GLOBALIZATION AND THE ENVIRONMENTAL SPILLOVER OF SECTORAL FDI†

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Abstract

We analyze the environmental impact of capital inflows and investigate the halo effect (FDI improves the environment), and the Environmental Kuznets Curve, EKC (pollution increases with growth, and declines when income reaches a threshold). We control for the type of FDI inflows and country income level, and find (i) a differential industry effect: FDI flows into manufacturing increases pollution (negative halo effect), while those flowing into services support the halo effect hypothesis; (ii) an income inequality effect: FDI flowing into low and middle income countries degrades the environment, while flows to high-income countries benefit the environment and support a halo effect; (iii) support for EKC effect if capital flows into agriculture and services in poorer countries and into mining and manufacturing in wealthier economies. We show that studies relying only on firm level or aggregate data, miss the sectoral spillovers, and thus may lead to misleading conclusions.

Key Words: Sectoral FDI, environmental spillovers, dynamic panel.
JEL Codes: F21, Q5

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Introduction

The 2008 financial crises and extreme climate events such as floods, hurricanes and droughts that the world has been experiencing with an increased frequency since the beginning of the 21st century have one common message: with globalization, extreme events are no longer rare and can hit both industrialized and developing economies alike. Just as the financial crisis that originated in the United States has transformed into a global recession, the climate change that started a while ago is being felt now throughout the world at an ever-increasing rate. The main difference is that unlike recessions, a change in the climate is not reversible.

The academic and public discourse link globalization and environment in several ways. Globalization is blamed to degrade the environment through two channels. (i) *The pollution haven, or race-to-the bottom*. Accordingly, with liberalized trade flows, businesses operating under tight environmental regulation in developed countries can shift polluting industries to countries with lax regulation; (ii) *The "Environmental Kuznets Curve"* (EKC), described by an inverse U-shaped relation between pollution and income, states that economic growth (often associated with globalization) increases pollution in low-income economies until they reach a certain level of development, and decreases it thereafter. Both channels, however, are mitigated by the more recent literature, which revealed a "halo effect". *The Halo Effect hypothesis* states that multinational companies disseminate superior knowledge and apply environmentally friendly practices while improving the environmental performance of domestic business.

The globalization's effect on the environment is mostly analyzed via the trade channel and less so via the capital flows channel, and more specifically, the foreign direct investment (FDI). All three effects can be triggered by multinational companies that invest in physical plants and equipment, and contribute to the production and growth in host countries, as well as affecting the environment. The view that multinationals impact the environment has its parallel in the literature that examines the productivity gains generated by foreign firms investing in host country, via spillovers of knowledge, knowhow, etc.

For a regulatory body it is crucial to know which effect is triggered by companies, whether foreign or domestic. For business, especially those operating internationally, it is critical to know its impact on carbon emissions and manage its risks. Business and investors are facing increased restrictions and regulations from authorities forced to cut emissions. Such regulations are already implemented by Australia that imposed a carbon trading scheme and the UK that requires the listed companies to report their carbon footprint. Managing the climate-generated risk is becoming an important objective of companies and therefore, many businesses and insurers are supporting clear measures and regulations.

In this study, we propose to understand the impact of globalization on the host country's environment by disentangling two of these effects (EKC and halo effects) of FDI inflows, controlling for a number of factors that may bias the results. Our goal is to assess specifically the halo effect by controlling for the EKC effect. Our study shows that unless it is considered at the sectoral level, the relation between foreign investment and the environment is not clear-cut. Our results help identify the sectors where more or less regulation is required.

Contribution of this study to the literature

The review of the literature below highlights various drawbacks that prevent establishing a clear relation between pollution and capital flows. First, most studies that examined the impact of globalization on the environment considered these effects separately, with a plethora of data and samples at the firm level or country level, which makes it difficult to draw any consistent conclusion. Second, the methodology adopted is time-averaged cross-section approach, which is inadequate to analyze a dynamic phenomenon such as greenhouse gas emissions with little or no reversion. Finally, idiosyncratic shocks to different sectors may overweigh the regional shocks and conceal differences at the industry level, and may explain the reason behind inconclusive results in the literature. We address these drawbacks by adopting a unified framework and a dynamic model that allows the analysis of all three effects over time and a long span of data covering multi-country and industries. We identify the channels through which the halo and the EKC effects manifest, controlling for the type of FDI inflows and the level of development of the economies.

The work on the environmental impact of total FDI uses an aggregate measure, which conceals sectoral effects. At the other end of the spectrum, the analyses that examine the investment decisions at the firm level miss the sectoral impact of these decisions and the intersectoral spillovers. Our industry analysis uses the largest and the longest data span available. Growth studies have shown that FDI that flows to different sectors have different impact on sectoral and aggregate growth, through spillovers to different industries (Doytch and Uctum, 2011). Likewise, we expect different effect by different sectoral FDI inflows on pollution (e.g., financial FDI might impact the environment even though it goes to a non-polluting services industry).

Many of the previous studies struggle with endogeneity and simultaneity. The explanatory variables used in the empirical studies are likely to influence each other, or the dependent variable can affect the independent variables. For example, a country with restrictive environmental laws may reduce pollution but they may be also a reaction to pollution; or pollution may change by FDI but it can also determine the amount of FDI inflows. Independent variables may also affect each other: laws may influence the flow of FDI, high growth can encourage FDI. The simultaneity problem can create substantial biases in the estimates, which make results meaningless. To address this issue, we adopt a dynamic panel data approach (Arellano and Bover, 1995; Blundell and Bond, 1998), a methodology that circumvents this problem.[1] Another advantage of the GMM estimator is that it exploits both the time series

[1] One notable exception is Frankel and Rose (2005), which examines the effect of trade on environment. Endogeneity of trade and income is controlled for by instrumental variable approach within a cross-country estimation in 1990. Although our approach is parallel to Frankel and Rose, it differs in several ways. First, we do not take a single year of data but examine the evolution of the phenomenon through time, over the course of 38 years. Second, our analysis is dynamic and not static. Third, our analysis is sectoral and thus is able to capture the intersectoral spillovers.

dynamics and the pooled country characteristics of the data while controlling for endogeneity and omitted variable biases. This allows us to retain the time-series aspect of the data and the dynamic aspects of changes in the sectoral flows of FDI, a feature that the traditional approach of the cross-sectional time-averaging methodology is not able to capture.

