1-1-2011

# The Impact of FDI on $CO_2$ Emissions in Latin America

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**Abstract**

*This paper uses panel Granger causality tests to study the relationship between sector specific FDI and $CO_2$ emissions. Using a sample of 18 Latin American countries for the 1980-2007 period, we find causality running from FDI in polluting intensive industries ("the dirty sector") to $CO_2$ emissions per capita. This result is robust to controlling for other factors associated with $CO_2$ emissions and using the ratio of $CO_2$ emissions to GDP. For other sectors, we find no robust evidence that FDI causes $CO_2$ emissions.*

**JEL categories:** F21, Q50

**Key words:** FDI, Pollution, Latin America

*We are thankful to Graham Veenstra for excellent research assistance. Any remaining errors are our own.

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## I. Introduction

The share of total foreign direct investment (FDI) inflows to less developed countries (LDCs) as a share of total world FDI has increased from 25% in the 1990s to 31% in the 2000s.[1] These inflows have been encouraged and welcomed by LDCs because of the important role they play in domestic economies as a source of growth and job creation. However, there are concerns that LDCs could competitively undercut each other's environmental regulations to attract FDI (Elliot and Shimamoto, 2008). This "race to the bottom" in LDCs may result in these countries becoming "pollution havens", where multinational corporations (MNCs) locate operations in order to save on environmental related costs. In this scenario, the MNCs that have more to gain from relocating are those in the most polluting intensive or "dirty" industries. Therefore, as LDCs continue to attract significant shares of FDI flows, it is important to assess whether FDI inflows to LDCs are associated with higher levels of pollution.

In this study, we analyse the link between FDI and $CO_2$ emissions in Latin America from 1980 to 2007. In particular, we conduct a panel Granger causality test of the relationship between FDI and $CO_2$ emissions. This approach allows us to address two important issues. First, it helps us to obtain more reliable estimates on the relationship between FDI and $CO_2$ emissions by addressing causality in the relationship. Second, since we are working with macro data, a panel approach allows us to increase the number of observations significantly and to draw conclusions that are region specific. In addition, our analysis expands on previous work by using FDI data disaggregated by sectors. Therefore, we are able to explore whether increases on FDI in pollution intensive sectors are associated with higher $CO_2$ emissions in Latin America.

Latin America is an interesting case study for exploring the relation between FDI and $CO_2$ emissions. This region receives the most capital inflows to LDCs after Asia, with a share of total FDI inflows around 30% (UNCTAD, 2010). In addition, as developing countries continue to grow, their $CO_2$ emissions have become an important issue in international agreements related to trade and the environment.

The results of our study indicate that FDI inflows in the pollution intensive sectors can be linked to increases in $CO_2$ emissions, but the same relationship does not hold for FDI in other sectors. Hence, policy makers in the region could benefit from considering this differentiated environmental impact of FDI.

The remainder of the paper is organised as follows. In Section II, we discuss the relationship between FDI and pollution with a review of the current literature. Section III provides a theoretical framework. Section IV describes the data used in the analysis, while section V covers the methodology. The discussion of the results with robustness tests is included in Section VI, and Section VII concludes.

## II. FDI and the Environment: A Review of the Literature

There is considerable literature studying FDI flows into LDCs. This interest is due, to some degree, to the significant increases of FDI inflows to LDCs over the last decade. Moreover, FDI has attracted attention as a potential engine to economic growth in emerging economies. The benefits of FDI on growth stem from its long-term nature, the creation of capital stock and employment and the transfer of skills and technology that lead to greater productivity (Borensztein, et al., 1999). These potential benefits of FDI over other types of capital inflows and the interest of MNCs to relocate have made attracting FDI an important component of the economic agenda in many emerging economies. Therefore, there is a strong competition among LDCs to attract FDI.

An important issue is whether lax environmental standards are part of the increasing desire of MNCs to relocate abroad. It is possible that the competition among LDCs may have induced a "race to the bottom” in relation to environmental regulation, where pollution-intensive MNCs relocate to LDCs with less stringent environmental standards (Xing and Kolstad, 2002). This is known as the "pollution haven" hypothesis (Grossman and Krueger, 1991; Mani and Wheeler, 1998). The empirical evidence has been mixed, with various studies finding no support for the pollution haven hypothesis (Mani and Wheeler, 1998; Eskeland and Harrison, 2003; MacDermott, 2009 and Wagner and Timmins, 2009).

The lack of consistent evidence in favor the pollution haven hypothesis may suggest that environmental regulations are unlikely to have an effect on plant location since the MNCs savings from lower environmental regulation could be small. Moreover, it is possible that pollution intensive industries relocating to LDCs can have cleaner production methods than similar domestic industries (see Grossman and Krueger, 1991). According to this view, FDI to LDCs may bring cleaner technologies in the long run. Likewise, it is expected that domestic firms will eventually acquire the cleaner technologies of foreign firms. This view is known as the “pollution halo” hypothesis and supports the notion that the presence of foreign-owned firms may yield substantial environmental benefits to LDCs (Grossman and Krueger, 1991; Zarsky, 1999; Antweiler, et al., 2001; Birdsall and Wheeler, 2001; Talukdar and Meisner, 2001). In general, the empirical evidence on the link between FDI and pollution has been ambiguous and concrete policy recommendations are difficult to make.

A possible explanation of the ambiguity in the empirical results across studies lies in the differences in the scope (or question) and the empirical approach (including differences in econometric methodologies, lack of comparable data, and proxies). The empirical approach to study the relationship between FDI and the environment can be seen from two perspectives. One approach relates to the studies that attempt to assess if firms choose to locate in countries with low environmental standards by using industry level data, measures of environmental stringency and pollution intensities by industries (using pollution abatement expenditures either at home and/or abroad). The majority of this work is composed of case studies or firm level analysis. A source of concern with this approach is that it is difficult to measure and to account for environmental stringency (Eskeland and Harrison, 2003; Albornoz, et al., 2009; Wagner and Timmins, 2009).

A second approach in the literature has concentrated on the impact of FDI on the environment. That is, once firms are located in other countries it is expected that the pollution levels will increase. In this context, it is argued that pollution levels could also work as a proxy of environmental stringency. Studying the empirical link between FDI and pollution is still a difficult task. Available data on country level FDI for developing countries tends to be at the aggregate level while FDI as a cause of pollution might be more related to certain types of industries. Moreover, pollution data by industry seldom exists for these types of countries.

