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FDI and the Capital Intensity of "Dirty" Sectors: A Missing Piece of the Pollution Haven Puzzle

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Abstract

In an increasingly integrated world, falling trade barriers mean that the role environmental regulations play in shaping a country's comparative advantage is greater than ever. This has lead to fears that "dirty" industries will relocate to developing regions where environmental regulations may be less stringent. A number of reasons have been offered to explain why, despite anecdotal evidence and the predictions of theoretical studies, little empirical verification for the existence of pollution havens has been found. Little attention, however, has been paid to the capital intensity of pollution intensive sectors. We investigate the relationship between US outward FDI and factor endowments across sectors to two developing countries. We highlight the role of capital and believe it partially explains why pollution havens are not more widespread. Our approach also highlights those countries that are likeliest to become pollution havens. A multivariate analysis reveals some evidence of pollution haven consistent behavior.

1. Introduction

In an increasingly integrated world, falling trade barriers mean that the role environmental regulations play in shaping a country's comparative advantage is greater than ever. If international competitiveness is influenced by differences in regulations, then changing trade patterns or the relocation of firms (foreign direct investment) may result in protectionist arguments for lower environmental regulations.[1] At the same time, in the US, the North American Free Trade Agreement (NAFTA) has rekindled fears that pollution intensive multinational corporations (MNCs) will relocate to Mexico where environmental regulations are less severe, the so-called pollution haven hypothesis.[2]

In the last 15 to 20 years, global FDI flows, and specifically those to developing countries, have increased considerably. In 1995 developing countries received US$90 billion (38%) of world wide FDI (World Bank, 1996), with the majority going to Asia (including China) and Latin America (UNCTAD, 1995). Such trends have encouraged a large literature examining the structural determinants of FDI flows (see, for example, Froot, 1993) and the relationship between FDI and productivity spillovers (see, for example, Aitken et al., 1996; Aitken and Harrison, 1999; Görg and Strobl, 2001). The relationship between FDI from industrialized to developing countries and the stringency of environmental regulations has, however, received relatively little attention and is the issue to which this paper contributes.

Of the papers that have examined the relationship between FDI and the environment, the majority generally find no firm link between industry abatement costs and

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developed country outbound FDI flows (see, for example, Dean, 1992; Zarsky, 1999; Fabry and Zenghi, 2000; Eskeland and Harrison, 2003). Indeed Repetto (1995) concludes that of the US foreign investment that went to developing countries, only 5% went to pollution-intensive sectors (compared to 24% of US investment to developed countries). Recent evidence that only examines US *inward* FDI has, however, had more success in finding a PHH effect (see, for example, List et al., 2001; Fredriksson et al., 2003; Keller and Levinson, 2002).[3]

The wider pollution haven literature that often focuses on trade flows, has also only found weak or mixed evidence for the PHH. Given the PHH's anecdotal and intuitive appeal, rather than trying to seek evidence for pollution havens, the more pertinent research question is to assess why we do not find more evidence.[4] In this paper, the authors suggest that one reason for the lack of pollution haven evidence, largely ignored within the literature, is the role of factor-endowments in the decision of a MNC to relocate or set up a plant in a foreign country. It has often been suggested that, like trade flows, foreign investment flows are at least partially driven by factor endowments, particularly those that flow from North to South (see, for example, Caves, 1982; Helpman, 1984; Markusen, 1984). If so, then we may expect a capital intensive firm to invest in a capital abundant country, whilst a labor intensive firm would prefer a labor intensive country. As is demonstrated, however, capital intensive sectors are also typically pollution intensive, yet capital abundant countries are typically those with some of the highest environmental regulations. Thus, this "capital-labour hypothesis" (KLH) appears to generate forces that oppose the PHH. The KLH implies that the capital abundant North will specialize in capital (and pollution) intensive production, whilst the labor abundant South will do the opposite. In contrast, the PHH implies that the low regulation South will specialize in pollution (and capital) intensive production whilst the North does the opposite. The opposing forces of the PHH and KLH may, therefore, explain why the empirical literature that tests the PHH finds at best mixed results.[5]

With these arguments in mind, the contribution of this paper is as follows. First, we demonstrate the relationship between the capital intensity and the pollution intensity of US industries, and also the link between the capital abundance of a country and the stringency of its environmental regulations. These empirical insights allow us to identify those countries that are most likely to become pollution havens. Second, with this information in mind, we undertake a detailed econometric analysis of the determinants of multi-sector outbound FDI to two countries who, by our reasoning, are indeed likely pollution havens—Mexico and Brazil. We provide a number of important insights into why pollution haven evidence has previously been so limited.

This remainder of the paper is organized as follows. Section 2 provides an overview of the previous theoretical and empirical literature on FDI flows. Section 3 then examines the linkages between capital, pollution intensity and environmental regulations, whilst section 4 provides the econometric analysis. Section 5 concludes.

2. Literature Review

This section provides a brief overview of some of the relevant theoretical and empirical issues relating to FDI. At a general level, FDI has potential benefits to both host and donor countries. The host may receive, for example, financial resources, new technology and management skills, employment and a skill-upgraded work force. The donor country on the other hand receives benefits over and above those associated with factor costs, and looks for a combination of cheap labor (with qualifications), reliable infrastructures, technological capabilities, local demand within an efficient market system and the stability of a range of political, institutional and legal environments (Van den Bulcke and Zhang, 1998).