We show that the capital flow-pollution nexus results depend critically on the type of FDI flows and income distribution. First, we find a differential industry effect: foreign investment that flows into clean industries such as services support the halo effect hypothesis, while those flowing into traditionally dirty industries such as manufacturing reflect a negative halo effect, which is consistent with the pollution haven hypothesis. Second, we uncover an income inequality effect: In general, foreign investment flowing into poorer countries has harmful effects on environment, while those flowing to richer countries have a beneficial effect and support the halo effect. Third, we resolve the ambiguity in the EKC literature. As countries become wealthier, evidence supports EKC (i.e. pollution decreases with economic development) in countries where capital was flowing to dirty industries, such as mining and manufacturing. If the flows go into industries traditionally considered to be clean such as services, the EKC is not validated by the data. This result shows that the inconclusiveness in the EKC literature is resolved if the industry specificity of FDI is accounted for.

FDI to GDP ratios across sectors and income levels

Figure 1 displays the FDI net flows since 1995 separated as all countries (upper left panel), high-income countries (upper-right panel) and middle-income and low-income countries (lower panels). Since the 1990s, the FDI/GDP ratio increased up until 2007 but abruptly fell during the crisis. The substantial rise in the early 2000 (and the subsequent fall) is predominantly led by FDI in financial services sector, followed by the nonfinancial services sector. FDI inflows into manufacturing, mining and agriculture, the traditionally dirty industry sectors have been declining or stable and insignificant. On this account we should expect a reduction in the pollution trends, since the services sector uses relatively clean technology.

Disaggregating the data according to income distribution, however, gives quite a different picture. The sectoral FDI/GDP patterns in the high-income countries follow closely those of the total sample, suggesting that FDI is likely to have a halo effect in wealthy economies. This is also consistent with the EKC hypothesis. The aggregate pattern is somewhat replicated in the middle-income countries, which enjoy a rise in the nonfinancial services FDI inflows. However, the small but positive trend in polluting industries, such as mining, mitigates the halo argument. The case with low-income economies, however, starkly contrasts with the rich countries. Despite a general decline in overall FDI flows, substantial increase in inflows into mining in the early 2000 and a leap in late 2000 dominate all flows to other industries. Our analysis examines these interactions rigorously and tests whether such causalities are supported by the data.

Literature Review

The two hypotheses discussed above, the Halo Effect and the Environmental Kuznets Curve (EKC) are interrelated. The halo effect follows the productivity literature in spirit, which examines the productivity spillovers by FDI, both at the firm and macroeconomic levels.[2] Positive environmental spillovers is triggered if the multinational corporations (MNCs) encourage the dissemination of environmentally clean technologies and management practices. This occurs when the foreign firm engages in contracts only with environmentally responsible domestic counterparts. This may happen under shareholder pressure at the MNC or because of practices established by the MNC's home country environmental regulations and standards. Further environmental knowledge can disseminate through the movement of trained workers from foreign to domestic firms (Görg and Strobl, 2005) or because of a direct competition of domestic firms with the MNCs.

The literature on environmental spillovers from FDI confines mainly to case studies of specific countries' manufacturing industry firms. The evidence with respect to the halo hypothesis has been mixed (Paigel and Wheeler, 1996). In a limited Indonesian manufacturing firms study conducted for the period 1989-90 with respect to water pollution, Hartman et al. (1997) conclude that "abatement... is... unaffected by foreign links (in ownership financing)". Dasgupta et al. (2000) examine the impact of regulation, plant-level management policies, and other factors on the environmental compliance of Mexican manufacturers and find no significance for the foreign ownership variable as well.

More recently, however, Eskeland and Harrison (2003) analyze outbound US FDI and find that foreign plants are significantly more energy efficient and cleaner in their energy uses than their domestic partners, which supports the halo hypothesis. Another supporting evidence for the halo hypothesis comes from the study by Cole et al. (2008) who assess the extent to which foreign ownership influences the energy intensity of firms in Côte d'Ivoire, Mexico and Venezuela, and Ghana. They find that foreign ownership reduces the energy intensity of plants.

Finally, in a sample of Argentinean firms, Albornoz et al (2009) find supporting evidence that (i) foreign-owned firms are more likely to implement environmental management systems compared to domestic firms; (ii) firms that supply sectors with high multinationals more likely adopt environmental management systems; (iii) firms' absorptive capacity, ownership and export status also influence the extent to which they benefit from environmental spillovers. [3]

EKC, the second but the older line of research in environmental economics, states that the quality of the environment worsens as the economy grows and once a certain threshold is reached, it starts improving, resulting in an inverse U-shaped pollution-GDP per capita pattern.

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[2] Firm level studies find mixed evidence of productivity spillovers, ranging from limited positive to no or negative spillovers. At the aggregate level, the evidence has been overwhelmingly in support of positive impact by FDI inflows. The sectoral level analysis reconciles these inconsistent results. Manufacturing FDI has positive spillovers that spur growth through its own sector, while financial services have a positive effect that spreads though services, whereas nonfinancial services drain resources from manufacturing with a negative effect on growth (see Doytch and Uctum, 2011 for a survey of the relevant literature and new results).

[3] The original pollution haven hypothesis (Copeland and Taylor, 1994) states that as trade is liberalized, industries that pollute shift from rich countries with tight regulation to poor countries with weak regulation and conversely, clean industries migrate towards rich countries. Although related to the halo effect, since our emphasis will not be on the impact of regulation on environment and investment decisions, we will not address this literature here. For a survey of the earlier literature see Jaffee et al. (1995) and more recent literature Dong et al. (2012) and Chung (2014).

This line of argument parallels that of the structural change in development whereby the share of manufacturing in the economy grows in the initial phase of development but later decreases as the services overtake the role of manufacturing in growth. The implication of EKC is that environmental quality increases with economic growth after a threshold. The estimation model consists of the cubic or quadratic income terms and their lagged values, and a vector of control variables including policy, trade, and institutional variables. The initial research corroborated the EKC argument (Shafik, 1994, Grossman and Krueger, 1995, Holtz-Eaking and Selden, 1995, Hilton and Levinson, 1998). More recent research, however casts doubt on the existence of a neat inverse U-shaped relation (Stern, 1998, Harbaugh et al. 2002, Hettige et al. 2000).