An additional limitation of both approaches is that most of the existing analyses do not study the causality between FDI, environmental policy and pollution. Causality is important since it is possible that MNCs relocate to countries which already have high pollution concentrations.  Conversely, MNCs may relocate to LDCs, and this will lead to an increase in pollutants concentrations. Moreover, these two situations are not mutually exclusive. In the literature, the most common approach assumes environmental regulation (or pollution) as a function of FDI or vice-versa. Since the impact of FDI on pollution may go both ways, the empirical methodology should take into account this bi-directionality. Only few studies have addressed this type of problem by conducting a causality or cointegration analysis (see Hoffmann, et al., 2005; Merican, et al., 2007; Acharyya, 2009; Lee, 2009). These studies have found that, in most instances, FDI can clearly be linked to pollution or environmental damage. In the next section we discuss the current literature and some of the trends of FDI and pollution in the case of Latin America.

***FDI and the Environment in Latin America***

The environmental consequences of globalization have been subject to a global heated debate. According to the Carbon Dioxide Information Analysis Center (CDIAC) in the last twenty years LDCs have more than doubled their carbon dioxide emissions (CDIAC). Moreover, developing countries are Annex II countries under the Kyoto protocol and are exempt from any mandatory emissions reduction.[2] In Latin America, total $CO_2$ emissions have been on the rise. Moreover, CDIAC reports that four countries of the region (Argentina, Brazil, Mexico and Venezuela) belong to the list of countries producing 90 percent of the world carbon dioxide emissions. Mexico and Brazil alone account for 52.7 percent of the 2007 regional emissions and belong in the list of top 20 highest fossil-fuel $CO_2$ emitting countries (Marland, et al., 2008).[3]

FDI flows to Latin America have increased dramatically over the past decades. Figure 1 illustrates the trends of pollution intensive and non-pollution intensive FDI, where both categories have been on the rise. Although there was a dramatic fall in FDI in 2000-2001, possibly because of the volatility in macroeconomic fundamentals in 1999, the 2000 Argentinean crisis and the 2001 US recession; the trend has in general been positive. Figure 2 depicts the trend of pollution intensive FDI as a share of total FDI, and it shows that the participation of dirty industries on total FDI has been relatively stable over time. Moreover, when looking at FDI flows into pollution intensive sectors disaggregated by industry, we find that the industries with the highest growth were mining, oil and chemical (Figure 3).

There is a scant literature on the relationship between FDI and pollution for the case of Latin America. Most of these studies are limited by the scope of the data used and, in most cases, they rely on a small sample period or a small number of observations. Moreover, most of the research for the region is country specific, and very few empirical studies have considered the region as a whole. In general, the overall evidence on the relationship between FDI and emissions is, at best, mixed.

Some studies, such as Cole and Ensign (2005), MacDermott (2006), Barbier and Hultberg (2007), and Waldkirch and Gopinath (2008) among others, have found evidence that MNCs locate operations in Latin America as a result of low environmental standards. MacDermott (2006), for example, finds that FDI from the United States can be associated with the pollution haven hypothesis after NAFTA. Conversely, Biglaiser and Staats

(2008) is one of the most recent studies that do not find support for the pollution haven hypothesis for Latin America, they use a survey of American executives of corporations with presence in Latin America and find that investment risk is the main factor driving FDI in the region. Additionally, Grossman and Krueger (1991), Carrada-Bravo (1995), and Cole and Ensign (2005) do not find empirical evidence that Mexico became a pollution haven with NAFTA. Furthermore, Birdsall, et al., (2001) find support for the "pollution halo" hypothesis in the case of Chile.

Our paper contributes to the above literature by looking at the causal relationships between FDI and the $CO_2$ emissions. We take a panel approach, which increases the number of observations significantly and allows us to draw conclusions that are region specific. In addition, our analysis expands on previous work by using FDI data disaggregated by sectors. We explore whether FDI in certain sectors is associated with greater emissions in Latin America. Moreover, our methodology differs from previous analyses as we incorporate time series econometric techniques that provide more reliable estimates on the relationship between FDI and pollution. Next, we describe the theoretical framework, the data used in our analysis and the econometric methodology.

## III. Theoretical Framework

The theoretical framework loosely follows Baumol and Oates (1988) and List and Co (2000). Since pollutant emissions are generated during production, we can consider without loss of generality that these emissions are inputs to the production process. Hence, the profits of a plant in region j are given by the following equation:

$$\pi_j = PQ - P_G G - P_Z Z \tag{1}$$

where $G$ is the vector of inputs and other characteristics which include labor, capital, distance to the markets, export and import taxes. $Z$ is the amount of emissions used in production and $P_Z$ is the unit price of emissions. Setting $\eta_G = \frac{G*}{Q*}$, $\eta_z = \frac{Z*}{Q*}$ where the superscript asterisk indicates the profit maximizing choice, the profits of the firm can be expressed as follows:

$$\pi_j^* = (P - \eta_G P_G - \eta_Z P_Z) Q^* \tag{2}$$

Equation (2) shows profits as a function of the input intensities and their prices. In the absence of any environmental regulation, the private marginal cost of emissions is zero (that is $P_Z = 0$). $P_Z$ will increase with higher or more stringent environmental regulation. Thus, the degree that environmental regulation (as reflected in $P_Z$) can affect the firm's profits depends on the pollution intensity of production. The profits of firms with high $\eta_Z$ will be more sensitive to changes in $P_Z$. Therefore in our analysis we concentrate on whether FDI in industries with high pollution intensities has a differential effect on pollution.

Thus, other things equal a firm will relocate to the region where $P_Z$ is the lowest. However, in many cases a new location implies also a new set of prices $P_G$ associated with different cost of labor, energy transportation, and imports and exports tariffs. It is likely that once a plant faces different prices, the input intensities will also change.

This implies that FDI will flow from a region with strong to non-existent (or weak) environmental regulations if the following condition is satisfied:

$$\pi^*_{j,s} = (P - \eta_{G,s}P_{G,s} - \eta_{Z,s}P_{Z,s})Q^* < (P - \eta_{G,w}P_{G,w})Q^*_w = \pi^*_{j,w} \quad (3)$$

where the subscript *s* denotes if the region enforces environmental regulations and *w* is the region without environmental regulations. To simplify Equation (3) we can assume that $P_Z = 0$ in the region with weak environmental regulation. Under the condition shown in Equation (3), the region with low environmental restrictions will receive FDI from high pollution intensity industries. However, notice that, as mentioned before, other inputs and characteristics in *G* can affect the location decision of the plant.

The location decision of the firm will depend on the actual values of the parameters in Equation (3) which requires estimating these values. Since it is difficult to compile firm level data consistent throughout the region to estimate the profit function for each plant, we look at FDI inflows to Latin American countries and sorted by different sectors in order to assess their effect on $CO_2$ emissions. That is, if the condition above holds then we would expect to observe that pollution intensive industries would relocate to countries with lax environmental regulation, leading to higher emissions in these countries.

