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Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America

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ABSTRACT

Effects of foreign direct investment (FDI) and income on pollution emissions are examined using time series data from 1980 to 2010 for 14 Latin American countries. Specifically, we test the validity of Pollution Haven Hypothesis (PHH) and Environmental Kuznets Curve (EKC) hypothesis for this region. Results from panel fixed and random effects models that controlled the effects of physical capital, energy, human capital, population density, and unemployment rate indicate the validity of both the PHH and EKC hypothesis. Estimating two separate models for high and low-income countries does not alter the findings for the PHH, however, the impacts of human capital on pollution emission are found to be different for the two groups of countries. Policies that focus on attracting clean and energy efficient industries through FDI have potential to improve environmental health while enhancing economic growth in Latin America.

1. Introduction

Foreign direct investment (FDI) inflows to Latin America and the Caribbean have reached to $217 billion in 2011, a 16% increase from 2010. This high growth in FDI is mainly attributed to expanding consumer markets, natural resource endowments, and relatively higher rate of return on investments in this region (UNCTAD, 2012). The top five FDI attracting countries in Latin America in 2011 include Brazil (43%), Chile (14%), Mexico (13%), Colombia (8%), and Argentina (6%).

Developing countries, emerging economies, and countries in transition have perceived FDI as a source of economic development and modernization, income growth, and employment (OECD, 2002). Envisaging the potential role of FDI inflows on economic growth and employment opportunities, such inflows are welcomed and encouraged by the recipient countries (Blanco et al., 2011). However, as FDI inflow has shown an increasing trend in this region, so does the pollution emission. Carbon Dioxide Information Analysis Center (CDIAC) reports that Mexico and Brazil belong to the list of top 20 highest fossil-fuel CO_2 emitting countries and they together accounted for about 53% of the 2008 regional total emissions (Boden et al., 2011). As developing countries continue to grow, their CO_2 emissions have become an important issue in international agreements related to trade and environment.

Polluting activities in high-income economies have higher regulatory costs than in developing countries (Jaffe and Peterson, 1995; Mani and Wheeler, 1998). Relatively weak environmental policies in the host countries may give the high-income economies a comparative advantage in pollution intensive goods, and hence the foreign direct investment (FDI) might harm the host country's environment through pollution, which is commonly known as Pollution Haven Hypothesis (PHH). With the increasing trend of FDI and pollution in Latin America, examining the validity of the PHH in this region seems to be quite interesting and worth pursuing.

Literature on relationship between FDI and environmental pollution in Latin American countries are sparse and inconclusive. Waldkirch and Gopinath (2008) examine if FDI flows into Mexico are affected by pollution intensity of production and find evidence of pollution haven effects in case of sulphur dioxide. On the other hand, Eskeland and Harrison (2003) find foreign firms to be significantly more energy efficient and use cleaner energy and hence do not support the PHH for Mexico and Venezuela, along with two African countries – Cote d'Ivoire and Morocco. Blanco et al. (2011) examine the relationship between sector specific FDI and CO_2 emissions using panel Granger causality test for 18

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Latin American countries. The result suggests that there is a causality running from FDI in pollution intensive industries to CO_2 emissions per capita.

Numerous studies (e.g., Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Selden and Song, 1994; Grossman and Krueger, 1995) have examined the relationship between income and pollution after Grossman and Krueger's (1991) path breaking study of the environmental impacts of North American Free Trade Agreement which gave rise to environmental Kuznets curve (EKC) hypothesis. According to the EKC hypothesis, environmental quality at first tends to worsen as per-capita GDP rises but then improves as per-capita GDP increases further, giving rise to an inverse U-shaped relationship between environment pollution and economic growth.