As this brief overview of the literature indicates, most studies and in particular those in environmental spillover literature are conducted at firm level. They give partial, industry-specific insight into the experience of a given country. It is not surprising that literature cannot provide us with a lesson about the global nature of capital flows, which could help us understand events in other contexts. For this, a multi-country, sectoral approach is more appropriate. Our study remedies this weakness and conducts such a sectoral level analysis of the impact of FDI on environmental performance of domestic economies, measured by the levels of air pollution. [4]

Conceptual framework

Our approach is in the spirit of Marcusen et al. (1995) extended to two imperfectly competitive firms operating in two countries in a partial equilibrium model. A domestic and a foreign firm compete in both markets with heterogeneous products that are imperfect substitutes for each other. Each individual firm can affect the price of its own product in the market it is competing. Each firm can choose whether to produce only domestically or to build plants in both countries and produce both locally and in the foreign country. Following the literature, we will denote the firm as "national" if it is producing domestically and as "multinational" if it is producing domestically and in the foreign country. The model considers only horizontal FDI and ignores vertical FDI following the evidence in the literature.[5]

Pollution is a by-product of the production of goods as assumed in the literature and created by local production. We keep the model as simple as possible and abstain from any strategic considerations between firms or governments, or issues around abatement or spatial effects. Pollution Z_{it}^{D} at time *t* in country *i* depends on total production Q and on an exogenous component D.

(1) $Z_{it} = D + \psi Q_t$

Total production in the host economy consists of the production of the domestic firm, which may or may not be a multinational, and the production of the foreign multinational firm:

(2) $Q_t = X_t + X_{ft}$

where X, X_f are, respectively, the domestic production of the domestic firm and the local production of the foreign firm if it is a multinational, or its export to the domestic country if it is a

[4] The only study that examines the relationship of FDI by sectors with CO2 emissions is Blanco et al. (2013). The study is specific to Latin America and the Caribbean and examines FDI in various manufacturing industries. The study uses a simple Granger causality framework and finds a positive effect of "dirty" sectors FDI on pollution, but does not look into intersectoral spillovers.

[5] See for example Markusen (1995), Carr et al. (2001).

foreign-national firm. Since the goal of this study is to examine the environmental impact of FDI inflows, we consider the specific case where the foreign firm is a multinational firm producing both at home and in the host country and the domestic firm is a national firm that produces locally. Both firms produce with the same technology using capital, K and labor, L and the pollution level (Z_D and Z_f) that minimize their cost. We consider pollution as an input to the production process but it could also be equivalently considered as a joint production technology (Siebert et al., 1980, Copeland and Taylor 2004). In a static equilibrium, ignoring the time subscript the cost minimization of the domestic firm can be written as:

$C = WL + RK + TZ$

subject to the resource constraint:

$Z_D^{\alpha} G(K, L)^{1-\alpha} \geq \bar{X}$

$Z_D \leq \overline{Z_D}$

where G(.) is increasing, concave and homogenous, $0 < \alpha < 1$, W, R and T denote the wage rate, capital rental rate and cost (price) of pollution, $\bar{X}$is the target output level and Z_D and $\bar{Z}_D$ are, respectively, pollution produced by domestic firm and the target or maximum allowable emission level for this firm. Substituting the conditional demands into the production function gives the optimal output of the domestic firm:

(3) $H = H(\Gamma,\ \bar{Z}_D,\ \bar{X})$

where $\Gamma$is a vector of domestic cost of production.

Foreign firm produces domestically and in the host country and thus contributes to emissions in both countries. For its production in the host country, it uses the local labor and pays the local wages. For its production in its home economy, it hires labor and pays salary of the foreign country. Since goods are imperfect substitutes, the cost function is separable. The foreign multinational firm minimizes

$C_f = \left(WL_f + W^*L^*\right) + \left(R^*K_f + R^*K^*\right) + (TZ_f + T^*Z^*)$

Subject to:

$Z_f^{\alpha} F\left(K_f, L_f\right)^{1-\alpha} \geq \bar{X}_f$

$Z^{*\alpha} F(K^*, L^*)^{1-\alpha} \geq \bar{X}^*$

$Z_f \leq \bar{Z}_f$

$Z^* \leq \bar{Z}^*$

To produce X_f in the host country the multinational firm employs labor from the host country, L_f, at the prevailing local cost, W and brings in FDI, K_f, which it rents at its home market at the rate R^*. It also produces X^* in its home market with labor and capital, at the cost of W^* and R^*. Both plants contribute to the emissions by Z_f in the host country, and Z^* in the home country of the multinational where the firm faces similarly target levels of emissions and output, and pays a price of T^*. To focus on the pollution produced in the host country, we will ignore the production activity of the multinational firm in its home country.

We substitute the optimal factor demands into the production functions to get the optimal output for each firm. After appropriate substitutions and log linearizing we can obtain a pollution equation of the form:

(4) $z \ = \ \alpha_0 + \alpha_1\gamma + \alpha_2\gamma_f + \alpha_3\bar{x} + \alpha_4\overline{x_f} + \alpha_5\overline{z_D} + \alpha_6\bar{z}_f + \alpha_7 f$

where lower case-letters are the logs of the upper-case letters, *f* is FDI inflows (see Appendix 1 for the derivation and the definition of coefficients in the equation).

Methodology

Several FDI studies in the literature examine the impact of environmental regulation as an independent variable. These studies belong to the strand of the literature emphasizing the determinants of FDI. Our emphasis differs in the sense that what we want to examine is how capital flows directly affect pollution in a country, while controlling for the EKC effect. It is clear that these factors are simultaneously determined and their nonlinear interaction is not addressed. The methodology outlined below is designed to control such biases.

To assess the impact of FDI and growth on pollution in a form comparable to the empirical studies in the literature, we can transform the equation (4) as follows:

(5) $z_t = \alpha_0 + \alpha_1 y_{1t} + \alpha_4 q_{it} + \alpha_6 z_t + \alpha_8 f_t$

where we used several assumptions: symmetric effect for each firm's output and target emissions on total pollution ($\frac{\partial z}{\partial \bar{z}_D} = \frac{\partial z}{\partial \bar{z}_f}$ and $\frac{\partial z}{\partial \bar{x}} = \frac{\partial z}{\partial \bar{x}_f}$), and the identities $q = \bar{x} + \bar{x}_f$ and $z = \bar{z}_D + \bar{z}_f$. The vector y_{1t} aggregates the control variables including the country-fixed effects that proxy the production costs, institutional and demographic variables.