## IV. Data

Our pollution measure is the growth in $CO_2$ emissions per capita. $CO_2$ is a pollutant commonly used in the literature because of its contribution to global warming, and it is generally involved as a main variable of concern in international agreements (Smarzynska and Wei, 2001; Talukdar and Meisner, 2001; Hoffmann, et al., 2005; MacDermott, 2006; Merican, et al., 2007; Acharyya, 2009; MacDermott, 2009). Furthermore, $CO_2$ emissions are the only indicator related to the environment that is available consistently over time for Latin American countries.

Previous work has used $CO_2$ emissions growth (Hoffmann, et al., 2005), total $CO_2$ emissions (Acharyya, 2009), $CO_2$ emissions to GDP ratio (MacDermott, 2009) and $CO_2$ emissions per capita in levels (Talukdar and Meisner, 2001; MacDermott, 2006). Few other papers have used other pollution measures such as $SO_2$, NOx and PT (see Xing and Kolstad, 2002; MacDermott, 2006; and Waldkirch and Gopinat, 2008). We place emphasis on the growth of $CO_2$ emissions per capita since total emissions can be associated with population growth (see MacDermott, 2006). We construct the growth of $CO_2$ emissions per capita as the first difference of the natural log of $CO_2$ emissions per capita. For the purpose of robustness, we use an alternative indicator of pollution. We use the growth of the $CO_2$ emissions to GDP ratio at 2005 constant international dollars (using purchasing power parity rates; where growth is constructed as the difference of the natural log). Both indicators of $CO_2$ emissions were obtained from the World Development Indicators (WDI, 2010).

Regarding FDI, we expand the literature by considering FDI inflows disaggregated by sector. As mentioned in Section III, plants in sectors with higher pollution intensity would be, at least in theory, more likely to be located in regions with weak environmental regulations. Therefore, to determine the type of capital inflows that are more detrimental to the environment we consider the three main different sectors: primary, secondary, and tertiary. We believe that this sectoral disaggregation for Latin America is an important contribution since most of the existing literature uses aggregate measures of FDI. Roughly speaking, the primary sector includes agricultural and mining activities, the secondary sector manufacturing activities, and the tertiary sector services. Table 1 shows a description of the industries/sectors included in each category. However, some industries within the sectors have vast differences in pollution intensities. Therefore, we consider an additional indicator that aggregates FDI in pollution intensive industries only. Considering FDI in pollution intensive industries is also a key contribution of this paper.

The methodology to categorise an industry as pollution intensive varies in the literature. For example, Kahn (2003) uses energy use and the toxic inventory, whereas List and Co (2000) considers emissions by industry and pollution abatement operating expenditures. Jaffe et al. (1995) and Levinson (1996) use pollution abatement capital expenditures as a percentage of new or total capital expenditures to compute an indicator of pollution intensity. Table 1 shows the industries that were considered as pollution intensive in some of the previous studies. Despite the differences in the number and detail of sectors, as well as in the methodology to obtain the pollution intensity, there are vast similarities in the industries labeled as pollution intensive. For example, chemicals, petroleum and primary metals are regarded as pollution intensive by most of these studies. Based on this information and the available data on disaggregated FDI, we categorise as pollution intensive: mining, quarrying and petroleum, wood and wood products, paper and paper products, chemicals and chemical products, non-metallic mineral products, metal and metal products, electrical and electronic equipment, and motor vehicles and other transport equipment. Hence, we create a pollution intensive or "dirty" sector comprised of these industries.

We also construct FDI inflows in different sectors (primary, secondary, tertiary, dirty) as a share of GDP. The data on FDI disaggregated by sector comes from the United Nations Conference on Trade and Development Data Extract Service Desk (UNCTAD/DITE, 2010). We construct FDI by sector as a share of GDP using data from the World Development Indicators (WDI, 2010), and use the natural log of the sectoral FDI inflow as a share of GDP.

Other control variables considered in the analysis are real GDP per capita (in constant 2000 US dollars) and the manufacturing value added share of GDP. We are interested in the growth of these variables, where both indicators are used as the first difference of the natural log and were obtained from the WDI (2010). The 18 Latin American countries considered for the estimations are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, and Venezuela. The period of analysis considered is between 1980 and 2007.[4] Tables 2 and 3 present a description and the summary statistics of the variables used in this analysis.

## V. Methodology

We use a Granger causality test in order to determine the relationship between sectoral FDI inflows and pollution emissions. The Granger causality test is based on the Vector Autoregressive (VAR) framework. Our empirical methodology contributes to the literature in the following two ways. First, our analysis focuses on Latin America and uses sectoral FDI. To our knowledge, there is no other analysis that looks at the region as a whole and uses a data on FDI by sector. We specifically test the impact of FDI inflows in those industries that are considered the most polluting. Second, we expand on previous work by using a Granger causality test in a framework that takes into consideration country characteristics and time specific effects. To check the robustness of our results we: i) extend our analysis to a multivariate VAR, where we control for other variables related to $CO_2$ emissions and ii) use $CO_2$ emissions to GDP ratio as an alternative indicator of emissions.

The modeling used for our Granger causality test, which relates to Hoffmann's et al. (2005) analysis, is explained in detail below. The panel VAR framework used in this analysis is specified as follows:

$$y_{i,t} = \sum_{j=1}^{k} \alpha_j x_{i,t-j} + \sum_{j=1}^{k} \beta_j y_{i,t-j} + a_i + \tau_t + e_{i,t} \tag{4}$$

$$x_{i,t} = \sum_{j=1}^{k} \delta_j x_{i,t-j} + \sum_{j=1}^{k} \gamma_j y_{i,t-j} + a_i + \tau_t + e_{i,t} \tag{5}$$

Where $y$ represents the growth of $CO_2$ emissions per capita and $x$ is the FDI inflows in a specific sector. The subscript $i$ represents the country ($i$ =1, 2, … N) and $t$ represents the time period ($t$ = 1, 2, … T). $k$ represents the number of lags of the variables $y$ and $x$ included as regressors, and $a_i$ and $\tau_t$ represent the country and time fixed effects. It is assumed that $x$ and $y$ are stationary and that the error term in both equations is uncorrelated white noise.

