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Does Foreign Direct Investment Harm the Environment in Developing Countries? Dynamic Panel Analysis of Latin American Countries

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Abstract: This article sets out to study the FDI–environment nexus within a dynamic panel data framework. To that end, the pooled mean group (PMG) method of Pesaran et al. (1999) is used to assess the impact of FDI on CO_2 emissions, controlling for income and energy consumption, using a panel of 17 Latin American countries. Our results using the full sample show that FDI increases CO_2 emissions, confirming the pollution haven hypothesis. But when splitting the data into different income groups, FDI inflows only in high-income countries increase CO_2 emissions. In addition, CO_2 emissions with growth tend to increase monotonically within the full sample and middle-income countries. Finally, energy consumption is found to increase CO_2 emissions in all cases: the full sample, high-, middle- and low-income countries.

Keywords: CO_2 emissions; FDI; Latin America; panel analysis; PMG

JEL Classification: C23; F18

1. Introduction

The impact of foreign direct investment (FDI) inflows on the environment in developing countries has been extensively assessed in the empirical literature. Traditional specification of this topic in any country includes an income variable (i.e., GDP per capita) and examines the so-called pollution haven hypothesis (PHH): a host country with slacker environmental regulations becomes dirtier with FDI inflows. Examples of the literature on this category are Talukdar and Meisner (2001), Smarzynska and Wei (2001), Xing and Kolstad (2002), He (2006), Hoffman et al. (2005) and Baek and Koo (2009). The results obtained from these studies are generally supportive of the PHH.

As we then glance through the existing literature more, we come across studies that claim that given the strong empirical evidence that energy consumption significantly affects environmental outcomes, early studies excluding this variable may suffer from the omitted variable bias, thereby providing unreliable results. When examining the PHH, the recent studies attempt to account for energy consumption as another important variable (in addition to income) in a model. Examples of this category include Kim and Baek (2011), Pao and Tsai (2011), Kivyiro and Arminen (2014), Lee and Brahmasrene (2014), and Neequaye and Oladi (2015). Notably, these studies provide mixed evidence on the PHH. The main contributing factor for the mixed findings may be closely associated with the use of small sample sizes (around 30–40 observations) driven by country-specific data and a time series approach—mainly based on an autogressive distributed lag (ARDL) method. Since small sample sizes increase the sample variances in each of the explanatory variables in regression models, this problem is likely to cause the estimates of a model to be inefficient due mainly to multicollinearity (Wooldridge 2009). Until recently, however, the second group of the literature has paid little attention to directly address this problem using a panel data method. When estimating models, panel data generally gives more variability through an increase in the sample size, thereby often mitigating multicollinearity problem and providing more efficiency (more reliable parameter results) (Harris and Sollis 2003).

In this article, therefore, we assess the FDI–environment nexus within a dynamic panel data framework. Given that the environmental impacts of FDI are generally regarded as a long-run phenomenon and CO_2 emissions are blamed for the main cause of global warming, our empirical attention is paid to examine the long-run effect of FDI inflows on CO_2 emissions, controlling for income and energy consumption, using a panel of 17 Latin American countries. The pooled mean group (PMG) estimator of Pesaran et al. (1999) (referred to here as PMG) is applied for empirical assessments. The major advantage of the PMG over the traditional panel methods is that it allows short-run dynamics to differ across countries while constraining the long-run relationships to behave identically. In fact, long-run responses of environmental outcomes to FDI and other economic activity are likely to be similar across countries, although the short-run adjustments depend on country characteristics such as economic growth paths and degrees of environmental regulations. It is thus hoped that this dynamic approach will shed new light on the debate over FDI and the environment in developing countries. It should be pointed out that Pao and Tsai (2011) and Neequaye and Oladi (2015) are perhaps the only panel studies addressing the FDI–environment nexus; however, their analyses only target at BRIC countries and a few Latin American countries, respectively.[1]

The rest of the article is presented as follows. Section 2 outlines the empirical models, estimation methods, and data. Section 3 discusses our main findings. Finally, Section 4 presents the short summary and conclusions.