Equation (5) is based on a static optimization of the firm's problem, which we use to guide us to determine the control variables consistent with the ones used in the literature. In order to capture the strong memory of pollution, as well as to test for the EKC, we extend our model to include dynamic effects. The estimated form that we adopt is therefore

$$(6)\ log(pol_{i,t}) = \beta_0 + \beta_1 \log(pol_{i,t-1}) + \beta_2 \log(q_{it}) + \beta_3 [\log(q_{i,t})]^2 + \beta_4 f_{i,t}^j + \beta_5 corr_t + \beta_6 dens_t + \beta_7 D^t + \mu_i + \varepsilon_{it}$$

with $\mu_i \sim i.i.d(0, \sigma_{\mu_i})$, $\varepsilon_{it} \sim$ i.i.d.$(0, \sigma_\varepsilon)$, $E[\mu_i \varepsilon_{it}] = 0$ and where where *i* is the country subscript, the subscript *j* stands for an index for total, agricultural, mining, manufacturing, total services, financial services, non-financial services FDI. The variable pol_t is a measure of air pollution, q_{it} is log of per capita GDP, ${f_{it}}^j$ is the net capital inflow share of GDP,. The variable $corr_t$ is "control of corruption", a proxy for the institutional variable. It is indexed between 1 and 10, 10 being the highest control of corruption; $dens_t$ represents population density, D^t is a time dummy and μ_i is an idiosyncratic country specific effect.

The level and the square of GDP capture the EKC hypothesis, $\beta_2 > 0,\ \beta_3 < 0$, which leads to an inverse-U shaped relation between *pol* and *y*. For the halo effect to hold, the null hypothesis is $\beta_4 < 0$. We expect $\beta_5 < 0$, that is, for an increase in the control of corruption to improve the institutions of a country and hence to reduce pollution through more stringent regulation to protect the environment, and $\beta_6 > 0$, population density to increase the pollution level.

We use the GMM methodology because it is more suitable for our purposes. Panel data is to be preferred to cross-sectional when analyzing change in the dependent variable because of the correlation between lagged dependent variables and the unobserved residual. Cross-section estimates produce a bias, caused by the correlation between $pol_{i,t-1}$ and μ_i, which disappears in samples with large time-dimension but does not disappear with time-averaging. Thus, if such a correlation exists, the true underlying structure has a dynamic nature and time-averaging cross-section techniques introduce a bias that cannot be removed by controlling for fixed-effects. Therefore, to avoid these pitfalls, we adopt the GMM methodology.

A potential problem of the Arellano-Bond difference GMM (Arellano and Bond, 1991) estimator is that, under certain conditions, the variance of the estimates may increase asymptotically and create considerable bias if: (i) the dependent variable follows a random walk, which makes the first lag a poor instrument for its difference, (ii) the explanatory variables are persistent over time, which makes the lagged levels weak instruments for their differences, (iii) the time dimension of the sample is small (Alonso-Borrego and Arellano, 1996 and Blundell and Bond, 1998).

An additional necessary condition for the efficiency of the Blundell-Bond system GMM estimator is that, even if the unobserved country-specific effect is correlated with the regressors' levels, it is not correlated with their differences. The condition also means that the deviations of the initial values of the independent variables from their long-run values are not systematically related to the country-specific effects.[6] We instrument both income and FDI with GMM style instruments, which will account for reverse causality between these variables and the pollution variable.[7] We impose a limitation on the number of lags used to preserve degrees of freedom. We use three lags and perform robustness checks removing the restriction on the lags.

Data and Sources

The data are yearly, multi-country, span a long period from 1970 to 2000, and come from various sources. Appendix 2 displays the list of countries in the sample. The key independent variables are disaggregated FDI flows share of GDP denominated in current USD. All *FDI* series are *net*

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[6] These sets of conditions are: (i) No second order autocorrelation in the error term: $E[pol_{i,t-s}\ (\varepsilon_{it}-\varepsilon_{i,t-1})]=0$ for s≥2 and t=3,….T ; $E[y_{i,t-s}(\varepsilon_{it}-\varepsilon_{i,t-1})]=0$ for s≥2 and t=3,….T; $E[f^j_{i,t-s}(\varepsilon_{it}-\varepsilon_{i,t-1})]=0$ for s≥2 and t=3,….T, where y_{it} , f^j_{it} are the level of income and FDI, respectively and where for instruments we use their past levels and differences. To instrument FDI and the lagged output we used Stata's *GMM-style option*, and to instrument the remaining variables, corruption and elements of the x_{it} matrix, we used the *iv-style option.* (ii) No correlation of the unobserved country-specific effect with their difference $E[(pol_{i,t-1}-pol_{i,t-2})(\mu_i+\varepsilon_{it})]=0$; $E[(y_{i,t-1}-y_{i,t-2})(\mu_i+\varepsilon_{it})]=0$; $E[(f^j_{i,t-1}-f^j_{i,t-2})(\mu_i+\varepsilon_{it})]=0$; (iii) The last condition allows using lagged first differences as instruments for levels.

[7] We present here a set of results based on the minimum optimum lags, an approach that we selected to preserve the degrees of freedom (Roodman, 2006).

flows, accounting for the purchases and sales of domestic assets by foreigners in the corresponding year. FDI is defined as investment that "reflects the objective of obtaining a lasting interest by a resident entity in one economy (''direct investor") in an entity resident in an economy other than that of the investor (''direct investment enterprise")" (OECD, *International direct investment database,* Metadata). This lasting interest implies a long-term relationship between the direct investor and the enterprise and a significant influence on the management of the enterprise. The data on sectoral FDI inflows to agriculture, mining, manufacturing, financial services and nonfinancial services FDI are compiled from *United Nations Conference on Trade and Development* (UNCTAD), *Organization for Economic Cooperation and Development* (OECD), *The Association of Southeast Asian Nations* (ASEAN), and individual national statistical agencies web sites.

The dependent variable, carbon dioxide (CO2) emissions are from OECD and World Development Indicators (WDI). CO2 emissions are defined as the emissions stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. CO2 emissions are measured in kilotons (kt).

Population density (people per sq. km of land area) is midyear population divided by land area in square kilometers. Population is based on the *de facto* definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.

Institutional variables are from the *International Country Risk Group* (ICRG). Following the FDI and pollution literature, we adopted the control of corruption as an independent variable and we conducted robustness check with law and order (see below). This measure is indexed from 0 to 6, 0 representing the countries with worst corruption and 6 representing countries with the best practices. Corruption includes financial corruption, favoritism, nepotism, etc.

Empirical Results

The idiosyncratic shocks to different sectors may overweigh the regional shocks, conceal differences at the industry level, and may explain the reason behind inconclusive results in the literature. Our aim is to expose such effects if they exist. For this, we now turn to analyzing the industry pollution spillover of sectoral and aggregate FDI, given a set of control variables. We examine the primary, secondary (manufacturing) and tertiary (services) sectors by further disaggregating the primary sector into agriculture and mining, and the tertiary sector into financial and nonfinancial sectors.