Despite rich literature on test for validity of EKC hypothesis for different countries, those either at an individual country or at a panel level for Latin America are sparse. Mart and Bengochea-Morancho (2003) examined the relationship between the economic growth and CO_2 emissions using time series analysis for a panel of 19 Latin American and Caribbean countries over the period 1975–1998. The result suggests that there is no clear pattern related to the carbon dioxide emissions path. Bhattarai and Hammig (2001) used data from 1972 to 1991 to estimate panel fixed and random effects models and found strong evidence for EKC relationship between income and deforestation for 20 Latin American countries. However, a recent study that examines the effects of FDI and income on environmental pollution for a panel of Latin American countries using appropriate econometric methodology is completely lacking.

The primary objective of this study is to examine the relationships between income and pollution as well as between FDI and pollution in Latin America. Specifically, we test for the validity of PHH and EKC hypothesis for this region using data from a panel of 14 countries.[1] Apart from FDI and income, we include other variables such as unemployment rate, physical and human capital, energy use, and population density in the model to control for their potential effects on pollution emissions.

This study would find its significance from policy formulation perspective, particularly with respect to FDI. Given the role FDI plays in country's economic growth, delineating its effect on the environment would guide policy makers frame critical decisions on FDI inflow. For instance, if FDI is found to have negative impact on the environment, then the government may want to focus on FDI on service sector or clean technology. On the contrary, if FDI is found to exert positive effect on the environment, then the current policy on FDI would be appropriate.

This paper contributes to the literature in the following ways. Firstly, to our knowledge, no study has analyzed the effect of FDI and income on environmental pollution in Latin America in a panel framework. Examination of such a relationship utilizing panel econometric methodology would not only allow for obtaining consistent estimates with increased number of observations, but also control for differences in environmental regulations and other unobserved factors by including country-specific effects in the model. Moreover, this study provides systematic information on the relationship between FDI, pollution, and income in Latin American countries using recent data. Secondly, we incorporate additional control variables in the model, which would minimize omitted variable bias together with delineating the effects of those variables in environmental pollution in the region. Thirdly, extending the Lan et al. (2012) study that considered the endogeneity issue related with unemployment rate in studying the relationship between FDI and pollution in China, we deal with the endogeneity of both unemployment rate and FDI variables in the models. Importantly, the endogeneity test results suggested use of alternative estimation techniques (e.g., use of instrumental variables) to take care of the potential simultaneity bias and obtain consistent estimates.

[1] The countries included are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela and are selected based on data availability.

The remainder of the paper is organized as follows. Next section provides an overview of literature on the relationships between FDI and pollution and between income and pollution. Section 3 describes data and variables where potential econometric issues are also discussed. Section 4 provides results and discussion. Section 5 concludes.

2. A brief review of literature on PHH and EKC hypothesis

2.1. Foreign direct investment and pollution

Impact of FDI inflow on host country's environment in developing nations is inconclusive. Some studies suggest that FDI is related to energy efficiency gains and increased environmental welfare through the transfer of eco-friendly technology and production process (Liang, 2008; Hubler and Keller, 2010; Letchumanan and Kodama, 2000; Eskeland and Harrison, 2003). For example, Liang (2008) examines the relationship between FDI and local air pollution in China and finds a negative correlation between the variables. The study suggests that trade and FDI could have beneficial effect on a developing country's environment as it improves productivity and energy efficiency through new and improved technology. In an examination of the relationship between FDI, growth, and environment for India using cointegration analysis, Acharyya (2009) concludes that the upsurge in FDI inflow in the 1990s did have a quite large positive impact on the CO_2 emissions through output growth. He (2006), examining the FDI-pollution relationship for China in a simultaneous equation framework, finds that a one percent increase in FDI capital stock increases industrial SO_2 emission by 0.098%.

Levels of human capital and economic growth are found to play important roles for the validity of PHH. The Lan et al. (2012) study reports that the impact of FDI on pollution emission is highly dependent on the level of human capital. The PHH is found to hold only in those Chinese provinces that have low human capital. The argument is that the higher (lower) level of human capital is more likely to absorb advanced (less) green technology and experience less (more) environmental pollution. Hoffmann et al. (2005), in their tests for Granger causality between FDI and pollution in a panel of 112 countries, find that the PHH is valid only for the low income countries and not for the middle and high income countries. They suggest that in the absence of FDI attracting factors like infrastructure and skilled labor, low income countries may use lax environmental regulations.