The more recent FDI literature attempts to provide models of FDI that contain elements of industrial organization, the theory of multinationals and location theory.[6] The standard approach to FDI inflows to developing countries is based on endogenous growth theory where FDI increases the capital stock and technological know how, which in turn raises income and labor productivity in the host country, which eventually results in higher GDP and tax revenues. The externality, usually modeled via an augmented Cobb–Douglas production function (then taking logs and time derivatives to derive a standard growth accounting equation), can also be negative if there are substantial remittances of profits and dividends, or the MNC has obtained significant tax or other concessions from the host government that crowds out domestic investment.[7]

Trade theories based on factor proportions (Heckscher–Ohlin) that predict the pattern of trade have also been used to explain foreign investment patterns between the North and the South, based on vertical expansion motives so that *ceteris paribus* firms are attracted to locations where factors that they use intensively are cheaper than at home (see, for example, Markusen, 1984; Helpman, 1984; Helpman and Krugman, 1985; Ethier and Horn, 1990). Multinational activities should only arise, therefore, in a single direction between countries with large factor proportion differences. Although relatively successful at explaining North–South FDI flows, as Brainard (1997) and others have pointed out, the factor proportions approach cannot explain that proportion of FDI that occurs between countries with similar endowments of capital and labor (a similar result is observed for trade patterns with a large proportion of trade occurring in similar products between similarly endowed countries). An alternative approach is the proximity-concentration framework where the proximity to customers or specialized suppliers makes horizontal expansion attractive at the expense of economies of scale (see, for example, Horstmann and Markusen, 1992; Brainard, 1992).

This paper, however, is concerned with the effect of sectoral differences in environmental regulations and capital intensities between developed and developing countries. In this case, sectors differ in their capital requirements and hence the degree of outbound US FDI in a sector will be dependent on, among other things, a sector's capital requirements (which, in turn, are correlated with the level of pollution intensity in a sector, shown later). We must, however, be careful with our interpretation of capital requirements. In a sense capital captures elements such as infrastructure, availability of machinery, spare parts, buildings, telecommunications, etc. While an MNC could relocate with its own capital in terms of funding and technology, certain industries still require a threshold level of development or level of capital sophistication to be attractive as a given location.

Arguably, the only study to theoretically model the effect of capital intensity and environmental regulations on outbound FDI is Eskeland and Harrison (2003). Using a simple model, they demonstrate that the effect on outward FDI of an increase in environmental regulations may be ambiguous. This ambiguity arises from the possible complementarity between capital and pollution abatement, where more stringent environmental regulations could lead to an increase or decrease in investment by profit maximizing firms in both the host (developing) and donor (developed) countries.

The parameters of their simple model determine whether: (i) a firm in a given sector stays at home, keeps the old technology and pays the abatements costs; (ii) moves location and keeps the old technology and pays lower abatement costs (and shuts the existing plant); or (iii) remains at home and invests in cleaner technology and pays lower abatement costs.

In this paper, the authors propose that a firm may have a preference to invest at home due to the relative capital intensity of pollution intensive industries. This feature makes these industries ill-suited for relocation from developed to developing countries since the scarcity (and hence cost) of physical capital in developing countries relative to the cost of capital at home, may outweigh any benefit from lower environmental regulations (the KLH). This may, therefore, reinforce a developed country firm's decision to invest at home rather than abroad, and may be part of the explanation for the limited number of empirical studies that have found evidence for pollution haven consistent behavior. Using a gravity equation approach (based on an estimating equation consistent with the Eskeland and Harrison theoretical framework) we, therefore, investigate the relationship between a sector's outbound FDI and abatement costs. We also control for a number of other relevant variables such as capital-labor ratios, market size, transport costs, wage differentials, availability of skilled labor and trade openness that are common to many empirical FDI papers (see, for example, recent studies by Brainard, 1997; Braconier and Ekholm, 2000; Carr et al., 2001; Eskeland and Harrison, 2003).

3. Empirical Considerations

The Characteristics of US Industries

In order to illustrate the opposing forces of the PHH and the KLH, we examine the pollution intensity and the capital intensity of US industries. We employ data derived from the US Bureau of the Census that reports the pollution abatement operating costs (PAOC) of US industry up to 1994. Measured as an average for the period 1989–94, Table 1 provides a ranking of two-digit Standard Industrial Classification (SIC) industries, in terms of PAOC as a percentage of value added and physical capital intensity per worker (PCIpw). We define the PCIpw of a sector as non-wage value added per worker in thousands of 1990 US$.

Observe that PAOC as a share of value added is the highest for SIC 29 (Petroleum), SIC 33 (Primary Metals), SIC 26 (Paper), and SIC 28 (Chemicals industries). Hettige et al. (1994) also find these four industries to have some of the highest air and water pollution intensities.

A factor largely overlooked in the existing pollution haven literature, however, is that the sectors facing the greatest pollution abatement costs share a common feature. They are typically more capital intensive than cleaner, less pollution intensive sectors. Capital-intensive production processes appear to generate more pollution per unit of output than labor-intensive processes. We substantiate this assertion in a number of ways. First, Table 1 provides a ranking of each two-digit sector in terms of PCIpw (again measured as an average for the period 1989–94). The correlation between PAOCva and PCIpw is clear. The five sectors with the highest PAOCva, for instance, are also those with the highest PCIpw. Statistically, significant correlation coefficients are estimated at the two- and three-digit levels (123 industries) with correlation coefficients of 0.69 (*t*-statistic of 4.1) and 0.53 (*t*-statistic of 6.8), respectively. We also consider PAOC expressed in per worker terms and find a correlation of 0.67 with PCIpw (*t*-statistic of 9.6).[8] A scatter plot of PCIpw against PAOCva for our 123 US industries is presented in Figure 1.