To control for heterogeneity caused by the level of development, we break down the data according to income distribution measures and examine the same effects in four income categories ranging from lowest to highest-income countries following the World Bank specification: low-income, lower-middle-income, upper-middle-income, high-income. Since the number of countries in lower income category is small, we combine the low-income with the lower-middle-income countries and report the combined results.

To give an overall view of the estimated regression equation and examine the EKC effect, Table 1 displays the full regression results for aggregate and sectoral FDI for all countries. The full sample results are consistent with the expected signs of the coefficients. They indicate a strong persistence effect (1st row), underlying the cumulative nature of environmental degradation. Evidence supports the EKC hypothesis when inflows of investment are in agriculture and services (column 2 and 5). The institutional variable, control of corruption, is significant and with the right sign in the regression with the total FDI (column 1), suggesting that less corrupt countries are also those implementing stricter measures against pollution. Support for the halo effect are found in the presence of manufacturing FDI and services FDI, respectively. As expected, the FDI-pollution estimate is often insignificant at the aggregate level, except in two industries. In manufacturing the positive and significant estimate suggests that flows into this industry degrade the environment in the host country. By contrast, the negative estimate in the services indicate that services FDI improve the environmental conditions, supporting the halo Hypothesis. The breakdown with income distribution will help disentangle further these results.

In our analysis, we concentrate on the estimates of β_4, the pollution effect of FDI flows, or the spillover effect. To save space, we summarize in one table its value across sectors and income distribution (Table 2). A negative value suggests that the data supports the Halo Effect hypothesis. In Table 3 we present the EKC estimates according to income distribution, which we obtain from the same regressions that give the results in Table 2.

(i) FDI impact on pollution

The effect of total FDI on CO2 pollution

The first row in Table 2 reproduces the same results as Table 1, row 7. Column 2 presents the breakdown of the impact of total FDI on the environment according to income categories. Although the aggregate impact of capital flows in the full sample is insignificant when all countries are taken together (1st cell), the analysis at different income levels reveals a striking regularity. Evidence shows a significant positive impact in low- and middle-income countries and a significant negative impact in high-income countries (first column), suggesting that FDI inflows deteriorate the environment in the relatively poorer countries, while they improve it in the wealthy countries. Results at the aggregate level thus support the Halo Effect hypothesis in rich countries and we find a negative impact of FDI in poorer countries. How robust is this result across industries? Next, we turn to the sectoral level analysis.

The effect of primary sector FDI on CO2 pollution

FDI inflows to both agriculture and mining continue not to have a significant effect on air pollution in the full sample. (Table 1, first row, columns 3, 4). FDI inflows in agriculture mimic the results of total FDI. They worsen the CO2 conditions in middle-income countries, while improving it in the high-income countries where the halo effect continues to be relevant (column 3). In mining, by contrast, data supports the Halo Effect hypothesis more frequently (column 4). Lower middle-income countries and high-income countries benefit from FDI inflows into mining, where they presumably bring in “clean” technology, and there is weak evidence that it does it also in the poorer countries as well. However, upper middle-countries do not benefit from this technology where FDI inflows contribute to the air pollution. Thus, overall the FDI flows into the primary sector (columns 3 and 4) by and large parallel the total FDI results (column 2). In the lower middle-income countries the net effect of inflows to the primary sector cancels out (row 4), the upper-middle-income countries get dirtier technology (row 5), while high-income countries receive cleaner technology (last row).

The effect of manufacturing FDI on CO2 pollution

Most of the negative impact of capital inflows on air pollution in host countries is generated by manufacturing FDI (column 5). Inflow of foreign investment into this sector raises the pollution level significantly in the full sample (1st row). This result is traced back to low and lower-middle-income countries and high-income countries. Manufacturing FDI is the only type of investment flow that does not benefit the rich countries. Surprisingly, a strong halo effect is present in the upper middle-income countries.

The effect of tertiary sector FDI on CO2 pollution

In the full sample, the FDI in services benefits the environment (column 6, 1st row). This strong halo effect in the full sample can be traced back to a significant effect in the upper middle-income countries. Although there are other halo effects (poorest and richest economies), they are insignificant. No significant environmental deterioration due to service sector FDI inflows is depicted by the data. At the disaggregated industry level, however, positive spillovers are harder to detect. Only the lower middle-income countries appear to benefit from the financial FDI flows (column 7). The only significant impact of nonfinancial FDI is to increase pollution in poor economies, consisting of low and low-middle-income countries (last column). This result is consistent with the negative halo effect of total FDI depicted in column 2. The insignificant estimate if services FDI in lower middle-income countries reflect the fact that the halo effect by financial FDI inflows is mitigated by the adverse environmental effect of nonfinancial FDI.

Summary and discussion of findings on the impact of sectoral FDI on CO2 pollution and income distribution

Our findings can be interpreted in two ways: at the sectoral level and at the income distribution level depending on whether the reader examines the results vertically or horizontally. Examining the columns, at the industry level our results suggest that, foreign investment inflows into manufacturing and nonfinancial sectors are most likely to increase pollution and refute the Halo Effect hypothesis. Evidence supports the halo effect for FDI in services on the aggregate sample.

Since we are able to partition the data according to income distribution, in this section we summarize our findings examining the rows as well. At the aggregate level, we find that only high-income countries benefit from clean technology brought in by total FDI. By contrast, total FDI flows use dirty technology at all other income levels. When we consider sectoral flows, although results are more nuanced, overall they parallel the total FDI results. High-income countries still benefit from all type of FDI inflows, save for manufacturing, which are environmentally friendly and support the Halo Hypothesis. However, more FDI flowing into lower and low-middle host countries have harmful effects.

More specifically, lower and lower middle-income countries' environment is degraded by FDI flowing in agriculture, manufacturing, and nonfinancial industries. However, FDI flowing into mining and financial services industries bring in clean technology. High-income countries' environment benefits significantly from FDI flowing in agriculture, and mining significantly and weakly from capital flowing into services. Only manufacturing FDI worsens air pollution in these countries. This result stands in contrast to upper middle-income countries where the primary sector FDI flows into agriculture and mining degrade the environment, while those flowing into manufacturing and services improve it.

(ii) The Environmental Kuznets Curve Hypothesis

The hypothesis that pollution worsens during the initial growth process followed by an improvement as income rises is verified frequently and follows a surprising pattern (Table 3). The breadth of our findings reveals a more complex set of interactions between the level of development and pollution in a context of globalization and provides a compelling explanation for the ambiguity in the EKC literature. We show that the EKC hypothesis depends on the type of capital flows the countries receive and their level of development, and thus highlights the importance of accounting for heterogeneity, regional effects and dynamics in the data.

