previous literature: FDI into Mexico is driven by its comparative advantage based on factor endowments, specifically its abundance of (unskilled) labor. The novel result is that there is also a positive relationship between the ability to pollute in Mexico and FDI inflows. It is economically significant, but the precise quantitative effect does depend on the empirical specification.

In column (5) of Table 3a, we estimate a different model. We construct a measure of FDI stocks from aggregate stocks and industry-level flow data. The argument that a partial adjustment model predicts a close relationship between stocks and flows continues to hold, but it is possible to develop a measure of foreign capital, K^*, given the time series on flows. Indeed, while the direct pollution coefficient remains negative, it is no longer statistically significant. Neither is the interaction term and hence there is no evidence of an effect of pollution in this model. This could be due to the smaller variation in stocks compared to flows which makes it hard to trace out the small pollution haven effect.

Table 3b shows results from a different set of robustness checks. Two features of our data are peculiar. First, not only is the bulk of FDI from the United States, but our pollution information for source countries is from the US also and hence we have limited our sample to developed countries only. However, pollution restrictions may be similar across a larger set of countries. Column (6) reports results from a regression using all available information, more than tripling our sample size. The results with respect to pollution are nearly identical to the ones from the basic sample. The share of industries in FDI and output for whom the pollution-FDI relationship is significantly positive is slightly larger at 5.2 and 5.7%, respectively. The results for some of the control variables are even stronger as for example both source country and Mexican GDP are now significantly positive.

Next, we run our regression for the US only and report the results in column (7) for flows and column (8) for stocks. A second feature is that FDI in the automotive sector makes up about 25% of all FDI flows in the sample, from various source countries. Thus, we report the results from estimating our base specification without the automotive sector in column (9). Finally, column (10) runs a regression on US non-automotive FDI only. The results confirm most of our previous ones. For the three specifications that use only US data, the signs of the central variables of interest remain and are significant at the one percent level, whereas the economic significance of those industries for which the FDI-pollution relationship is positive varies considerably, although it is in all cases larger than in our base case. The share of FDI and output into industries for which the FDI-pollution relationship is significantly positive is highest for the full US sample using FDI flows, accounting for about 30%. Another difference to the basic results is that the beta coefficients on both Mexican pollution intensity and the interaction term are much larger for the US only sample, indicating that pollution control is of particular importance for these firms, more so than those from other countries.

Excluding the automotive industry in either the full or the US sample still gives us a quantitatively significant effect for industries with a positive FDI-pollution relationship in case of the latter. The share of non-auto industries for which this obtains is about 13%, the share of output of those industries is about 22%. We believe that these results largely underscore the robustness of our qualitative result on the pollution haven effect.

As we (and others) have argued, sulfur dioxide is the superior choice of pollutant to test for a pollution haven effect. Still, it is useful to re-run our regressions with other, less-regulated pollutants. If we find that there is no effect of the pollution intensity of other pollutants on FDI, it would further underscore that our finding of a positive relationship in the case of sulfur dioxide is indeed evidence of a pollution haven effect rather than a spurious correlation due to unobserved factors that affect both pollution intensities and FDI in the same direction.

In order to conserve space, we only show the coefficients, significance tests and estimated quantitative effects of the pollution variables, omitting other coefficients whose signs and significance levels are virtually the same as in the case of SO_2. Tables 4 and 5 show the results for nitrogen oxide and particulate matter, respectively. There is not a single case in which the coefficient on pollution intensity in Mexico is significantly negative, hence there is no evidence of any kind of substitution effect. In some regressions, the pollution coefficients are jointly insignificant. In that case, the share of FDI and output of industries with a positive relationship is set to zero. There are a number of regressions in which the interaction term (and for particulate matter the Mexican pollution coefficient) is significantly positive, in which case there is ostensibly a positive relationship between pollution intensity and FDI in all industries. This could be due to the nontradable nature of sectors that are intensive in these pollutants. These results are inconsistent with the predictions of the theory, and therefore we do not take them to indicate a pollution haven effect in the case of nitrogen oxide and particulate matter.