Table 1. US Industries Ranked by Pollution Abatement Costs and Physical Capital Intensity (Average 1989–94)

	SIC sector	*PAOC % of v.a.*		*SIC sector*	*PCIpw*[a]
29	Petroleum and coal products	9.9	28	Chemicals and allied products	129.4
33	Primary metal industries	3.5	29	Petroleum and coal products	125.9
26	Paper and allied products	2.7	33	Primary metal industries	82.1
28	Chemicals and allied products	2.4	26	Paper and allied products	80.8
21	Tobacco products	2.3	21	Tobacco products	64.4
31	Leather and leather products	1.5	38	Instruments and related	57.4
32	Stone, clay and glass	1.4	27	Printing and publishing	48.8
34	Fabricated metal products	0.9	32	Stone, clay and glass	45.6
24	Lumber and wood products	0.8	20	Food and kindred products	45.1
22	Textile mill products	0.8	36	Electronic equipment	44.6
20	Food and kindred products	0.7	35	Industrial machinery	41.8
37	Transportation equipment	0.7	37	Transportation equipment	39.2
30	Rubber and misc. plastics	0.7	34	Fabricated metal products	33.1
25	Furniture and fixtures	0.5	30	Rubber and misc. plastics	32.1
36	Electronic equipment	0.5	39	Misc. manuf. industries	29.7
39	Misc. manuf. industries	0.4	31	Leather and leather products	27.7
35	Industrial machinery	0.3	22	Textile mill products	24.4
38	Instruments and related	0.3	25	Furniture and fixtures	24.2
27	Printing and publishing	0.2	24	Lumber and wood products	23.1

[a] Thousand 1990 US dollars.

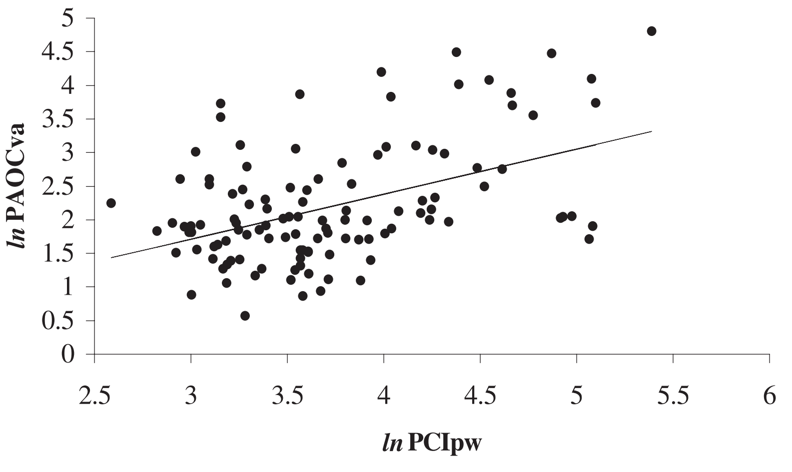

Figure 1. The Relationship Between Physical Capital Intensity and Pollution Abatement Costs

Country Characteristics

The evidence suggests that those sectors that face the greatest pollution abatement costs utilize production processes that are highly capital intensive. Conversely, such sectors tend to have lower labor intensity than cleaner sectors.[9] These relationships are important to the notion that low-income countries, with their typically less stringent environmental regulations, will become the repository of the world’s dirty industries. Common features of developing countries are their low levels of capital accumulation, generally due to a low share of savings in national income, and their relative abundance of low wage labor. As such, pollution intensive industries would appear to be the least suitable for migration to the developing world. Unless comparative advantage in pollution intensive output is driven purely by differences in environmental regulations, it appears questionable whether developing regions enjoy such an advantage.

Pollution intensive sectors have two key characteristics: (i) they face high pollution abatement costs; (ii) they use capital-intensive, rather than labor intensive, production processes. When deciding whether to invest abroad, a US firm in a pollution-intensive sector is therefore likely to have, other things being equal, a preference for a host country with a relatively high capital–labor ratio (K/L), and a relatively low level of environmental regulations. These characteristics are not often found within the same country.

Table 2 provides a ranking of 60 industrialized and developing countries in terms of their capital–labor ratios and the stringency of their environmental regulations. The first column lists the 10 countries with the highest and lowest capital stocks per worker, whilst the second column lists the top and bottom 10 countries in terms of the stringency of environmental regulations.[10] Observe that the countries with the highest capital–labor ratios typically have the highest levels of environmental regulations and vice versa. The final column provides the logged ratio of K/L to environmental regulations, and thereby indicates those countries with the highest K/L relative to environmental regulations. According to the capital–labor and pollution haven hypotheses, the top 10 (bottom 10) countries are those most (least) likely to become pollution havens.[11] The top 10 countries are made up of developing countries with reasonably high capital–labor ratios, but with environmental regulations that are typically lower than in the majority of developing countries.[12] The bottom 10 countries all have a very low level of environmental regulations, but since they also have very low capital–labor ratios they are, by our reasoning, unsuitable as pollution havens.

Table 2, and our argument so far, allows us to identify those countries that are most likely to have become pollution havens. As Table 2 indicates, Brazil and Mexico are two developing countries with reasonably high capital–labor ratios, yet with reasonably low levels of environmental regulations.[13] Furthermore, both countries have large domestic markets and are reasonably close to the donor country in question (the US)—two commonly identified determinants of FDI (Singh and Jun, 1995). In addition, throughout the 1990s, Mexico and Brazil have received the second and third highest shares of FDI among developing countries (with China receiving the highest share).[14] We may therefore speculate that, if pollution havens exist anywhere, Brazil and Mexico are two of the more likely contenders.