Few studies have examined the impact of environment regulations on FDI. Spatareanu (2007) suggests that more stringent environmental regulations in the investor's country relative to those in the potential host country are positively correlated with the probability of investment as well as with the volume of FDI. List and Co (2000) report that foreign firms are more sensitive to pollution regulations than their domestic counterparts.

2.2. Income and pollution

Studies that look at the relationship between income and pollution abound. The methods used are time series models (cointegration and vector error correction) as well as panel models (fixed and random effects) and the findings are mixed. For example, Narayan and Narayan (2010) test EKC hypothesis for 43 developing countries using panel cointegration and panel long-run estimation techniques and find that CO_2 emission has fallen with a rise in income in Middle Eastern and South Asian countries. Existence of a long-run and an inverted-U shape relationships between CO_2 emissions and GDP are reported for Malaysia (Saboori et al., 2012), India (Kanjilal and Ghosh, 2013), Pakistan (Nasir and Rehman, 2011), Tunisia (Fodha and Zaghdoud, 2010), France (Iwata et al., 2010), South Korea (Baek and Kim, 2013; Onafowora and Owoye, 2014), and Japan (Onafowora and Owoye, 2014), among others. However, some studies find monotonically increasing (Holtz-Eakin and Selden, 1995; Shafik, 1994)) and some find

Table 1
Summary statistics.

Variables	Units	Mean	S.D.	Min	Max
Foreign direct investment	Net inflows, constant 2005 US$ (in billion)	3.20	6.46	−1.37	39.10
Gross fixed capital formation	Constant 2005 US$ (in billion)	408.80	966.67	0.35	5582.98
Unemployment rate	% of total labor force	8.54	4.12	0.9	22.45
Human capital	Average years of total schooling of age 15+	6.98	1.50	2.77	10.17
GDP per capita	Constant 2005 US$	3547.22	1948.38	799.95	8605.07
Population density	People per sq. km of land area	29.12	18.09	4.96	91.45
CO_2 emissions	Metric tons per capita	2.06	1.59	0.36	7.63
Energy use	Kg of oil equivalent per capita	956.23	537.24	334.82	2599.64

N-shaped relationship (Friedl and Getzner, 2003) between GDP and CO_2 emissions.

Some other studies have used pollutants other than CO_2 as the measure of pollution. Vincent (1997) uses six pollutant measures (water, particulates, carbon monoxide, sulphur oxides, nitrogen oxides, and hydrocarbons) and examines the relationship between income and pollution for Malaysia. The result does not support the EKC hypothesis for all six pollutants. Stern and Common (2001) using panel fixed and random effect model suggest that sulphur emission is a monotonic function of income when the global sample is used whereas it is an inverted U-shaped function of income when only a sample of high-income countries are used.

3. Methodology and data description

3.1. Empirical model

The empirical model is specified as follows:

$$\text{Pollution}_{it} = \beta_0 + \beta_1 \text{FDI}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{GDP}^2_{it} + \beta_X \text{X}_{it} + \eta_i + \gamma_t + \varepsilon_{it} \tag{1}$$

In Eq. (1), the dependent variable is pollution emission where CO_2 emission per capita is used as the measure of emission. The explanatory variables are FDI stock, GDP per capita, square of GDP per capita, and other control variables X, where $X = \{$energy use per capita, human capital, fixed capital formation, population density, unemployment rate$\}$. η is time invariant country specific effect and γ is location or country invariant time specific effect. All variables (both dependent and explanatory) are transformed into natural logarithms. The above equation, including all variables, can be expressed as:

$$\begin{aligned}\text{Pollution}_{it} = {} & \beta_0 + \beta_1 \text{FDI}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{GDP}^2_{it} + \beta_4 \text{Energy}_{it} \\ & + \beta_5 \text{Capital}_{it} + \beta_6 \text{Popden}_{it} \\ & + \beta_7 \text{Unemp}_{it} + \beta_8 \text{HC}_{it} + \eta_i + \gamma_t + \varepsilon_{it}\end{aligned} \tag{2}$$