2. Methodology

2.1. Model to Be Estimated

In attempting to isolate the independent effect of FDI on CO_2 emissions, we rely on an empirical framework developed by Kim and Baek (2011) and Pao and Tsai (2011). The long-run form of the panel equation to be estimated is specified as follows:

$$c_{it} = \alpha_0 + \alpha_{1i} y_{it} + \alpha_{2i} {y_{it}}^2 + \alpha_{3i} en_{it} + \alpha_{4i} fdi_{it} + u_{it} \quad (1)$$

where c_{it} is CO_2 emissions in period t for country i; y_{it} is real GDP per capita; en_{it} is energy consumption; fdi_{it} is FDI inflows; u_{it} is the error term. In Equation (1), when the coefficient on y_{it} is positive and the coefficient on ${y_{\text{it}}}^2$ is negative, the quadratic has a parabolic shape, thereby confirming the so-called *Environmental Kuznets curve* (EKC) hypothesis: growth has a diminishing effect on CO_2 emissions after a certain (per capita) income turning point. The rise in energy consumption mainly driven by growth is likely to result in increasing CO_2 emissions; hence, the coefficient on en_{it} is expected to be positive. Finally, if an increase in the inflow of FDI increases (decrease) CO_2 emissions by attracting more pollution intensive industries (adopting greener technologies), the coefficient on fdi_{it} is expected to be positive (negative).

[1] It is important to emphasize that our article is part of a larger literature that has established the channels of the impacts of variables of interest used in our analysis. For example, the FDI–environment nexus is studied by Dasgupta et al. (2000), Copeland and Taylor (2004), and Doytch and Uctum (2016). The FDI–energy consumption nexus is investigated by Eskeland and Harrison (2003), Cole et al. (2008), Sadorsky (2010, 2011), Çoban and Topcu (2013), Shahbaz et al. (2013), and Doytch and Narayan (2016). The growth-energy consumption is examined by Sardosky (2009), Payne (2010) and Narayan and Doytch (2017). However, few studies have modeled the effect of FDI on the environment, controlling for income and energy consumption. This observation has motivated the current study.

When estimating Equation (1) using the PMG estimator,[2] Pesaran et al. (1999) recommend that the short-run dynamics among the variables for each country be incorporated into an error-correction modeling format. For this, by imposing one as the maximum lag length and using Akaike Information Criterion (AIC), the autogressive distributed lag (ARDL) (1, 1, 1, 1) equation is first determined as the most appropriate form for the analysis:

$$\begin{aligned} c_{it} = & \mu_t + \delta_{10i} y_{it} + \delta_{11i} y_{i,t-1} + \delta_{20i} y_{it}^2 + \delta_{21i} y_{i,t-1}^2 \\ & + \delta_{30\mathrm{i}} en_{it} + \delta_{31i} en_{i,t-1} + \delta_{41i} fdi_{it} + \delta_{42i} fdi_{it-1} + \lambda_i c_{it-1} + \varepsilon_{it} \end{aligned} \quad (2)$$

The error-correction modeling format is then specified as follows:

$$\begin{aligned} \Delta c_{it} = & \phi_i (c_{i,t-1} - \alpha_{0i} - \alpha_{1i} y_{it} - \alpha_{2i} y_{it}^2 - \alpha_{3i} en_{it} - \alpha_{41} fdi_{it}) \\ & - \delta_{11\mathrm{i}} \Delta y_{it} - \delta_{21i} \Delta y_{it}^2 - \delta_{31i} \Delta en_{it} + \delta_{41i} \Delta fdi_{it} + \varepsilon_{it} \end{aligned} \quad (3)$$

where $\alpha_{0i} = \mu_i/(1-\lambda_i)$; $\alpha_{1i} = (\delta_{10i} + \delta_{11i})/(1-\lambda_i)$; $\alpha_{2i} = (\delta_{20i} + \delta_{21i})/(1-\lambda_i)$; $\phi_i = -(1-\lambda_i)$. In Equation (3), α_{it} captures the long-run relationship between c_{it} and its determinants, whereas δ_{i1t} represents the short-run coefficients. Finally, ϕ_i is the error-correction term and gauges how fast c_{it} adjusts to the long-run equilibrium when a change in its determinants takes place.