Table 2. A Ranking of 60 Countries by Capital–Labor Ratio and Environmental Regulations

Country	*K/L*[a]	*Country*	*Env. reg.*[b]	*Country*	*Ratio*[c]
		Top 10			
1. Japan	288	1. Switzerland	186	1. Argentina	4.03
2. Switzerland	247	2. Germany	182	2. Brazil	3.93
3. Norway	232	3. Sweden	181	3. Czechoslovakia	3.86
4. Germany	203	4. Finland	177	4. Jordan	3.85
5. Austria	187	5. Norway	173	5. Turkey	3.85
6. Denmark	161	6. UK	172	6. Trinidad and Tobago	3.83
7. France	157	7. Canada	171	7. Japan	3.82
8. Belgium	156	8. Ireland	170	8. Thailand	3.82
9. Finland	154	9. Austria	169	9. Venezuela	3.8
10. Netherlands	147	10. Denmark	165	10. Mexico	3.8
		Bottom 10			
1. Senegal	2.4	1. Malawi	76	1. Zambia	3.29
2. India	2.0	2. Paraguay	76	2. Mozambique	3.29
3. Kenya	2.0	3. Senegal	76	3. Kenya	3.27
4. Zambia	1.7	4. Thailand	76	4. Pakistan	3.26
5. Bangladesh	1.4	5. Egypt	74	5. Malawi	3.25
6. Malawi	1.3	6. Tanzania	72	6. Tanzania	3.25
7. Tanzania	1.1	7. Nigeria	71	7. Nigeria	3.25
8. Nigeria	1.0	8. Papua NG	68	8. Bangladesh	3.24
9. Mozambique	0.7	9. Mozambique	62	9. India	3.22
10. Ethiopia	0.3	10. Ethiopia	49	10. China	3.20

[a] 1995 data in thousands of 1990 US$. See Appendix 1 for sources and method of calculation.
[b] Eliste and Fredriksson's (2001) index of the stringency of environmental regulations.
[c] The logged ratio of K/L to environmental regulations.

4. Econometric Analysis

The Determinants of US Outbound FDI

We therefore now consider the determinants of US multi-sector FDI to Brazil and Mexico. We estimate the following equation;

$$\begin{aligned} USFDI^{i}_{jt} &= \alpha_i + \delta_t + \beta_1 PCIpw_{it} + \beta_2 PAOCva_{it} + \beta_3 MKT_{it} + \beta_4 WAGE_{it} \\ &\quad + \beta_5 RD_{it} + \beta_6 EMPL_{it} + \beta_7 IMP_{it} + \beta_8 TRANS_{it} + \varepsilon_{it}. \end{aligned} \tag{1}$$

Our dependent variable is US FDI stocks in sector *i*, for country *j* in year *t*, where country *j* is Brazil or Mexico. Each sector's FDI stocks are expressed as a share of total US FDI stocks in country *j* in that year. Our analysis is undertaken at the three-digit US SIC level of industry aggregation for the period 1989–94. We concentrate on FDI stocks since the US Bureau of Economic Analysis does not report detailed sector capital outflows. Our FDI data have two deficiencies. First, the BEA only reports FDI stocks for 36 sectors for Mexico and 31 sectors for Brazil. However, since the BEA reports the same sectors for all countries, rather then those sectors with the highest FDI, the extent of any bias is unclear. Second, the FDI stocks are recorded at historical cost rather than at current market value, thereby preventing us from calculating the change in stocks as a measure of flows.[15]

PCIpw is the physical capital intensity of sector *i* in the US, measured as non-wage value added per worker. This measure was discussed in Section 3. *PAOCva* is a measure of sector *i*'s pollution abatement costs as a share of value added (in the US), again, as discussed earlier. *MKT* is a measure of market size for each sector, within Brazil or Mexico under the assumption that US FDI will be attracted to a large domestic market. Ideally, this would be a measure of the domestic consumption of the output of each sector. However, such data proved unattainable and hence we use each sector's production (in Brazil and Mexico) as a share of total manufacturing output.

WAGE is a measure of the wage differential between Brazil/Mexico and the US within each sector. *RD* is research and development expenditure as a share of value added within each sector, in the US. The recent literature on FDI has emphasized the issue of "ownership" as a determinant of FDI (see, for example, Dunning, 2000) and the importance of managerial abilities and technologies. In order to utilize such assets, the firm must maintain control of its production. For example, if a firm is concerned about the maintenance of intellectual property rights, it might prefer to sell a research intensive product via foreign direct investment rather than through a licensing agreement with a local firm (Eskeland and Harrison, 2003). The variable *RD* is therefore intended to capture such effects.

EMPL measures the number of employees per firm within each sector in Brazil/Mexico as a proxy for economies of scale in that sector. The inclusion of this variable allows us to assess whether such economies of scale attract US FDI. *IMP* denotes the import penetration within each sector in the host country, defined as imports within the sector as a share of the sector's production. The inclusion of this variable tests whether investors prefer to invest in a sector that is protected from overseas competition. Finally, *TRANSP* is the unit value of the output from each sector defined as price per kilogramme. A high unit value implies low transport costs and vice versa. The relationship between FDI and transport costs is likely to depend on whether the plant in the host country will serve the domestic (host) market or the donor (US) market. Firms in an industry with high transport costs (low unit values) would prefer to be located within the market that they are serving. Thus, if this is the host market, high transport costs will encourage FDI, whilst if the aim is to supply the US market, high transport costs will discourage FDI.

Our prior expectations are that the estimated coefficients for *PCIpw*, *PAOCva*, *MKT*, *WAGE*, *RD*, and *EMPL* will be positive, whilst the coefficient for *IMP* will be negative. The coefficient on *TRANS* could be positive or negative. Table 3 provides results estimated using both fixed effects and random effects specifications. Appendix 2 provides estimated elasticities.