Eq. (2) is estimated using annual country level data from 1980 to 2010 for 14 Latin American countries. The data for all variables are obtained from the World Development Indicators (World Development Indicators, The World Bank, 2011). Table 1 presents the summary statistics of the data. To show how the values of variables vary across countries, mean values of all the variables for each country are provided in Table 2. Description of the individual variables follows.

3.2. Description of variables

3.2.1. Pollution

CO_2 emission, used as the indicator of pollution emission, is expressed in metric tons per capita. CO_2 has been widely used as the indicator of pollution emission in the literature (Yang, 2001; Holtz-Eakin and Selden, 1995; Hoffmann et al., 2005; Acharyya, 2009) as it is the primary greenhouse gas causing global warming. Moreover, reliable time series data on CO_2 emissions are available for most countries as compared to other pollutants.

3.2.2. FDI

FDI flow is transformed into FDI stock variable in order to account for the longer-term effect of FDI on the pollution emissions from production activities. Formula[2] used for calculating the FDI stock is the same as that used for calculating capital stock (Lan et al., 2012):

$$FDI_{i,t+1} = (1-\delta)\text{FDI}_{it} + I^F_{i,t+1} \tag{3}$$

where δ is the average depreciation rate, *FDI* is FDI stock,[3] and I^F is the annual FDI inflow. As common in literature, the average depreciation rate is assumed to be 10% for all countries (Wacker, 2011; Bitzer and Gorg, 2009).

FDI can affect pollution in both directions - positive and negative - through different channels. For example, an increase in FDI may increase pollution by attracting more pollution intensive industries, thus, supporting the pollution haven hypothesis. In the other case, increase in FDI may reduce pollution through the adoption of more advanced and energy efficient technologies by the FDI attracting firms.

3.2.3. Income

Income is measured as GDP per capita in 2005 constant US$. If the estimated coefficient of GDP per capita is positive and significant and that of its square is negative and significant, then the EKC is said to be estimated. The EKC is an inverted U shaped locus of points that relates pollution emission with income of a country. Intuitively, once a country achieves a certain level of income (or it reaches an economic turning point), it becomes more concerned about the environmental health and hence, makes effort towards reducing the pollution.

3.2.4. Energy

Energy is measured as energy use per capita in *kt* of oil equivalent. The expected sign of energy coefficient is positive because increase in energy consumption can be thought of as increased number of capital-intensive industries, which leads to increased pollution.

3.2.5. Capital

As the data on capital stock is not available, we used gross fixed capital formation as a proxy for capital stock. Gross fixed capital formation could be a reliable proxy for "changes" in capital stock if we assume a constant depreciation rate (Soytas et al., 2007). The coefficient of capital is expected to be positive. This is because employment of more capital in a production process generally consumes more energy thus, leading to increased pollution.

[2] Since the FDI data is already in constant dollars, price index is not used in the formula (Eq. (3)).

[3] We calculated the FDI stock for most countries starting from 1975, however, for some countries, data were not available for that period. Hence, the initial years for some countries differ.

Table 2
Mean values of variables by country.