To sum up, our results indicate that for a highly regulated pollutant whose primary source is industrial production, SO_2, less strict environmental regulations appear to attract some polluting industries. These industries account for a non-zero fraction of FDI flows, output and overall emissions. Comparative advantage resulting from factor abundance continues to remain a significant determinant of the location of production. Pollution intensities of other,

Table 4 Results for nitrogen oxide

Regressors	Dependent variable: inward FDI				
	(1)	(2)	(3)	(4) Cross section	(5) Dep. Var FDI stocks
pollutionmex	−7.155	−7.164	−7.063	−3.007	−25.45
	(6.094)	(6.081)	(5.974)	(4.013)	(48.60)
pollutionmex ∗ *output*	0.739^{*}	0.745^{*}	0.730^{*}	1.518^{***}	2.858
	(0.411)	(0.410)	(0.389)	(0.313)	(5.244)
pollutionsrc	−1.021	−0.988	−1.259	−5.101	-168.7^{*}
	(8.567)	(8.564)	(8.456)	(5.749)	(88.11)
Observations	3,956	3,956	3,956	598	3,841
Log likelihood	−8,016	−8,015	−8,016	−1,307	−8,541
Sign., all pollution coeff.	0.11	0.11	0.10	0.00	0.17
Sign., Mex. poll. coeff.	0.05	0.05	0.05	0.00	0.62
Share of FDI into ind. with $\frac{dFDI}{dpollutionmex} > 0$	0	0	0	$1^{\#}$	$0^{\#}$
Share of output of ind. with $\frac{dFDI}{dpollutionmex} > 0$	0	0	0	$1^{\#}$	$0^{\#}$

Regressors	(6) Extended sample	(7) U.S. only	(8) U.S. only stocks	(9) No auto.	(10) U.S. only No auto.
pollutionmex	−2.591	6.775	59.66	−7.526	−4.406
	(3.418)	(39.60)	(328.8)	(6.329)	(43.53)
pollutionmex ∗ *output*	0.216	25.93^{***}	215.5^{***}	0.747^{*}	24.03
	(0.401)	(4.745)	(40.50)	(0.429)	–
pollutionsrc	0.233	-304.0^{***}	$-2{,}504^{***}$	−0.951	−117.5
	(4.458)	(86.85)	(723.6)	(8.818)	(115.8)
Observations	12,926	322	318	3,870	315
Log likelihood	−15,846	−809.4	−868.8	−7,175	−704.6
Sign., all pollution coeff.	0.70	0.00	0.00	0.12	–
Sign., Mex. poll. coeff.	0.50	0.00	0.00	0.06	–
Share of FDI into ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$1^{\#}$	$1^{\#}$	0	$0^{\#}$
Share of output of ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$1^{\#}$	$1^{\#}$	0	$0^{\#}$

Notes: All results from estimating a censored regression model as described in the text
Robust standard errors are in parentheses; ***, * denote significance at the 1, and 10% level, respectively
$^{\#}$ Share = 0 when pollution coefficients are insignificant. Share = 1 when the pollution interaction term is positive, but *pollutionmex* is insignificant

Table 5 Results for particulate matter

Regressors	Dependent variable: inward FDI				
	(1)	(2)	(3)	(4) Cross section	(5) Dep. Var FDI stocks
pollutionmex	4.603*	4.588*	4.694**	3.025*	38.09**
	(2.370)	(2.367)	(2.368)	(1.561)	(17.55)
$pollutionmex * output$	−0.158	−0.155	−0.151	0.534	−5.340
	(0.549)	(0.548)	(0.534)	(0.388)	(4.740)
pollutionsrc	−21.50*	−21.49*	−21.78*	−19.33**	−316.4*
	(11.38)	(11.39)	(11.43)	(8.318)	(175.1)
Observations	3,956	3,956	3,956	598	3,841
Log likelihood	−8,010	−8,009	−8,009	−1,308	−8,531
Sign., all pollution coeff.	0.10	0.09	0.10	0.05	0.14
Sign., Mex. poll. coeff.	0.15	0.15	0.14	0.09	0.09
Share of FDI into ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$0^{\#}$	$0^{\#}$	$1^{\#}$	$1^{\#}$
Share of output of ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$0^{\#}$	$0^{\#}$	$1^{\#}$	$1^{\#}$

Regressors	(6) Extended sample	(7) U.S. only	(8) U.S. only stocks	(9) No auto.	(10) U.S. only No auto.
pollutionmex	−0.962	35.25***	286.3***	4.788*	34.49***
	(1.303)	(13.16)	(112.1)	(2.453)	(13.63)
$pollutionmex * output$	−0.315	8.878***	72.48***	−0.175	10.30***
	(0.417)	(3.012)	(25.24)	(0.567)	(3.325)
pollutionsrc	−9.138*	−919.3***	−7, 577***	−22.22*	−850.0***
	(4.733)	(269.5)	(2,255)	(11.76)	(265.8)
Observations	12,926	322	318	3,870	315
Log likelihood	−15,835	−812.0	−871.7	−7,169	−707.7
Sign., all pollution coeff.	0.27	0.00	0.00	0.10	0.00
Sign., Mex. poll. coeff.	0.56	0.00	0.00	0.15	0.00
Share of FDI into ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$1^{\#}$	$1^{\#}$	$0^{\#}$	$1^{\#}$
Share of output of ind. with $\frac{dFDI}{dpollutionmex} > 0$	$0^{\#}$	$1^{\#}$	$1^{\#}$	$0^{\#}$	$1^{\#}$