The Hausman (FE vs. RE) test indicates that for the US–Brazil estimations the effects α_i and δ_t are correlated with the independent variables and therefore the random effects model cannot be estimated consistently. The fixed effects results are therefore preferred. No such correlation is found for US–Mexico. Breusch–Pagan tests and regressions of residuals on lagged residuals suggested that initial estimations of equation (1) suffered from both heteroscedasticity and first order autocorrelation. The estimations in Table 3, therefore, use a heteroscedastic error structure as well as data transformed by the autocorrelation coefficient, ρ, following Baltagi and Wu (1999).

We can see that for all four estimations, the physical capital intensity of a sector and the pollution abatement costs within the sector are positive and statistically significant determinants of US FDI to Brazil and Mexico. The F tests, which restrict the coefficients of *PCIpw* and *PAOCva* to zero, also confirm that these variables are jointly significant.

Table 3. Estimation Results from Equation (1)

	US–Mexico		*US–Brazil*	
	Fixed effects	*Random effects*	*Fixed effects*	*Random effects*
PCIpw	0.088**	0.21***	0.11***	0.11**
	(2.4)	(4.2)	(3.2)	(2.0)
PAOCva	0.037***	0.057***	0.052***	0.088***
	(4.9)	(2.6)	(3.2)	(3.3)
MKT	0.016	0.034	–0.020	–0.033
	(0.4)	(0.8)	(–0.5)	(–0.8)
WAGE	–0.55***	–1.27***	–0.55**	–0.51
	(–3.9)	(–2.9)	(–2.3)	(–0.1)
RD	0.011	0.058	0.0052	0.015
	(0.7)	(1.2)	(0.2)	(0.3)
EMPL	0.73	–0.099	2.17	–0.51
	(1.3)	(–0.1)	(0.6)	(–0.1)
IMP	–0.0076	0.49	0.15	0.45
	(–0.04)	(0.7)	(0.8)	(0.8)
TRANS	0.010	0.022	0.010***	0.0085***
	(1.2)	(0.5)	(5.6)	(3.0)
R^2	0.53	0.45	0.54	0.42
F-test (*PCIpw* and *PAOCva*)	26.0	27.4	19.4	12.8
	(0.00)	(0.00)	(0.00)	(0.00)
Hausman (FE vs. RE)	11.97 (0.15)		30.92 (0.00)	
n	216	216	186	186

Figures in parentheses are *t*-statistics and significance levels for test statistics. ***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

In addition, we find the wage difference between the US and Braz/Mex, within each sector, to be a *negative* determinant of FDI. This is contrary to our prior expectations and therefore warrants a closer inspection. Previous FDI studies have often found wage costs to be an insignificant determinant of FDI (Owen, 1982; Gupta, 1983), although those to have estimated North–South FDI typically find them to be significant (Wheeler and Mody, 1992; Singh and Jun, 1995). However, we are estimating multi-sector FDI to one country, rather than aggregate FDI flows to a number of countries. Thus, we are not estimating whether more aggregate US FDI goes to Mexico and Brazil compared to similar countries with higher wages, but whether sectors with higher wages (relative to Mexican and Brazilian wages) generate more FDI than those with lower wages. Our wage differential variable is almost perfectly correlated with average US wages in each sector,[16] and replacing the wage differential variable with this latter measures does very little to change the results. By effectively measuring the level of US wages in each sector, it would therefore appear that we are capturing the human capital intensity of each sector. High skill sectors typically have a higher share of white-collar workers and hence higher average wages.[17] We would not expect US high skill sectors to invest in Mexico and Brazil and hence the negative coefficient seems appropriate when viewed in this context. Finally, it is worth noting that when examining the determinants of FDI in four developing countries, Eskeland

and Harrison (2003) find the US wage in an industry to be a negative determinant in seven out of nine regressions.

The estimated coefficients on the remaining independent variables are generally statistically insignificant, with the exception of our unit value variable (*TRANS*) for Brazil. A positive coefficient implies that a sector with low transport costs (high unit value) will undertake more FDI than a sector with high transport costs (low unit value). This would suggest that the output from the Brazilian investment is to be exported to the US market, and hence output with a high transport cost will be less suitable for this purpose.

Instrumental Variables

Our measure of pollution abatement costs, *PAOCva*, suffers from two potential weaknesses. First, since US polluters may respond to more stringent regulations by investing in green technologies, pollution abatement operating costs, which do not include such capital expenditures, may underestimate true regulation costs for some industries. Second, faced with the rapid migration of firms within certain industries, the US government may respond by reducing regulation costs within those industries. This would suggest that *PAOCva* could be endogenous with regard to FDI.[18]

In order to address both of these issues, we undertake instrumental variables estimations. First, we instrument *PAOCva* using *PAOCva* for the period 1973–78, the earliest reported observations for pollution abatement costs. To test the robustness of these results, in separate estimations we use industry specific pollution intensities reported by Hettige et al. (1994) as instruments for *PAOCva*. Whilst these intensities are highly correlated with pollution abatement costs, they are only reported for a single year (1987) and hence we use the between effects estimator (which averages over time for each cross-section) for these latter estimations.[19]

Table 4 provides the instrumental variable results. The results using lagged *PAOCva* as instruments stem from a fixed effects specification, with random effects results available upon request.

It can be seen that *PCIpw* and *PAOCva* remain positive, statistically significant determinants of US FDI to both Mexico and Brazil. Furthermore, the *WAGE* variable again has a negative estimated coefficient, which is significant in three of the four estimations. Although not reported for reasons of space, estimated elasticities are comparable in size to those reported in Appendix 2 that stem from the estimations in Table 3.

In sum, the results in Table 4 appear to fully support those reported in Table 3, suggesting that endogeneity and/or measurement error are not unduly influencing our *PAOCva* variable.