We have an unbalanced panel for the estimations of equations 4 and 5 due to missing observations for the sectoral FDI variables. The Granger causality test for our analysis takes the following steps. First, using equation 4 to test causality from FDI to pollution, we set the following hypotheses:

Ho: $\sum_{j=1}^{k} \alpha_j = 0$, where FDI does not cause $CO_2$ emissions per capita growth

Ha: $\sum_{j=1}^{k} \alpha_j \neq 0$, where FDI does cause $CO_2$ emissions per capita growth

An F statistic is constructed using the normal Wald test for the coefficient restrictions. If Ho is rejected, then we can conclude that there is evidence that FDI in a specific sector Granger causes $CO_2$ emissions per capita growth. If we fail to reject Ho, there is no evidence of causality running from sectoral FDI to $CO_2$ emissions.

Second, to test causality from $CO_2$ emissions to sectoral FDI, we use equation 5 and set the following hypotheses:

Ho: $\sum_{j=1}^{k} \gamma_j = 0$, where $CO_2$ emissions growth does not cause FDI inflows

Ha: $\sum_{j=1}^{k} \gamma_j \neq 0$, where $CO_2$ emissions growth does cause FDI inflows

In this case, rejecting Ho will lead to conclude that $CO_2$ emissions will cause FDI inflows in a specific sector. Our model is specified in Equations 4 and 5 in a bivariate VAR form, but it can be extended to a multivariate form by expanding the number of regressors. Since our main focus is on the impact of FDI on $CO_2$ emissions, we limit our discussion of Granger causality running from FDI to $CO_2$ emissions. For the multivariate VAR, following Talukdar and Meisner's (2001) approach, we include GDP per capita growth and the growth of manufacturing value added as a share of GDP. Both indicators are likely to be important determinants of pollution and $CO_2$ levels.

The Granger causality test with fixed effects used in this analysis provides the advantage of accounting for country characteristics and time effects. Including country and time fixed effects in a panel VAR estimation allows us to deal with omitted variable bias, an important aspect when considering causality.[5] In particular, country fixed effects control for characteristics that do not change for a given country, such as the proximity to the US or other markets. The time effects control for events within a year that are common to all the countries such as regional economic crisis or variations in oil prices.

Furthermore, an important condition for the validity of our analysis is that the variables used in the analysis are stationary. We perform the panel unit root test that assumes individual unit root processes proposed by Im, Pesaran and Shin (2003) in the following variables: FDI by sector in levels (all in natural logs), $CO_2$ per capita growth, $CO_2$ to GDP ratio growth, GDP per capita growth, and manufacturing value added share of GDP growth (for all variables, growth estimated as the first difference of the natural log). We reject the null hypothesis that the series are non-stationary at the 5 percent level for all the variables. The number of lags included in the estimations is selected according to the Akaike Information Criterion (AIC).

## VI. Results

Table 4 presents the estimates of the Granger causality test with fixed effects specified in the methodology section for the bivariate and multivariate VAR. The Table presents the F test (along with the probability in parenthesis) and also, in brackets, the table presents the addition of the coefficients of the causally prior lagged regressor in the estimation (independent variable in the estimation). Number of lags and observations are also provided in Table 4.

In Table 4, the estimates in column 1 present the Granger causality test when we use total FDI inflows, and columns 2-4 when we use FDI in primary, secondary and tertiary sectors. Estimates in column 5 of Table 4 are those derived from the Granger causality test when we use the aggregated FDI inflows to dirty industries. Looking at the bivariate

VAR results, there is evidence that sectoral FDI Granger causes $CO_2$ emissions in 2 cases at the 5 percent level of significance. When using FDI in the tertiary and dirty sectors, this null hypothesis is rejected at the 5 and 1 percent level, respectively. When looking at causality running from $CO_2$ emissions to sectoral FDI for the bivariate VAR, we find that, at the 5 percent level, we do not reject the null hypothesis that $CO_2$ emissions do not Granger cause FDI.

For the purpose of robustness, we estimate the Granger causality test in a multivariate VAR that includes the growth of GDP per capita and manufacturing value added. Estimates of Granger causality test for the multivariate VAR are also shown in Table 4. We find that the null hypothesis that FDI does not Granger cause $CO_2$ emissions is rejected only when we use FDI inflows in the dirty sector. For all the other estimations, that use FDI in different sectors (total, primary, secondary, and tertiary), we fail to reject the hypothesis that FDI does not Granger cause $CO_2$ emissions. For the multivariate VAR, we find that we fail to reject the hypothesis that $CO_2$ emissions Granger cause FDI in all cases.

We also explore whether our results are robust to using the growth of the ratio of $CO_2$ emissions to real GDP. This indicator is useful since changes in economic activity can affect $CO_2$ emissions, and it directly represents the emissions to output intensity of production. Thus, cleaner technologies could be reflected in lower emissions of $CO_2$ per unit of real GDP. In Table 4, column 6 shows the estimates obtained for the Granger causality test using the growth of the ratio of $CO_2$ emissions to real GDP and FDI in dirty sectors. When we use this alternative indicator of pollution emissions for the bivariate and multivariate VAR, we only find evidence of causality running from FDI in dirty sectors to $CO_2$ emissions at the 1 percent level. This corroborates our previous results.[6]

The estimates for the bivariate and multivariate VAR models with aggregate FDI in dirty industries are shown in Table 5. Columns 1 and 2 show the estimates for the bivariate model (coefficients with standard errors in parenthesis). When having $CO_2$ emissions as dependent variable in the bivariate VAR, we observe that the first and second lag of FDI in dirty sectors is statistically significantly at the 5 and 1 percent level, respectively. Estimates for the multivariate VAR are shown in columns 3 and 4. For the multivariate VAR, we find that FDI in the dirty sector continues to have a significant effect on $CO_2$ emissions even when we control for other variables, where the second lag of FDI in the dirty sector is statistically significant at the 1 percent level. For the control variables, we find that the first lag of GDP per capita growth and the second lag of manufacturing value added growth have a statistically significant positive effect on $CO_2$ emissions at the 5 and 1 percent level, respectively. Estimates from the bivariate VAR when we use the growth of the ratio of $CO_2$ emissions to GDP are shown in columns 5 and 6. These estimates are very similar to those shown in columns 1 and 2 for the bivariate VAR with $CO_2$ emissions per capita. When using growth of the ratio of $CO_2$ emissions to GDP, we find that the first lag of FDI in the dirty sector has a significant positive effect on $CO_2$ emissions at the 10 percent level, while the second and third lag have a significant effect at the 1 and 5 percent level, respectively.