Notes: All results from estimating a censored regression model as described in the text

Robust standard errors are in parentheses; ***, **, * denote significance at the 1, 5, and 10% level, respectively

Share = 0 when pollution coefficients are insignificant. Share = 1 when the pollution interaction term is positive, but *pollutionmex* is insignificant or positive

less-regulated pollutants do not appear to drive FDI flows. While this result in itself is novel, the inclusion of other robust determinants of FDI makes us confident that we have indeed isolated the effect of pollution intensity of an industry on FDI flows and that the results are unlikely to be due to omitted variable bias.

5 Conclusion

This study has tested for and quantified a pollution haven effect for the case of Mexico. We investigate whether FDI flows into Mexico are indeed affected by the pollution intensity of production. In spite of recent improvements in laws and enforcement in the wake of NAFTA, looser environmental regulation in Mexico may make it an attractive production location for polluting industries. The existing literature has largely failed to find much evidence of a pollution haven effect, in accordance with the notion that pollution abatement costs simply constitute too small a fraction of total cost to drive location decisions of firms.

We improve on and complement the existing literature in several ways. By focusing on pollution intensities rather than abatement cost, we allow for the substitution of pollution and capital and avoid the problem of identifying pollution expenditures. We have information on host country pollution intensities and thus do not need to assume identical pollution intensities in Mexico and its source countries. The availability of detailed FDI information, including the source country of investment, allows us to control for a wide range of determinants of FDI drawn from theory and thus greatly reduces the likelihood of finding spurious correlations.

We find that there is indeed evidence of a pollution haven effect. While only a few industries are estimated to have a positive correlation between pollution and FDI flows, these account for a nontrivial share of received FDI and output of up to 30%. At the same time, there are a number of industries for which the FDI-pollution relationship is negative. Other than that, FDI is largely driven by Mexico's comparative advantage in labor-intensive production processes. Finally, these results are obtained for sulfur dioxide emissions, a highly regulated pollutant that largely originates in industry. For other pollutants that are less regulated or come largely from non-industry sources, no systematic relationship between FDI and pollution is detected.

The finding that pollution and FDI flows have a positive relationship has important policy implications. Lowering developed (home) country environmental regulations may not be desirable or politically feasible, but options exist to induce a host country to raise its regulatory level (e.g., side agreements to NAFTA or EU accession). However, inducing one or a small group of countries to tighten regulation is likely to simply shift the problem of pollution-intensive production to other favorable developing-country hosts over time. Restricting imports from pollution havens may violate WTO agreements and likely addresses only a part of the problem if FDI is used instead to access host or other foreign country markets. It might be in the best interest of developed economies to achieve a minimum set of global environmental standards, which can provide policy options to regulate pollution locally and globally.

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Table A1 Countries and years

Base sample includes		Extended sample also includes			
Country	Years	Country	Years	Country	Years
United States	1994–2000	Finland	1994–2000	Peru	1995–2000
United Kingdom	1994–2000	Greece	1995–1999	Uruguay	1995–2000
Austria	1995–1999	Iceland	1995–1999	Venezuela	1995–2000
Belgium	1994–2000	Ireland	1995–1999	Israel	1995–2000
Denmark	1994–2000	Portugal	1994–2000	Egypt	1995–1999
Germany	1994–2000	Spain	1994–2000	Hongkong	1995–2000
Italy	1994–2000	Turkey	1995–2000	South Korea	1994–2000
Netherlands	1994–1999	Australia	1994–2000	Malaysia	1995–2000
Norway	1994–2000	New Zealand	1995–1999	Pakistan	1995–2000
Sweden	1994–2000	Bolivia	1995–2000	Philippines	1995–2000
Switzerland	1995–1999	Chile	1995–2000	Singapore	1995–1997
Canada	1994–2000	Colombia	1995–2000	Thailand	1995–2000
Japan	1994–2000	Costa Rica	1995–1999	Czech Republic	1995–2000
		Ecuador	1995–2000	Slovac Republic	1994–2000
		El Salvador	1995–2000	Hungary	1995
		Honduras	1995–2000	Poland	1995
		Panama	1995–1999	Romania	1994–2000
		Paraguay	1995–2000		

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