In the full sample the EKC is strongly present in countries receiving agriculture and services FDI (Table 1). The same pattern is repeated in low-income and lower middle-income countries, and in each subsector of the services industries. In other words, the EKC is confirmed in relatively poor countries, especially those receiving FDI flows in agriculture, financial and nonfinancial services. Interestingly, upper middle-income countries exhibit the EKC only when FDI flows to mining and manufacturing. Another intriguing finding of our study is to show that EKC is mostly inexistent in high-income countries, except when they host FDI in manufacturing. The traditional EKC results thus still hold at an early level of development, for most types of capital inflows. As countries become wealthier, EKC is supported if countries allow capital inflows in traditionally dirty industries, such as mining and manufacturing.

(iii) Additional tests: alternative measures of pollution and institutional variables

In this and the next subsections we discuss some additional results we obtained by using different data and controlling for different factors. We do not display the results for sake of preserving space; however they are available from the authors.

Does FDI inflows change air pollution caused by particles other than CO_2, such as SO_2 (sulfur dioxide), NO_2 (nitrogen dioxide) and CO (carbon monoxide)? Although most of the discussion about man-made climate change centers around the impact of CO_2, the other particles are greenhouse gases directly generated by industrial pollutants. Since data are available only for the OECD countries, we were able to conduct the analysis only at the sectoral level and not income levels. We found that the halo effect is visible in services FDI also with SO_2 and NO_2 pollutants, especially in nonfinancial flows, whereas financial FDI contributes to a decline in NO_2. In contrast, data reflects a bleak picture for the CO pollution. Evidence suggests that among OECD countries, FDI flows into mining and services raises the levels of CO significantly in host countries, raising a broader concern on FDI-induced air pollution.

We tried alternative measures of institutional variables. One such measure from the same data source is law and order. Results were largely consistent but with fewer significant coefficients. Since this is a variable more broadly defined and less precise than the corruption measure we used, we thus favored the latter in line with the literature.

We also wanted to examine if the Kyoto Protocol signed in 1997 by 191 countries and entered into force in 2005 had any impact on the estimates and parameter stability. If the protocol had a significant impact, possible changes we expected were an increase in the production costs of polluting industries, therefore a decline in the positive coefficients, and/or a decrease in the costs of clean industries and a rise in the negative coefficients. To our surprise, our results remained unchanged. This may mean either that the protocol has been ineffective, or it did not have time to work through the estimated coefficients.

(iv) Other estimates of the model

Here we briefly review the remaining parameter estimates in the income categories. We find that the persistence of pollution is highly robust to income distribution. Control of corruption is significant reduces pollution in upper middle-income countries that are host to FDI in mining and all services sectors, and in high-income countries that are host to FDI in manufacturing and in both services subsectors. Control of corruption in general has no effect on environmental degradation in poorer countries. Population density increases pollution in lower middle-income countries receiving manufacturing and agricultural FDI, but it has a negative impact on pollution in high-income countries and in high middle-income countries.

Conclusion

The literature on the effect of globalization on the environment is ambiguous, partly due to the range of different approaches followed and partly due to the drawbacks of methodologies. We address these issues by adopting a unified framework and a dynamic model that allows the analysis of various effects over time, and a long span of data covering multi-country and industries. Our study tests the Halo Effect hypothesis, which argues that foreign direct investment is beneficial to the host country because by bringing in clean technology and know-how, it improves the environmental standards. We identify the channels through which the halo effect manifests and simultaneously investigate the Environmental Kuznets Curve effect (an inverse U-shaped relation between pollution and the income) by controlling for the type of FDI inflows and the level of development of the economies.

We find that results vary critically according to the type of capital flow and income category. Foreign investment flows into manufacturing tend to degrade the environment (negative halo effect), while those flowing into services support the halo effect hypothesis. In general, foreign investment flowing in poorer countries has more harmful effects on environment, while those flowing to richer countries have a beneficial effect and support a halo effect. However, when air pollution is measured by a different pollutant measure more industrialized countries may be adversely affected.

Furthermore, in our analysis we shed light on the inconclusive results of the EKC literature. We show that the traditional EKC results hold at an early level of development for most types of capital inflows. As countries become wealthier, EKC is supported if countries allow capital inflows in traditionally dirty industries, such as mining and manufacturing

Our results thus suggest that studies relying simply on aggregate data or on firm level data to analyze the relation between the environment and globalization miss the subtle characteristics of the data due to complex interaction of sectoral flows and the environment. These studies can lead to wrong or inconclusive inference and thus to misleading policy prescriptions, with a long lasting impact.

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Appendix 1

The optimal output of the multinational in the host country's market is:

$H_f = H_f[\Gamma_f, K_f, \bar{Z}_f, \bar{X}_f]$ (1a)

where Γ_f is a vector of cost of production of the multinational in the host country. Since K_f will be a covariate in our reduced form pollution equation, we do not replace it in the output equation. The pollution equation is obtained by substituting equations (2), (3), and (1a) into (1):

$$Z = D + \psi\left[H[\Gamma, \overline{Z_D}, \bar{X})] + H_f[\Gamma_f, K_f, \bar{Z}_f, \bar{X}_f]\right] = Z(D, \Gamma, \Gamma_f, K_f, \bar{Z}_D, \bar{Z}_f, \bar{X}, \bar{X}_f)$$

Substituting for the optimal demand for FDI is equivalent to instrumenting K_f using factor prices. Instead, the GMM methodology that we adopt computes internal instruments. The instrumental matrix consists of lagged levels and lagged differences of FDI, where current levels of FDI are instrumented by lagged differences and current differences of FDI are instrumented by lagged levels.

Log-linearizing both sides of the equation around the steady-state we get:

$$\frac{dZ}{Z} = \frac{D}{Z}\frac{dD}{D} + \psi\delta\left\{\epsilon_\Gamma \frac{d\Gamma}{\Gamma} + \epsilon_{z_D}\frac{d\bar{Z}_D}{\bar{Z}_D} + \epsilon_X \frac{d\bar{X}}{\bar{X}}\right\} + \psi(1-\delta)\left\{\phi_{\Gamma_f}\frac{d\Gamma_f}{\Gamma_f} + \phi_{z_f}\frac{d\bar{Z}_f}{\bar{Z}_f} + \phi_{X_f}\frac{d\bar{X}_f}{\bar{X}_f} + \phi_{K_f}\frac{dK_f}{K_f}\right\}$$

where $\delta, 1-\delta$ are the share of domestic firm's and the multinational firm's respective outputs in total output Q; ϵ_j, ϕ_j for $j = \{\Gamma, Z, Z_D, X \; and \; X_f\}$ are, respectively, the elasticities of optimal output of domestic and foreign firms with respect to *j*.