It is worth mentioning that, when estimating dynamic (heterogeneous) panels, it is fairly common to see researchers apply alternative methods and then formally test for statistically significant differences in the selected estimators. In estimating Equation (3), therefore, we also employ the two alternative methods such as the mean group (MG) and dynamic fixed effect (DFE) estimators in addition to the PMG. The MG method does not impose homogeneity restrictions on the parameters across countries; hence, the estimates are the unweighted average of estimated coefficients in a single country (Pesaran and Smith 1995). In the DFE method, on the other hand, the parameters of the short- and long-run (except for the intercepts) are assumed to be homogenous across countries. The PMG estimator restrains the long-run parameters to be homogenous while allowing other parameters to vary among countries; hence it is known as an intermediate estimator between the MG and DFE estimators. The Hausman test is generally used to identify the difference in the three methods.

2.2. Data

We use the 41 years (1971–2011) of the panel dataset from 17 Latin America countries to estimate Equation (3). Our dataset contains the balanced panel with 697 observations (for example, $N = 17$ countries and $T = 41$ years). The CO_2 emissions are defined as metric tons of CO_2 emissions per capita. The income is measured by the logarithm of GDP per capita in constant 2005 dollar. The energy consumption is represented by energy use (kg of oil equivalent) per capita. These variables are obtained from the World Development Indicators (WDI). The inflow of foreign direct investment (FDI) is measured by the percentage share of gross fixed investment formation and is taken from the United Nation Conference on Trade and Development (UNCTAD) GlobStat Database.[3]

It should be noted that, because of high variations in the values of variables among the selected countries, Equation (3) is estimated for the full sample and then separately for different country groups. More specifically, following the World Bank's country classification, 17 countries used in our analysis are categorized into the following three groups: (1) four high-income economies (Argentina, Uruguay, Chile and Venezuela); (2) eight middle-income economies (Brazil, Columbia, Costa Rica, Mexico,

[2] The possibility of endogeneity of income and FDI could be an issue in estimating Equation (1). As Barguellil et al. (2013) note, the dynamic panel approach could address the endogeneity problem. One of the most popular methods to estimate the dynamic panel model is GMM of Arellano and Bond (1991) and Blundell and Bond (1998). The other popular approach is the PMG estimator of Pesaran et al. (1999) used for this study.

[3] Since the inflow of FDI is measured by a percent, this variable appears in Equation (3) in original form. The coefficient on FDI thus has a percentage interpretation when it is multiplied by 100, which is so-called the log-level model (Wooldridge 2009).

Peru, Dominican Republic, Ecuador and Paraguay); and (3) five low-income economies (Bolivia, Honduras, Nicaragua, El Salvador and Guatemala). Table 1 reports descriptive statistics for our data; for example, the average incomes for high-, middle-, and low-income groups are $5165, $3338, and $1548, respectively.

Table 1. Descriptive statistics of data, 1971–2011.

Country	CO_2 Emissions		Income		Energy Consumption		FDI	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
4 High-income economies	3.60	1.68	5164.87	1350.66	1470.68	573.00	9.67	11.27
8 Middle-income economies	1.65	0.88	3337.64	1651.47	770.21	280.52	9.36	8.03
5 Low-income economies	0.76	0.27	1548.38	575.29	530.61	97.98	11.14	12.28
17 Latin American economies	1.85	1.46	3241.32	1877.77	864.56	490.19	9.96	10.24

Notes: CO_2 emissions (*c*) are measured in metric tons of CO_2 emitted per capita. Income per capita (*y*) is measured in 2005 USD. Energy consumption (*en*) is measured in kg of oil equivalent per capita. FDI is measured in 2005 USD billion.