Dynamic Estimations

Our analysis so far has been purely static. We here consider whether FDI should be modelled as a dynamic process and investigate the role played by a lagged dependent variable. The inclusion of a one-period lagged dependent variable in equation (1) does little to change the sign and significance of the other variables and is statistically significant.[20] However, the lagged dependent variable is likely to be correlated with the error term.[21] A solution to this problem is to follow Arellano and Bond (1991) and to estimate a dynamic panel using $USFDI^{i}_{jt-2}$ as an instrument for $USFDI^{i}_{jt-1}$ and to first difference all variables.

Table 4. Instrumental Variable Results

	US–Mexico		US–Brazil	
	IV = lag PAOCva	IV = poll'n int.	IV = lag PAOCva	IV = poll'n int.
PCIpw	0.17**	0.21***	0.56***	0.25**
	(2.0)	(2.8)	(5.9)	(2.2)
PAOCva	0.084***	0.087**	0.30***	0.19**
	(3.1)	(2.0)	(7.9)	(2.0)
MKT	0.050	0.13	–0.16**	–0.12
	(0.4)	(1.0)	(–2.3)	(–1.1)
WAGE	–1.40***	–1.55*	–0.39***	–0.89
	(–4.1)	(–1.9)	(–5.5)	(–1.1)
RD	0.0031	0.083	–0.061	0.036
	(0.04)	(0.8)	(–0.8)	(0.3)
EMPL	0.85*	1.05	–2.19**	0.86
	(1.6)	(0.5)	(–2.0)	(0.8)
IMP	–0.59	–0.60	–0.94*	0.14
	(–0.4)	(–0.3)	(–1.7)	(0.1)
TRANS	0.032	0.036	0.013***	0.021**
	(1.2)	(0.3)	(9.1)	(2.2)
R^2	0.49	0.61	0.59	0.65
F-test	4.9	13.3	33.7	5.1
(*PCIpw* and *PAOCva*)	(0.00)	(0.00)	(0.00)	(0.02)
n	216	36	186	31

Estimations using lagged *PAOCva* as the instrumental variable are estimated using fixed effects, those using pollution intensities use between effects.

We therefore estimate equation (2).

$$\Delta USFDI^{i}_{jt} = \delta_t + \theta\Delta USFDI^{i}_{jt-1} + \beta\Delta X_{it} + \Delta\varepsilon_{it}. \qquad (2)$$

Where Δ denotes first differences and X_{it} denotes the independent variables from equation (1). Note that taking first differences removes the sector effects α_j. This equation is still complicated by correlation between lagged US FDI and the error term and so it is necessary to use an instrumental variable for $\Delta USFDI^{i}_{jt-1}$. We use $\Delta USFDI^{i}_{jt-2}$ (i.e. $USFDI^{i}_{jt-2} - USFDI^{i}_{jt-3}$), although $USFDI^{i}_{jt-2}$ or $USFDI^{i}_{jt-3}$ would be equally acceptable. Table 5 provides the results.

We can see that for US FDI to both Mexico and Brazil, a lagged dependent variable is positive and statistically significant. Furthermore, *PCIpw* and *PAOCva* remain positive and significant determinants of FDI, with the exception of *PAOCva* for US–Mexico that, although positive, is not significant. We no longer find the wage differential variable to be significant, although it remains negative for US–Mexico. Note also that our unit value measure, *TRANS*, remains a positive and significant determinant of FDI for US–Brazil, again implying that, *ceteris paribus*, a sector with low transport costs will undertake more FDI than a sector with high transport costs. Finally, our first- and second-order autocorrelation tests accept the null of no autocorrelation.

Table 5. Dynamic Estimation Results from Equation (2)

	US–Mexico	*US–Brazil*
lagFDI	0.97 (14.1)***	0.501 (7.1)***
PCIpw	0.00020 (2.8)***	0.000097 (2.2)**
PAOCva	0.00016 (0.6)	0.00027 (2.3)**
MKT	–0.00037 (–1.1)	–0.000018 (–0.03)
WAGE	–2.55e-7 (–0.6)	5.62e-8 (0.09)
RD	4.53e-6 (0.03)	–0.00029 (–1.8)*
EMPL	8.5e-7 (0.04)	0.000012 (0.5)
IMP	–0.010 (–1.6)	0.0011 (0.7)
TRANS	–6.03e-8 (–1.2)	2.32e-8 (1.9)*
Constant	0.00010 (0.3)	0.00039 (0.9)
AR(1) test	–1.1 (0.27)	–1.64 (0.10)
AR(2) test	–0.5 (0.61)	0.46 (0.64)
n	144	124

Figures in parentheses are *t*-statistics and significance levels for test statistics. ***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively. AR(1) and AR(2) are Arellano–Bond tests of first and second order autocorrelation. The null hypothesis is no autocorrelation.

The authors' dynamic estimation results, therefore, generally support the static results from Tables 3 and 4. In sum, this analysis suggests that US FDI to Mexico and Brazil is concentrated in sectors that are both capital intensive and pollution intensive and that do not require a highly-skilled workforce.

5. Summary and Conclusions

A number of reasons have been offered to explain why, despite the predictions of many theoretical studies, little or no empirical evidence of pollution havens has been found. The role of factor endowments has been widely neglected, however, despite the fact that most pollution intensive sectors are also highly capital intensive, as Section 3 illustrated. The aim of this paper has, therefore, been to illustrate the importance of capital to any attempt to identify pollution havens.

If comparative advantage is determined by both differences in factor endowments *and* environmental regulations, then pollution intensive FDI will be drawn to countries with a high level of capital endowment relative to the stringency of their environmental regulations. Following this line of reasoning suggests that countries such as Brazil and Mexico may be the countries most likely to be pollution havens. Section 4, therefore, examined the determinants of US multi-sector FDI to Brazil and Mexico and found the capital requirements of a sector to be a key determinant of FDI. It also found the level of pollution abatement costs in a US industry to be a statistically significant determinant of that industry's FDI providing evidence of a pollution haven effect.