It is necessary to discuss the magnitude of the effect that FDI in the dirty sector has on $CO_2$ emissions. Using the estimates shown in Table 4 for the bivariate VAR (where the growth of $CO_2$ emissions per capita is the dependent variable and FDI in the dirty sector in the independent variable), we find the following effect for the average country. An increase on FDI in the dirty sector as share of GDP by one standard deviation increases $CO_2$ emissions per capita by 0.96 percent in the next two periods after the initial increase on FDI in the dirty sector. An increase on $CO_2$ emissions per capita of 0.96 percent for the average country represents an increase of 0.03 emissions of $CO_2$ metric tons per capita. This effect is of significant magnitude considering that for 2007, the emissions of $CO_2$ ranged between 1 and 2 metric tons per capita for the majority of the countries in the sample (13 out of 18 have a value in this range).

In summary, our analysis shows that there is robust evidence that FDI in the dirty sector Granger causes $CO_2$ emissions. This suggests that as FDI in the dirty sector increases, $CO_2$ emissions are likely to increase, even after controlling for country and time specific characteristics. Thus, in line with MacDermott's (2006) analysis for Mexico, our results suggest that there may be a significant negative environmental impact of FDI inflows in dirty sectors for the Latin American region. However, we find no robust effect of FDI in other sectors on $CO_2$ emissions. Our results at first sight contrast with some of the previous findings by Grossman and Krueger (1991); Carrada-Bravo (1995); Birdsall, et al. (2001); Albornoz, et al., (2009). However, these studies did not considered the role of dirty industries separately and the possible endogeneity in the FDI-pollution relationship.

## VII. Concluding Remarks

FDI to LDCs has increased over the last decades. As a result, academics and policy makers are interested on determining the environmental effects of these flows. In this paper, we analyze the relationship between FDI and $CO_2$ concentrations in Latin America from 1980 to 2007 and provide insights on the environmental effect of FDI.

We find evidence that, in the case of some Latin American countries, FDI inflows in pollution intensive industries can be linked to increases in $CO_2$ emissions per capita and per unit of GDP. Distinguishing the environmental effect of FDI by sectors is relevant for policymakers. It is unlikely that Latin American countries would want to restrict the inflows of FDI in the pollution intensive sectors since this form of investment represents a large share of total FDI. In our sample, about 37 percent of total FDI inflows have, on average, gone to pollution intensive industries.

An important policy implication of our analysis is that FDI in pollution intensive industries should be closely monitored. It is relevant for governments in the region to be aware of the detrimental effects that this form of FDI has on the environment. The creation of a fund for environmental improvement in these countries might be a possible policy action that will ensure better environmental conditions in the region. The size of this fund should be dependent on the amount of FDI in the polluting sectors and estimations of the environmental damage associated with the increase in $CO_2$ emissions, where the public and private sector can contribute.

While our analysis shows that FDI in pollution intensive sectors causes higher $CO_2$ emissions in Latin America, we are unable to directly support or reject the pollution haven or pollution halo hypothesis. The lack of readily available firm level data for Latin America does not allow us to empirically test these hypotheses.

**Endnotes**

[1] This information was obtained by calculating percentages of FDI flows using data from the United Nations Conference on Trade and Development (UNCTAD, 2011).
[2] It is important to note, however, that developing countries can work together with developed countries under the mechanisms of the Kyoto protocol and reduce emissions that will count toward developed countries quota. For example, China is the largest $CO_2$ emitter and while it has not signed specific agreements to cut back emissions, it has been willing to compromise in this issue.
[3] Mexico and Brazil emit more than 100 million metric tons of carbon. CDIAC reports that six other countries in the region are now emitting more than 10 million metric tons of carbon annually: Argentina (50.1), Venezuela (45.1), Chile (19.6), Colombia (17.3), Peru (11.7), and Trinidad and Tobago (10.1).
[4] Not all 18 countries and not all years are included in all the estimations due to data unavailability.
[5] Refer to Wooldridge (2002) for a discussion on fixed effects model in a panel framework and to Holtz et al. (1988) for a discussion on the benefits of using fixed effects in a panel VAR.
[6] Other estimations using the growth of the ratio of $CO_2$ to GDP and FDI in different sectors are not included for purpose of space, but are available upon request

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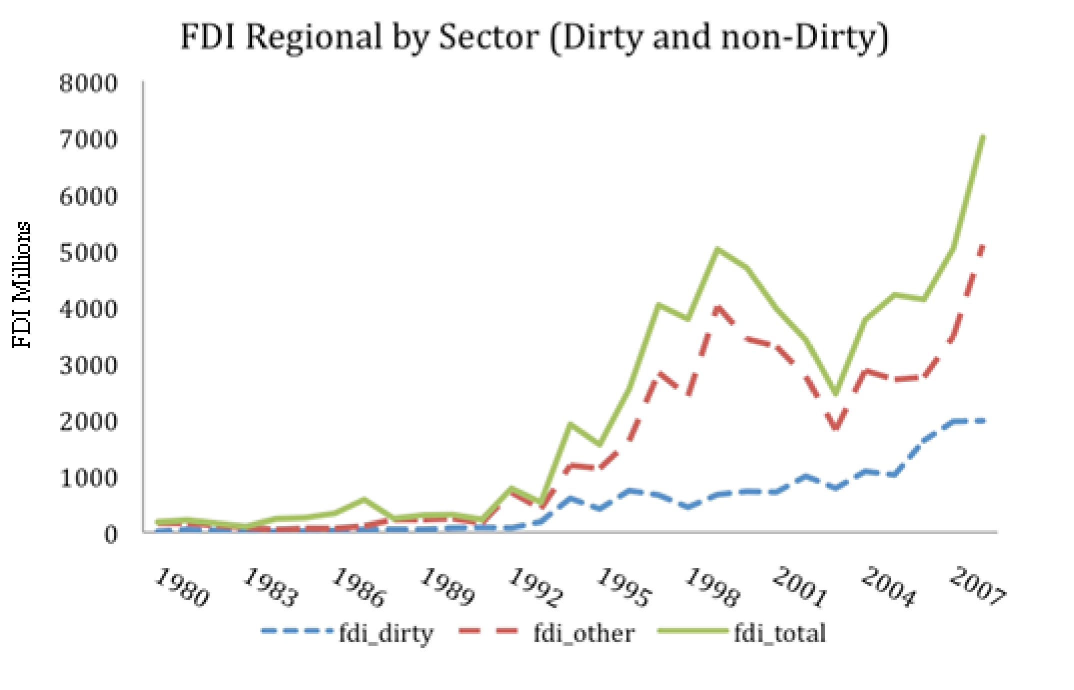
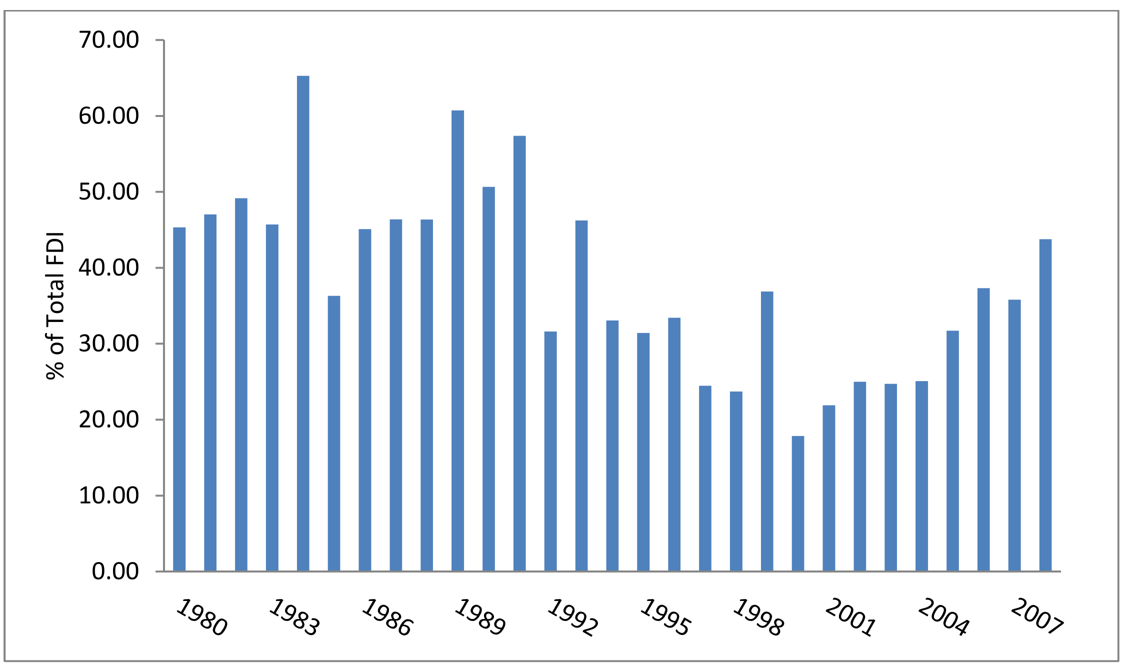
Figure 1 – Regional FDI total and disaggregated by more (less) pollution intensive industries*