3. Empirical Results

Before discussing our empirical results, we briefly need to address two modeling issues. The first issue to be addressed is the need to test for the presence of unit roots in panel data. Kim et al. (2010) demonstrate that, although the three alternative estimators can be applied even in the case that some variables are I(1) and some I(0), they cannot be applicable to I(2) or higher series. In order to ensure that not all variables are I(2) variables, testing for unit roots in panel data is implemented using LLC, Breitung, IPS, Fisher ADF and Fisher PP tests. The results generally confirm that all variables in the full sample and subsamples appear to comprise either I(1) or I(0) processes. For example, applying the five tests to the full sample produces the results presented in Table 2, confirming that FDI is I(0), whereas all remaining variables are I(1).[4]

Table 2. Results of panel unit roots tests with the full sample.

Variable	Common Unit Root				Individual Unit Root					
	LLC		Breitung		IPS		ADF		PP	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
CO_2 emissions	−0.99 [0.16]	−11.88 [0.00] **	−1.28 [0.10]	−9.51 [0.00] **	−0.26 [0.40]	−13.20 [0.00] **	34.39 [0.45]	218.36 [0.00] **	31.33 [0.60]	784.33 [0.00] **
Income	−0.50 [0.31]	−10.23 [0.00] **	−3.53 [0.00] **	-	−0.40 [0.34]	−8.53 [0.00] **	38.16 [0.29]	135.60 [0.00] **	25.22 [0.86]	147.53 [0.00] **
$(\text{Income})^2$	−0.33 [0.37]	−10.35 [0.00] **	−3.62 [0.00] **	-	−0.08 [0.47]	−8.52 [0.00] **	35.21 [0.41]	135.36 [0.00] **	23.12 [0.92]	147.69 [0.00] **
Energy consumption	0.08 [0.53]	−6.71 [0.00] **	0.50 [0.69]	−9.28 [0.00] **	0.87 [0.81]	−9.96 [0.00] **	29.86 [0.67]	158.49 [0.00] **	28.03 [0.75]	385.39 [0.00] **
FDI	−5.10 [0.00] **	-	−3.49 [0.00] **	-	−5.13 [0.00] **	-	195.00 [0.00] **	-	158.22 [0.00] **	-

Notes: All variables are in natural logarithms. ** and * denote rejection of the null hypotheses of a unit root at the 5% and 10% significance levels, respectively. *p*-values are in brackets. All tests include a constant and a trend.

The second modeling issue to be addressed is testing whether there is evidence of cointegration relationship among variables. We solve the issue by applying multiple panel cointegration tests

[4] Since similar results are obtained from the three subsamples, we only report the results of the full sample for brevity.

suggested by Pedroni (1999). As reported in Table 3, the test results are mixed; for the 28 cases, for example, the no-cointegration hypothesis is rejected only for 14 cases at the 10% level. Since obtaining mixed results from Pedroni's tests is not too rare, an error correction term—that is, ϕ_i in Equation (3)—is used as an alternative criterion in uncovering the cointegration relationship (Harris and Sollis 2003). In fact, all of the error-correction terms in the full sample and subsamples are found to be negative and highly significant, supporting evidence of cointegration relationship among the five variables in all cases (Tables 4 and 5).

Table 3. Results of panel cointegration tests.

Pedroni Test	Full Sample	Sub Samples		
		High-Income Economies	Middle-Income Economies	Low-Income Economies
Panel v-Statistic	0.2178	−1.4363	0.1143	0.6691
Panel rho-Statistic	−1.4921	0.1384	−1.2086	−0.8671
Panel PP-Statistic	−6.1891 **	−1.7845 **	−5.3073 **	−2.8096 *
Panel ADF-Statistic	−1.9271 **	−2.3165 **	−3.5069 **	1.7384
Group rho-Statistic	0.6682	0.8292	0.4555	−0.0857
Group PP-Statistic	−4.5762 **	−1.6202 *	−3.7564 **	−2.2375 **
Group ADF-Statistic	−1.5565 *	−1.9121 **	−2.6885 **	2.2409

Notes: ** and * denote rejection of the null hypotheses of no cointegration at the 5% and 10% significance levels, respectively. All tests include a constant and a trend.