We do not suggest that pollution havens are widespread. Theoretical models that have predicted the widespread formation of pollution havens are typically set in worlds in which comparative advantage is determined purely by differences in the stringency of environmental regulations. In reality, those countries with lax environmental standards typically do not have the level of accumulated capital that is necessary to attract capital (pollution) intensive investment.[22] By focusing on the relationship between capital intensity and pollution intensity, we are able to identify the likeliest countries to be considered as pollution havens. Examining these countries alone provides reasonably robust evidence that the higher the abatement costs in a US industry, the greater the FDI from that industry.

Appendix 1: Data Information

Industry-Specific Variables (used in Sections 3 and 4)

USFDI The US Bureau of Economic Analysis only provides detailed industry data for 'US investment position abroad' that is a measure of FDI stock. The data is expressed as a share of total FDI to Brazil/Mexico (e.g. FDI in industry *x* to Mexico as a share of total US FDI to Mexico). Source: US Bureau of Economic Analysis.

PCIpw Physical capital intensity per worker, defined as non-wage value added per worker and expressed in tens of thousands of 1990 US$. Source: US Bureau of the Census, *Annual Survey of Manufactures*, various years.

PAOCva Pollution abatement operating costs normalised by industry value added (in 1990 US$). Source: US Department of Commerce, *Pollution Abatement Costs and Expenditures*, various years. The US Department of Commerce also reports pollution abatement capital expenditures (PACE), however, these are highly correlated with PAOC and also tend to be significantly smaller.

MKT Measured as the domestic market share of each industry in the host country defined as industry output as a proportion of total manufacturing output. Source: United Nations, *Industrial Statistics Yearbooks*, various years.

WAGE Wage differential is defined as the average US manufacturing wage minus the average Mexican/Brazilian wage in each industry in tens of thousands of 1990 US$. Sources: US wages from the US Bureau of the Census, *Annual Survey of Manufactures*, various years. Mexican/Brazilian wages from UN *Industrial Statistics Yearbooks*, various years.

RD Percentage share of research and development expenditure in value added (in US). Source: National Science Foundation (2000). *Research and Development in Industry* 1998. NSF 01-305.

EMPL Measured as thousands of employees per firm. Source: UN *Industrial Statistics Yearbooks*, various years.

IMP Share of imports in industry output in Brazil and Mexico. Source: United States International Trade Commission database.

TRANS Price per kilogramme of industry output in thousand 1990 US$. Source: United States International Trade Commission database.

Appendix 2

Table A. Estimated Elasticities from Section 4 (Based on Results in Table 3)

	US–Mexico		*US–Brazil*	
	Fixed effects	*Random effects*	*Fixed effects*	*Random effects*
PCIpw	0.69***	0.99***	0.79***	0.64**
	(3.0)	(3.6)	(2.9)	(1.9)
PAOCva	0.50***	0.34**	0.49***	0.70***
	(4.3)	(2.4)	(3.3)	(2.9)
MKT	0.17	0.11	–0.21	–0.28
	(0.9)	(0.8)	(–0.5)	(–0.8)
WAGE	–0.83***	–0.62***	–0.92**	–0.38
	(–3.7)	(–2.6)	(–2.1)	(–0.4)
RD	0.026	0.20	0.027	0.067
	(0.08)	(1.2)	(0.2)	(0.3)
EMPL	0.23	–0.022	0.33	–0.065
	(1.4)	(–0.1)	(0.6)	(–0.1)
IMP	–0.13	0.13	–0.21	0.14
	(–0.5)	(0.7)	(–0.5)	(0.8)
TRANS	0.017	0.013	0.070***	0.050***
	(0.8)	(0.5)	(4.9)	(2.7)

Estimated at the means of the independent variables.
***, ** and * indicate statistical significance at 99%, 95% and 90% confidence levels, respectively.

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Notes

1. Esty and Gerardin (1998) argue that under certain political economy conditions, competitiveness fears may have a greater effect on the regulation of environmental standards than is rational. Some economists believe that governments will attempt to attract FDI by competitively undercutting each others' environmental regulations (race to the bottom), while environmentalists believe that multilateral trade agreements prevent countries from setting their desired (perhaps higher) level of regulations.

2. The pollution haven hypothesis (PHH) argues that a country with a lower than average level of environmental regulations will find itself with a comparative advantage in pollution intensive production. Due to the close correlation between a country's per capita income and environmental regulation stringency (Dasgupta et al., 1995), the PHH argues that developing countries or regions (the South) will become pollution havens, whilst the developed world (the North) will specialize in clean production.

3. In contrast to the limited attention paid to *outward* FDI and pollution haven effects, there is a burgeoning literature that examines US inward FDI and plant location choice at the US state or county level (see, for example, Levinson, 1996; Kahn, 1997; Henderson, 1996, 1997; Becker and Henderson, 1997; List, 2001; List and Co, 2000). Many authors (see, for example, Bartik, 1988; Crandall, 1993) conclude that plant level inertia is greater than any additional costs associated with environmental regulations, although List et al. (2001) demonstrate that a county's regulatory stringency does have a statistically significant negative effect on the number of relocating plants that choose the county as a destination. The issue of the endogeneity of environmental regulations and FDI has been more recently addressed by among others, Fredriksson et al. (2003) and List et al. (2001) who generally find greater evidence that regulations influence plant location choice in the US.