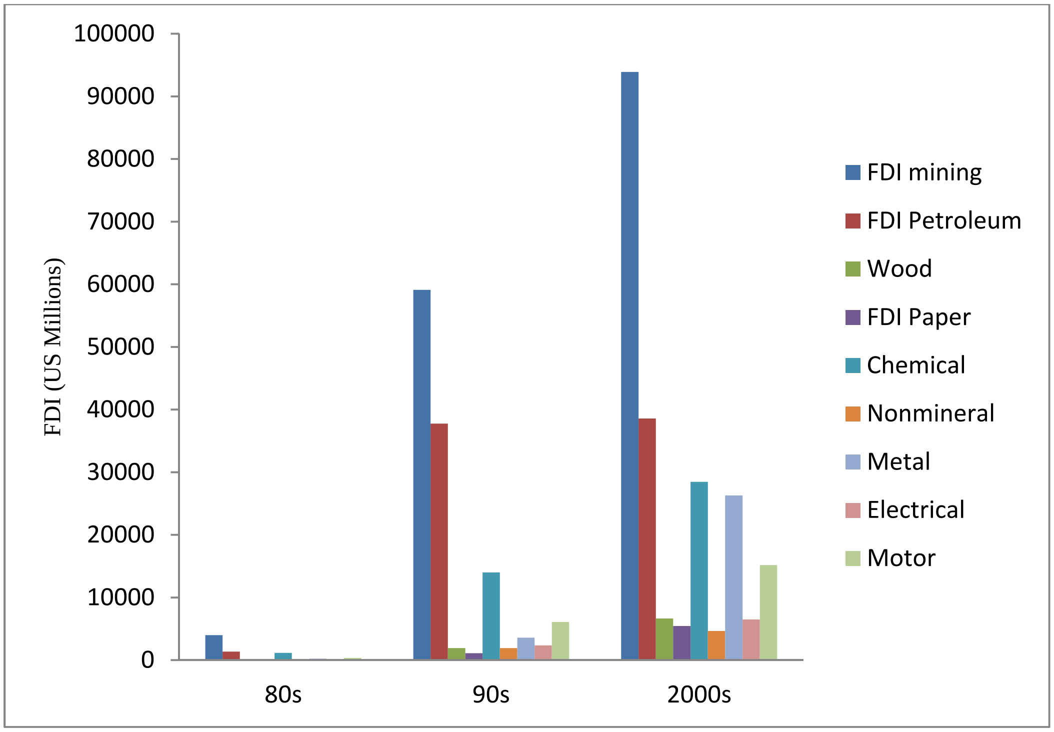

* Source: UNCTAD/DITE.

Figure 2 – FDI flows to dirty industries as a share of total FDI to Latin America*




* Source: UNCTAD/DITE.

Figure 3 – FDI to Latin America by Industry (Pollution Intensive Sectors)*




* Source: UNCTAD/DITE.

Table 1 – Pollution Intensive Industries by Selected Study.