Integrating both sides and rearranging, we get the equation (4) in the text:

$$z = \alpha_0 + \alpha_1\gamma + \alpha_2\gamma_f + \alpha_3\bar{x} + \alpha_4\overline{x_f} + \alpha_5\overline{z_D} + \alpha_6\overline{z_f} + \alpha_7 f$$

where lower case variables are the natural logs of higher-case variables and the elasticities are defined as:

$\alpha_0 = \frac{D_0}{Z}$; $\alpha_1 = \psi\delta\,\epsilon_\Gamma$; $\alpha_2 = \psi(1-\delta)\,\phi_{\Gamma_f}$; $\alpha_3 = \psi\delta\,\epsilon_X$;

$\alpha_4 = \psi(1-\delta)\,\phi_{X_f}$; $\alpha_5 = \psi\delta\,\epsilon_{z_D}$; $\alpha_6 = \psi(1-\delta)\,\phi_{z_f}$; $\alpha_7 = (1-\delta)\phi_{K_f}$

Appendix 2: Country list

Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Belarus, Belgium, Bolivia, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Cameroon, Canada, Chile, China, Colombia, Congo, DR., Congo, Rep., Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Estonia, Ethiopia, Finland, France, Gabon, Gambia, The , Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong, China, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea, Rep., Kuwait, Latvia, Lebanon, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Malta, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Saudi Arabia, Senegal, Sierra Leone, Slovakia, Slovenia, Somalia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Syria, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, UAE, UK, US, Uruguay, Venezuela, Vietnam, Zambia, Zimbabwe.

Table 1*: Full regression results "All countries"

Log CO2 All countries	Total FDI/GDP	Agriculture FDI/GDP	Mining FDI/GDP	Manuactur. FDI/GDP	Services FDI/GDP	Finance FDI/GDP	Nonfinancial FDI/GDP
$\log\ (CO2_{t-1})$	1.005*** (140.23)	1.006*** (148.66)	1.014*** (129.78)	1.003*** (205.47)	1.001*** (183.70)	1.005*** (188.40)	1.004*** (152.65)
$log\ (Real\ GDP\ per\ capita)$	-0.010 (-0.16)	0.252*** (3.21)	0.064 (0.72)	0.025 (0.36)	0.104** (2.34)	0.082 (1.16)	0.108 (1.27)
$[log\ (Real\ GDP\ per\ capita)$	0.001 (0.42)	-0.015*** (-3.33)	-0.005 (-1.15)	-0.001 (-0.20)	-0.007** (-2.40)	-0.005 (-1.23)	-0.006 (-1.32)
$log\ (Control\ of\ corruption$	-0.044*** (-2.60)	-0.011 (-0.52)	0.026 (1.63)	-0.057 (-1.53)	0.009 (0.35)	-0.026 (-1.31)	-0.016 (-0.61)
$log(Density)$	-0.005 (-0.84)	-0.004 (-1.02)	-0.004 (-1.22)	-0.001 (-0.48)	-0.001 (-0.57)	-0.004 (-1.49)	-0.003 (-1.26)
$log\left(\frac{FDI}{GDP}\right)_{t-1}$	0.008 (1.39)	-0.002 (-0.64)	-0.001 (-0.21)	0.017** (2.55)	-0.015* (-1.95)	0.001 (0.39)	0.009 (1.59)
#Observations	2479	714	796	1084	1108	933	859
#Countries	131	78	74	86	86	77	76

* Figures in parentheses are t-statistics; * and ** denote significance at the 10 % and 5 % respectively. Results are robust to heteroscedasticity.

Table 2: Effect of FDI on CO2 emissions*

$log\ CO2$	Total FDI/GDP	Agriculture FDI/GDP	Mining FDI/GDP	Manufact. FDI/GDP	Services FDI/GDP	Finance FDI/GDP	Nonfinancial FDI/GDP
All countries	0.008 (1.39)	-0.002 (-0.64)	-0.001 (-0.21)	0.017** (2.55)	-0.015* (-1.95)	0.001 (0.39)	0.009 (1.59)
#obs.	2479	714	796	1084	1108	933	859
#countries	131	78	74	86	86	77	76
AR(2)	0.646	0.712	0.338	0.567	0.434	0.656	0.108
Lower and Lower middle-income countries	0.014* (1.92)	0.0002 (0.03)	-0.005 (-1.32)	0.012* (1.65)	-0.015 (-0.86)	-0.008 (-1.50)	0.022*** (3.51)
# obs.	1307	227	301	325	341	236	212
#countries	68	32	31	35	35	27	26
AR(2)	0.563	0.330	0.312	0.295	0.703	0.788	0.471
Lower middle-income countries	0.019* (1.64)	0.008** (2.06)	-0.005*** (-2.77)	0.012** (1.97)	0.012 (1.32)	-0.005* (-1.68)	0.031*** (6.55)
# obs.	634	168	214	231	244	168	170
#countries	34	21	20	23	23	19	19
AR(2)	0.621	0.334	0.560	0.703	0.621	0.569	0.329
Upper middle-income countries	0.016** (2.12)	0.008* (1.88)	0.008*** (3.21)	-0.009*** (-2.67)	-0.007* (-1.73)	-0.001 (-0.29)	0.000 (0.06)
# obs.	444	187	186	248	257	234	222
#countries	25	19	17	20	20	20	20
AR(2)	0.792	(0.329)	0.225	0.555	0.454	0.345	0.579
High-income countries	-0.013** (-2.30)	-0.004* (-1.88)	-0.003* (-1.95)	0.010*** (2.60)	-0.004 (-1.15)	-0.001 (-0.46)	-0.003 (-0.81)
# observations	728	300	309	511	510	463	425
#countries	38	27	26	31	31	30	30
AR(2)	0.764	0.194	0.803	0.033	0.165	0.402	0.096