Table 4. Results of alternative estimates of the full sample.

Variable	(1) Poole Mean Group (PMG)	(2) Mean Group (MG)	(3) Dynamic Fixed Effects (DFE)
Income	2.9989 (0.6992) **	31.3043 (29.4335)	3.4602 (1.6636) **
$(\text{Income})^2$	−0.1787 (0.0439) **	−2.0985 (1.9481)	−0.1987 (0.1075) *
Energy consumption	0.750 (0.0754) **	1.0039 (0.1827) **	0.8083 (0.1873) **
FDI	0.0025 (0.0011) **	0.0011 (0.0061)	0.0031 (0.0021)
Error correction	−0.2793 (0.0549) **	−0.3999 (0.0682) **	−0.2184 (0.06439) **
Observations	629	629	629

Notes: All variables except for foreign direct investment (FDI) are in natural logarithms. Standard errors are in parentheses. ** and * indicate the 10% and 5% significance levels, respectively.

Table 5. Results of alternative estimates of the subsamples.

Variable	High-Income Economies			Middle-Income Economies			Low-Income Economies		
	(1) PMG	(2) MG	(3) DFE	(1) PMG	(2) MG	(3) DFE	(1) PMG	(2) MG	(3) DFE
Income	−6.1061 (4.7915)	−5.5461 (14.0448)	−1.8983 (3.4619)	2.576 (1.5116) *	22.5691 (11.0571) **	7.0936 (1.1857) **	2.5938 (4.1011)	74.7611 (102.6996)	−3.0953 (3.9747)
$(\text{Income})^2$	0.3379 (0.2791)	0.2991 (0.8264)	0.0864 (0.2039)	−0.1421 (0.0881) *	−1.3969 (0.6995) **	−0.4239 (0.0718) **	−0.1489 (0.2862)	−5.1392 (6.7951)	0.2476 (0.2771)
Energy consumption	1.2077 (0.1976) **	1.3267 (0.3100) **	1.4419 (0.0753) **	0.6544 (0.1206) **	0.4852 (0.1740) **	0.7952 (0.2103) **	0.5126 (0.1527) **	1.5754 (0.3183) **	0.4622 (0.1937) **
FDI	0.0043 (0.0025) *	0.0001 (0.0021)	0.0008 (0.0029)	−0.0014 (0.0019)	0.0044 (0.0082)	0.0019 (0.0019)	0.0044 (0.0019) **	−0.0033 (0.01738)	0.0019 (0.0054)
Error correction	−0.2529 (0.1164) **	−0.4201 (0.1636) **	−0.3970 (0.1341) **	−0.3250 (0.0850) **	−0.4365 (0.0826) **	−0.3176 (0.1053) **	−0.2742 (0.1319) **	−0.3254 (0.1614) **	−0.1532 (0.0941) **
Observations	148	148	148	296	296	296	185	185	185

Notes: All variables except for FDI are in natural logarithms. Standard errors are in parentheses. ** and * indicate the 10% and 5% significance levels, respectively.

3.1. Results for the Full Sample of 17 Latin American Countries

Table 4 reports our estimation results of the full sample, where Equation (3) is estimated in turn by the three alternative estimators. The results of pair-wise Hausman tests show that the PMG and DFE methods are preferred to the MG. When slopes turn out to be heterogeneous, however, the DFE may provide inconsistent estimates, thereby potentially misleading results (Pesaran and Smith 1995). The PMG is thus more desirable than the DFE because the PMG can allow short-run coefficients to be different across countries. Accordingly, our presentation for the full sample focuses on the results derived from the PMG.