| Study | SIC of Dirty Industries |
|---|---|
| Akbostanci et al (2007) | Basic Industrial Chemicals (3511); Fertilizers and Pesticides (3512); Iron and Steel (3710); Nonferrous Metal (3720) |
| List et al (2004); List and Millimet (2004) | Pulp and Paper Mills (2611-31); Printing and Binding (2711-89); Industrial Inorganic Chemicals (2812-19); Industrial Organic Chemicals (2861-69); Petroleum Refining (2911); Rubber and Miscellaneous Plastics (30); Stone, Clay, and Glass (32); Steel and Electrometallurgical Products(3312-3); Iron and Steel Foundries(3321-5); Fabricated Metal Products (34); Motor Vehicles and Equipment(371) |
| Kahn (2003) | Primary Metals; Stone, Clay and Glass Products; Petroleum and Coal; Chemical and Allied Products; Textile Mill Products. |
| Greenstone (2002) | Printing (2711-89); Organic Chemicals (2861-9); Rubber and Miscellaneous Plastic Products (30); Fabricated Metals (34), Motor Vehicles, Bodies, and Parts (371); Inorganic Chemicals (2812-9); Lumber and Wood Products (24); Nonferrous Metals (333-4); Petroleum Refining (2911); Stone, Clay, Glass, and Concrete (32); and Pulp and Paper (2611-31) and Iron and Steel (3312-3 and 3321-5). |
| Kolstad and Xin (2002) | High: Chemicals and Allied Products; Primary Metals Industries. Moderate: Food and Kindred Products; Industrial Machinery and Equipment; Electronic and Other Electric Equipment; Transportation Equipment. |
| Becker and Henderson (2000) | Industrial Organic Chemicals (2865 and 2869); Miscellaneous Plastic Products (308), Metal Cans and Barrels 3411 and 3412); Wood Furniture (2511); Commercial Printing, Gravure (2754); Motor Vehicle and Car Bodies (3711) |
| List & Co (2000) | Fabricated Meal Products (34); Stone, Clay, and Glass Products (32); Paper and Allied Products (26); Transportation Equipment (37); Primary Metal Industries (33); Chemicals and Allied Products (28); Petroleum and Coal Products (29). |
| Mani and Wheeler (1998) | Iron and Steel, Non-Ferrous Metals, Industrial Chemicals, Pulp and Paper, and Non-Metallic Mineral Products |
| Levinson (1996) | Petroleum and Coal (29); Chemicals (28); Primary Metals (33) |
| Jaffe et al (1995) | High: Paper and Allied Products; Chemical and Allied Products; Petroleum and Coal Products; Primary Metal Industries. Moderate: Furniture and Fixtures; Fabricated Metal Products; Electric, Electronic Equipment |
| Tobey (1990) | Iron Ore, Concentrates (281); Ores of Nonferrous Base Metals (283); Silver, Platinum, etc (681); Copper (682); Nickel (683); Lead (685); Zinc (686); Tin (687); Nonferrous Base Metals (689) , Pulp and Waste Paper (251); Paper and Paperboard (641); Articles of Paper (642); Pig Iron (671); Ingots (672); Iron and Steel Bars (673); Universal, plates (674); Hoops and Strips (675); Railway Material (676); Iron and Steel Wire (677); Tubes and Fittings (678); Iron, Steel Castings (679); Inorganic Elements (513); Other Inorganic Chemicals (514); Plastic Materials (581) |

Table 2. Variable Description

| Variable | Description |
|---|---|
| $CO_2$ per capita growth | Log difference of $CO_2$ emissions per capita (metric tons per capita). Source: Authors' construction using World Development Indicators (2010). |
| $CO_2$ RGDP share growth | Log difference of $CO_2$ emissions as a share of real GDP (CO2 emissions kg per 2005 PPP $ of GDP). Source: Authors' construction using World Development Indicators (2010). |
| FDI total (% GDP)* | Log of the total FDI inflows as a share of GDP. Source: Authors' construction using data from UNCTAD/DITE (2010). |
| FDI primary (% GDP)* | Log of the total FDI inflows in primary sector as a share of GDP. For FDI primary we aggregate FDI in the following categories: 1) agriculture, hunting, forestry and fishing, and *2) mining, quarrying and petroleum. Source: Authors' construction using data from UNCTAD/DITE (2010). |
| FDI secondary (% GDP) | Log of the total FDI inflows in secondary sector as a share of GDP. For FDI tertiary we aggregate FDI in the following categories: 1) food, beverages and tobacco, 2) textiles, clothing and leather, *3) wood and wood products, *4) paper and paper products, *5) chemicals and chemical products, 6) rubber and plastic products, *7) non-metallic mineral products, *8) metal and metal products, 9) machinery and equipment, *10) electrical and electronic equipment, and *11) motor vehicles and other transport equipment. Source: Authors' construction using data from UNCTAD/DITE (2010). |
| FDI tertiary (% GDP) | Log of the total FDI inflows in tertiary sector as a share of GDP. For FDI tertiary we aggregate FDI in the following categories: 1) electricity, gas and water, 2) construction, 3) trade, 4) hotels and restaurants, 5) transport, storage and communications, and 5) finance. Source: Authors' construction using data from UNCTAD/DITE (2010). |
| FDI dirty (% GDP) | Log of the total FDI inflows in dirty industries as a share of GDP. For FDI dirty we aggregate FDI in the categories denoted above with "*". Source: Authors' construction using data from UNCTAD/DITE (2010). |
| GDP growth | Log difference of real GDP per capita (constant 2000 US dollars). Source: Authors' construction using World Development Indicators (2010). |
| Manuf. val. add. growth | Log difference of manufacturing value added as a share of GDP. Source: Authors' construction using World Development Indicators (2010). |

FDI aggregation by sector is done adding the available observations with a positive value. Variable is truncated for non-positive values in order to take natural log (a value of 1E-11 is assigned for non-positive values). Series filled in with linear interpolation for missing observations.

Table 3. Summary Statistics

| Variable name | Transformation | Mean | Std. Dev. | Max. | Min. | Obs. |
|---|---|---|---|---|---|---|
| *Log and difference transformation (series used in the analysis)* | | | | | | |
| $CO_2$ per capita growth | D(Ln(CO2 per capita)) | 0.013 | 0.103 | 0.511 | -0.593 | 486 |
| $CO_2$ RGDP share | D(Ln(CO2 per real GDP)) | 0.002 | 0.100 | 0.534 | -0.619 | 486 |
| FDI total (% GDP) | Ln(FDI total) | 0.297 | 3.649 | 2.858 | -30.542 | 381 |
| FDI primary (% GDP) | Ln(FDI primary) | -2.942 | 7.135 | 2.804 | -30.752 | 355 |
| FDI secondary (% GDP) | Ln(FDI secondary) | -2.147 | 5.537 | 1.325 | -29.703 | 361 |
| FDI tertiary (% GDP) | Ln(FDI tertiary) | -1.233 | 4.580 | 2.612 | -29.954 | 381 |
| FDI dirty (% GDP) | Ln(FDI dirty) | -1.691 | 4.782 | 2.807 | -30.752 | 327 |
| GDP per capita growth | D(Ln(GDP per capita)) | 0.011 | 0.044 | 0.150 | -0.164 | 486 |
| Manuf. val. add. growth | D(Ln(Manuf. val. add. share)) | -0.009 | 0.096 | 0.529 | -0.692 | 407 |
| *Raw series* | | | | | | |
| $CO_2$ per capita | None | 2.913 | 3.952 | 27.862 | 0.325 | 504 |
| $CO_2$ GDP share | None | 0.360 | 0.259 | 1.573 | 0.091 | 504 |
| FDI total (% GDP) | None | 3.128 | 2.745 | 17.421 | 5.44E-14 | 381 |
| FDI primary (% GDP) | None | 1.053 | 1.782 | 16.515 | 4.41E-14 | 355 |
| FDI secondary (% GDP) | None | 0.624 | 0.644 | 3.760 | 1.26E-13 | 361 |
| FDI tertiary (% GDP) | None | 1.373 | 1.869 | 13.630 | 9.8E-14 | 381 |
| FDI dirty (% GDP) | None | 1.165 | 1.873 | 16.555 | 4.41E-14 | 327 |
| GDP per capita | None | 3111.2 | 1942.7 | 10738.0 | 632.5 | 504 |
| Manuf. val. add. | None | 18.163 | 5.654 | 34.560 | 5.548 | 426 |