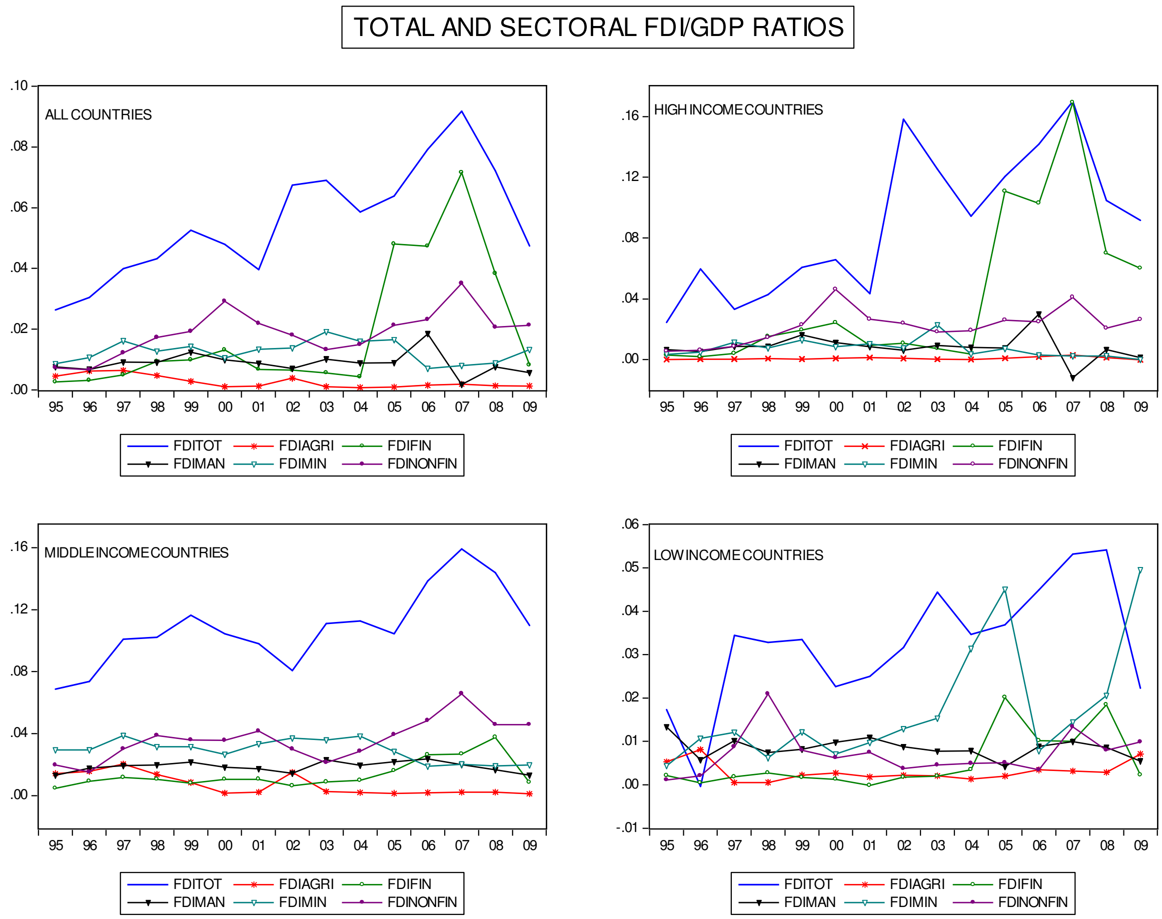
* The first entry in each cell is the estimate of the effect on pollution of FDI flows, estimated by the System GMM method. Figures in parentheses are t-statistics; * and ** denote significance at the 10 % and 5 % respectively. Results are robust to heteroscedasticity.

Table 3 : Environmental Kuznets Curve (EKC) with CO2 emissions*

$log\ CO2$	Total FDI/GDP	Agriculture FDI/GDP	Mining FDI/GDP	Manufact. FDI/GDP	Services FDI/GDP	Finance FDI/GDP	Nonfinancial FDI/GDP
All countries							
$log\ (Real\ GDP\ per\ capita)$	-0.010 (-0.16)	0.252*** (3.21)	0.064 (0.72)	0.025 (0.36)	0.104** (2.34)	0.082 (1.16)	0.108 (1.27)
$[log\ (Real\ GDP\ per\ capita)]^2$	0.001 (0.42)	-0.015*** (-3.33)	-0.005 (-1.15)	-0.001 (-0.20)	-0.007** (-2.40)	-0.005 (-1.23)	-0.006 (-1.32)
Low and lower middle-income countries							
$log\ (Real\ GDP\ per\ capita)$	-0.023 (-0.17)	0.462** (2.17)	-0.442 (-1.54)	-0.012 (-0.11)	0.314** (2.06)	0.320*** (2.67)	0.287** (2.15)
$[log\ (Real\ GDP\ per\ capita)]^2$	0.001 (0.16)	-0.033** (-2.02)	0.032 (1.53)	0.001 (0.18)	-0.025** (-2.07)	-0.021** (-2.38)	-0.021** (-2.11)
Lower middle-income countries							
$log\ (Real\ GDP\ per\ capita)$	0.215 (0.42)	1.834*** (2.81)	0.375 (0.71)	0.699 (1.22)	0.874 (1.47)	1.596*** (2.77)	1.440*** (2.87)
$[log\ (Real\ GDP\ per\ capita)]^2$	-0.014 (-0.40)	-0.126*** (-2.80)	-0.027 (-0.75)	-0.047 (-1.21)	-0.061 (-1.49)	-0.111*** (-2.77)	-0.099*** (-2.84)
Upper middle-income countries							
$log\ (Real\ GDP\ per\ capita)$	0.140 (0.25)	0.434 (0.63)	0.568** (2.23)	0.975*** (2.92)	0.507 (1.39)	0.333 (0.72)	0.595 (1.53)
$[log\ (Real\ GDP\ per\ capita)]^2$	-0.007 (-0.21)	-0.025 (-0.60)	-0.034** (-2.15)	-0.059*** (-2.91)	-0.031 (-1.42)	-0.020 (-0.74)	-0.035 (-1.50)
High-income countries							
$log\ (Real\ GDP\ per\ capita)$	1.725 (1.54)	-0.028 (-0.14)	0.274 (1.20)	0.506* (1.87)	0.651 (1.34)	0.038 (0.14)	0.039 (0.13)
$[log\ (Real\ GDP\ per\ capita)]^2$	-0.089 (-1.53)	0.001 (0.06)	-0.014 (-1.20)	-0.026* (-1.92)	-0.034 (-1.36)	-0.002 (-0.15)	-0.002 (-0.16)

* Figures in parentheses are t-statistics; * and ** denote significance at the 10 % and 5 % respectively. Results are robust to heteroscedasticity.

FIGURE 1**



**FDIX is foreign direct investment where X stands for TOT (total), AGRI (agriculture), MAN (manufacture), MIN (mining), FIN (financial services), NONFIN (nonfinancial services).