The long-run results of the PMG method (Column (1) of Table 4) show that the income is significantly positive and the quadratic term is significantly negative, demonstrating the EKC hypothesis: after the so-called turning point income, CO_2 emissions are declining as income increases. For example, the estimated coefficients on the income and the quadratic term are +2.9989 and −0.1787, indicating that before (after) an income threshold, a 1% rise in income leads to an increase (decrease) in CO_2 emissions by 2.9989% (0.1787%). When calculating the turning point income, however, it turns out to lie outside the sample period and hence the quadratic to the right of the value can be ignored. Therefore, it can be seen that CO_2 emissions increase monotonically with growth.

Of greater interest is the estimated effect of the energy consumption on CO_2 emissions. The estimated coefficient is positive and highly significant, suggesting that CO_2 emissions increase as energy consumption increases with growth. For example, when energy consumption increases by 1%, CO_2 emissions increase by approximately 0.75%, holding income and FDI fixed. This result provides empirical evidence supporting the claim of the recent literature that energy consumption should be accounted for when measuring the FDI impact on the environment suitably.

Our central interest is on assessing how FDI affects CO_2 emissions. The estimated coefficient is positive and statistically significant at the 5% level, meaning that CO_2 emissions rises with higher FDI flows to the Latin American countries. For example, a 1% point increase in FDI inflows leads to an increase in CO_2 emissions by 0.25%. This finding thus provides evidence supporting the pollution haven hypothesis: that is, FDI encourages Latin American countries to specialize in dirtier industries.

3.2. Results for the High-, Middle-, and Low-Income Subsamples

Table 5 summarizes our estimation results for the high-, middle-, and low-income subsamples. The Hausman tests show that the PMG estimators are consistent and more efficient than the MG ones for the high- and middle income subsamples, while the DFE is preferred over the MG for the low-income subsample. For the high- and middle-income countries, therefore, our discussion focuses on the results from the PMG. For the low-income group, on the other hand, our presentation emphasizes the DFE estimates.

The long-run results of high-income countries using the PMG (first three columns of Table 5) show that the income is positive and the quadratic term is negative, respectively. But they are not significant even at the 10% level. For middle- and low-income countries, on the other hand, the estimated coefficients of the income and the quadratic term are positive and negative, respectively. Statistically, however, they are highly significant only for the middle-income subsample. This indicates that the EKC hypothesis exists only for middle-income countries. As seen in the full sample, since the computed turning point income is found to be outside the sample period, CO_2 emissions actually increase monotonically with growth in middle-income countries.

The estimated effects of the energy consumption on CO_2 emissions are always positive and highly significant, evidence that increased energy consumption has a detrimental effect regardless of the level of economic development. It should be noted that the estimated coefficients increase from low- to middle- to high-income countries, evidence that richer countries play a greater role in polluting the environment.

The estimated effect of FDI is positive for high- and low-income countries and negative for middle-income countries. Statistically, however, it is highly significant only in the case of high-income countries. This thus validates the pollution haven hypothesis only for high-income countries.

4. Conclusions

In this short paper, the effects of FDI, income, and energy consumption on CO_2 emissions are investigated in the framework of dynamic panel data analysis. Our results spanning 17 Latin American countries over 1971–2011 show that income growth appears to increase CO_2 emissions monotonically. The same is true of FDI inflows, evidence supporting the pollution haven hypothesis. But when splitting the data into different income groups, it is found that income growth only in the middle-income countries increases CO_2, while FDI inflows increase it only in the high-income countries. Energy consumption, on the other hand, tends to increase CO_2 in all cases.

A clear implication that can be derived from our finding is that, considering income growth generally hand in hand with increasing energy consumption, any effort to promote economic growth in Latin American countries (i.e., middle-income economies) causes a corresponding increase in CO_2. Another important implication is that, since FDI is generally considered an engine of economic growth in developing countries, Latin American countries (i.e., high-income economies) need to focus on attracting clean and energy efficiency industries through FDI, thereby mitigating global warming.

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