Summary statistics of available observations for 18 countries, between the period 1980-2007

Table 4. Granger Causality Test

| | FDI Total (1) | FDI Prim (2) | FDI Sec (3) | FDI Ter (4) | FDI Dirty (5) | FDI Dirty (6) |
|---|---|---|---|---|---|---|
| *Null Hypothesis: FDI does not Granger-cause $CO_2$ growth* | | | | | | |
| Bivariate | 1.395 | 2.609 | 0.195 | 4.058 | 7.229 | 7.241 |
| | (0.249) | (0.076) | (0.900) | (0.018) | (0.000) | (0.000) |
| | [0.003] | [0.002] | [0.001] | [-0.003] | [0.006] | [0.008] |
| | <2, 337> | <2, 313> | <3, 300> | <2, 337> | <3, 272> | <3, 272> |
| Multivariate | 0.342 | 0.894 | 0.817 | 1.741 | 7.355 | 6.717 |
| | (0.795) | (0.410) | (0.486) | (0.178) | (0.001) | (0.002) |
| | [-0.002] | [0.0014] | [-0.001] | [-0.002] | [0.003] | [0.004] |
| | <3, 282> | <2, 275> | <3, 264> | <2, 299> | <2, 253> | <2, 253> |
| *Null Hypothesis: $CO_2$ growth does not Granger-cause FDI* | | | | | | |
| Bivariate | 0.790 | 0.225 | 2.089 | 0.296 | 0.356 | 0.374 |
| | (0.455) | (0.798) | (0.102) | (0.744) | (0.785) | -0.772 |
| | [1.598] | [3.236] | [1.607] | [1.267] | [-3.794] | [-3.268] |
| | <2, 352> | <2, 328> | <3, 314> | <2, 352> | <3, 285> | <3, 285> |
| Multivariate | 0.818 | 0.038 | 1.699 | 0.545 | 0.583 | 0.583 |
| | (0.485) | (0.963) | (0.168) | (0.580) | (0.559) | -0.559 |
| | [7.110] | [1.839] | [3.474] | [2.481] | [-4.981] | [-4.981] |
| | <3, 296> | <2, 290> | <3, 277> | <2, 314> | <2, 266> | <2, 266> |

F-values with probabilities in parenthesis and the sum of the coefficients of the causally prior lagged regressors in brackets. Lag and observation numbers indicated by <lag, obs>. Granger causality test estimated with country-time fixed effects and one FDI indicator at the time (in logs). We use the growth of $CO_2$ per capita for estimations in columns 1 through 5, while column 6 we use the growth of $CO_2$ as a share of real GDP.

Table 5. VAR Estimates

| | Bivariate ($CO_2$ per capita) | | Multivariate ($CO_2$ per capita) | | Bivariate ($CO_2$ GDP share) | |
|---|---|---|---|---|---|---|
| *Dependent variable: $CO_2$ growth* | | | | | | |
| FDI dirty $_{t-1}$ | 0.002 | (0.001) ** | 0.001 | (0.002) | 0.002 | (0.001) * |
| FDI dirty $_{t-2}$ | 0.002 | (0.001) *** | 0.002 | (0.001) *** | 0.002 | (0.001) *** |
| FDI dirty $_{t-3}$ | 0.002 | (0.001) | | | 0.003 | (0.001) ** |
| $CO_2$ growth $_{t-1}$ | -0.276 | (0.106) *** | -0.097 | (0.075) | -0.287 | (0.115) *** |
| $CO_2$ growth $_{t-2}$ | -0.337 | (0.086) *** | -0.205 | (0.069) *** | -0.389 | (0.077) *** |
| $CO_2$ growth $_{t-3}$ | -0.013 | (0.084) | | | -0.041 | (0.086) |
| GDP per capita growth $_{t-1}$ | | | 0.293 | (0.144) ** | | |
| GDP per capita growth $_{t-2}$ | | | 0.169 | (0.108) | | |
| Manuf. val. add. growth $_{t-1}$ | | | 0.044 | (0.052) | | |
| Manuf. val. add. growth $_{t-2}$ | | | 0.132 | (0.050) *** | | |
| Constant | 0.120 | (0.023) *** | 0.004 | (0.006) | 0.122 | (0.026) *** |
| R-sq | 0.246 | | 0.250 | | 0.296 | |
| Obs | 272 | | 253 | | 272 | |
| *Dependent variable: FDI* | | | | | | |
| FDI dirty $_{t-1}$ | 0.412 | (0.204) ** | 0.334 | (0.282) | 0.413 | (0.201) ** |
| FDI dirty $_{t-2}$ | -0.129 | (0.157) | 0.139 | (0.219) | -0.129 | (0.153) |
| FDI dirty $_{t-3}$ | 0.366 | (0.215) * | | | 0.364 | (0.213) * |
| $CO_2$ growth $_{t-1}$ | -1.694 | (2.228) | -3.979 | (3.972) | -3.044 | (3.444) |
| $CO_2$ growth $_{t-2}$ | -2.028 | (2.124) | -1.002 | (3.281) | -0.577 | (3.577) |
| $CO_2$ growth $_{t-3}$ | -0.072 | (1.889) | | | 0.353 | (2.181) |
| GDP per capita growth $_{t-1}$ | | | 22.682 | (11.517) ** | | |
| GDP per capita growth $_{t-2}$ | | | -11.620 | (12.490) | | |
| Manuf. val. add. growth $_{t-1}$ | | | 1.557 | (1.725) | | |
| Manuf. val. add. growth $_{t-2}$ | | | 2.802 | (2.277) | | |
| Constant | -5.459 | (3.794) | 2.258 | (1.202) * | -5.500 | (3.724) |
| R-sq | 0.407 | | 0.474 | | 0.409 | |
| Obs | 285 | | 266 | | 285 | |

VAR model estimated with country-time fixed effects. Standard errors are in parenthesis. '***', '**', '*' denote significance at the 1, 5, and 10 percent level. We use the growth of $CO_2$ per capita in the first two sets of estimations, while we use the growth of $CO_2$ as a share of GDP for the last set of estimates.