4. In the existing literature, early support for the PHH was found by Lucas et al. (1992) and Birdsall and Wheeler (1993) who claimed that the growth in pollution intensity in developing countries was highest in periods when OECD environmental regulations were strengthened, and by Mani and Wheeler (1998) who found a temporary pollution haven effect in an examination of import–export ratios for dirty industries. More recent work by Fontagne et al. (2001) and Keller and Levinson (2002) that controls for endogeneity between trade and regulations also finds renewed support for the PHH. In contrast, earlier papers by Tobey (1990), Jaffe et al. (1995), Van Beers and Van den Bergh (1997), and Janicke et al. (1997) found no evidence that the stringency of a country's environmental regulations is a determinant of its dirty product net exports, or has a significant effect on the industrial competitiveness of developed countries.

5. Studies that model the impact of trade on the environment are now beginning to take into account the role of factor endowments (Antweiler et al., 2001; Cole and Elliott, 2003). Other reasons for the lack of pollution haven evidence may include: (i) the belief that pollution will reduce the productivity of the host's labor force, thus raising labor costs; (ii) the lack of environmental regulations may be a reflection of the poor quality of the existing government's ability

to manage the economy; (iii) the level of sunk costs in terms of clean technology development already committed to the home market; (iv) the endogeneity of environmental regulations which means that cross sectional analyses cannot control for unobserved heterogeneity among countries or regions; and (v) countries with weak regulations will, typically, have weaker legal systems and lack well defined business rights and responsibilities, whereas a developed country investor is likely to prefer a country with clear regulations, thereby avoiding the arbitrary enforcement and deal-making inherent in a country with a weak legal system In the context of North–South FDI flows, Smarzynska and Wei (2001) also suggest a number of additional reasons for the lack of PHH evidence including the use of country or industry-level data (masking pollution haven effects at the firm level) and the accuracy of the measurement of the pollution intensity of multinational firms.

6. See Markusen et al. (1995) and Markusen (2002) for an overview and Beckman and Thisse (1986), Fujita et al. (1999), and Mayer (1998) for surveys of the different strands of the FDI literature.

7. The negative externality is deepened if there is no significant technological spillover effect or restrictive intellectual property rights and/or prohibitive royalty payments and leasing fees. See De Mello (1997) for a selective survey of the FDI and growth literature, and Ramirez (2000) for detailed cointegation analysis for FDI in Mexico.

8. We examine other measures of PCI (for example, non-wage value added as a share of value added) and also correlations for individual years (rather than an average for 1989–94) with similar results.

9. The correlation coefficient between PAOCva and the share of payroll in value added, a measure of labor intensity, is –0.33 (t-statistic of –3.9) based on 123 US industries between 1989 and 1994.

10. Building on the work of Dasgupta et al. (1995), the measure of environmental regulations is provided by Eliste and Fredriksson (2001). Dasgupta et al. gather information from individual country reports compiled under United Nations Conference on Environment and Development (UNCED) guidelines. Each report is based on identical survey questions and provides detailed information on the state of environmental policies, legislation and enforcement in each country. Using this information, Dasgupta et al. (1995) develop an index of the stringency of environmental regulations for 31 countries. Eliste and Fredriksson (2001) then use the same methodology to extend the index to measure the stringency of environmental regulations in the agricultural sectors of 60 countries. The focus on the agricultural sector does not appear to be problematic for our purposes, since Eliste and Fredriksson’s index is highly correlated with Dasgupta et al.’s index, for the 31 countries that are common to both.

11. Note that this is a simplification as we are assuming that an investor places an equal weight on capital requirements and environmental costs, and that these are the only factors that are considered in the decision-making process.

12. The exception is Japan that finds itself in the top ten due to its extremely high level of capital stock per worker.

13. Although regulations may not be stringent, Dasgupta et al. (2000), Hettige et al. (1996), and Hartman et al. (1997) have shown for Asia and Mexico that these regulations are generally complied with.

14. Jenkins (1998) provides case studies of FDI into Mexico and Malaysia.

15. Whilst *increases* in stocks (measured in historical costs) would be an appropriate measure of capital flows, reductions in stocks would not be, particularly if the initial investment was made some years ago. For example, if the US made an investment of $50 million in Mexico in 1960, but sold it in 2000 for $500 million, the value of the stock would fall by the original $50 million rather than by $500 million. Thus the change in stock would be –$50 million whereas the current value of the capital flow should be –$500 million.

16. This implies that US sectoral wages are correlated with Mexican and Brazilian sectoral wages.

17. Replacing the wage differential variable with a sector’s share of white-collar workers in total employment does little to alter results. The estimated coefficient remains negative.

18. List et al. (2001) and Fredriksson et al. (2003) both argue that US environmental regulations may be endogenous with regard to *inbound* FDI into the US.

19. Using pollution intensities as instruments in a standard OLS estimation (as opposed to a between-effects estimation) yields very similar results, as does the use of both lagged *PAOCva* and pollution intensities as instruments within the same estimations.

20. Space constraints mean it is not possible to report these results. They are available upon request.

21. The inclusion of the lagged dependent variable is not favored on the grounds that both $USFDI^{i}_{jt}$ and $USFDI^{i}_{jt-1}$ will be functions of α_j, our industry characteristics. Since α_j is part of the unobserved error term, it means that $USFDI^{i}_{jt-1}$, an independent variable, is correlated with the error term and hence OLS estimates will be biased.

22. This, we would argue, at least partly explains why Eskeland and Harrison (2003) find no evidence of pollution haven effects in Morocco and the Cote d'Ivoire. These countries do not have the capital endowments that are necessary to attract investment in capital (pollution) intensive industries. We are less clear, however, why Eskeland and Harrison find no pollution haven evidence for Venezuela and Mexico. One reason may be that their analysis is undertaken using *total* FDI into these countries rather than FDI from the US or from developed countries as a whole. Furthermore, the analysis for Mexico is based on data for 1990 alone.