Country	FDI	Gross fixed capital	Unemployment rate	Human capital	GDP per capita	Population density	CO_2 emission per capita	Energy use per capita
Argentina	3.08	2944.35	10.70	8.50	4349.39	12.64	3.80	1585.21
Bolivia	0.26	1.06	8.69	7.78	946.57	7.09	1.07	470.73
Brazil	13.49	132.64	6.97	5.43	4369.33	19.05	1.64	1042.01
Chile	4.41	15.19	9.98	8.71	5531.49	19.22	2.99	1297.24
Colombia	2.92	2145.29	9.31	6.37	3020.53	33.01	1.59	682.88
Costa Rica	0.51	2.63	6.02	7.52	3803.68	68.59	1.30	682.03
Honduras	0.24	170.20	4.82	5.56	1253.58	49.88	0.74	521.26
Mexico	15.18	124.61	3.69	7.04	6928.97	48.70	3.78	1426.55
Nicaragua	0.15	1.24	11.78	4.99	1111.61	38.21	0.66	497.71
Panama	0.64	2.12	12.34	8.26	3993.20	37.52	1.69	779.43
Paraguay	0.08	146.54	6.14	6.51	1471.15	12.10	0.63	710.38
Peru	1.74	12.45	7.85	7.68	2622.66	18.52	1.18	503.29
Uruguay	0.34	2.91	10.70	7.68	4675.30	18.22	1.61	854.59
Venezuela	1.81	22.02	10.50	5.77	5583.63	25.01	6.25	2333.95

3.2.6. Population density

As migration pattern is generally towards industrialized and urban areas rather than unindustrialized and rural areas, be it for the search of employment or for other purposes, population tend to expand most rapidly in industrialized areas. Hence, the most densely populated areas have always been the most industrialized. However, population density can affect pollution in both positive and negative directions. On one hand, in a densely populated area, more people will be adversely affected by pollution and hence, opposition to such plants may be greater. On the other hand, a pollution intensive plant may be less visible in a densely populated, urban area and hence, may escape the attentions of local population (Cole et al., 2008; Lan et al., 2012).

3.2.7. Unemployment rate

Unemployment rate can also affect pollution in both positive and negative directions. In the first case, as explained by Lan et al. (2012) and Cole et al., 2008, unemployment increases pollution through two different channels: 1) the government or the regulator allocates more resources to solve the unemployment problem and thus, fewer resources to solve environmental problems; and 2) communities in that region would be willing to accept polluting plants nearby if they provide more job opportunities. On the other hand, if the policy for environmental regulation is made stringent by increasing environmental tax and use that tax revenue to decrease labor tax, this would increase the employment (Bayindir-Upmann and Raith, 2005). If the net-wage income does not fall, this will lead to a positive income effects and raises both clean and dirty consumption, resulting in a lower environmental quality than before. Hence, the variable unemployment rate can also be taken as a proxy for policy related to environmental regulation.

3.2.8. Human capital

The data on human capital is difficult to obtain because of quite low frequency of census data available for all countries. Different studies provide data on educational attainment which can be used as a proxy for human capital. However, the data from these studies are available only for every 10 years (Cohen and Soto, 2007) or every 5 years (Barro and Lee, 2001, 2013). In this study, we used the latest data on educational attainment, as a proxy for human capital, from Barro and Lee (2013), which is available for every 5 years. We then linearly interpolated[4] this data to obtain annual data for all countries. Barro and Lee use the average years of schooling to measure the educational attainment of the population aged 15 and above as an indicator of human capital stock. The expected sign of human capital is negative implying that human capital plays a positive role in reducing pollution because countries with higher level of human capital are able to and have skills in adopting more advanced and cleaner technology.

3.3. Model selection and potential problems

The first concern in a panel data analysis is to choose a valid model. In panel data analysis, the ordinary least squares (OLS) method provides biased estimates because the unobserved error term η_i (in Eq. (2)) is correlated with the error term. Hence, in order to obtain consistent and efficient estimates, we first run both fixed and random effects models and then choose a valid model based on Hausman specification test (Hausman, 1978). The null hypothesis in Hausman specification test is $H_0: E(\varepsilon_i|X_{it}) = 0$ which implies that random effects model yields consistent and efficient estimates if H_0 is true. However, under the alternative, the fixed effects model is consistent, but the random effects model is not. The fixed effects model is estimated using pooled OLS estimator based on time demeaned variables and since we subtract the between variation, the estimator is also called within-estimator. Generalized least square estimator (GLS) which generates a matrix average of the between and within estimator results is used for estimating the random effects model.[5]

Another econometric issue is the endogeneity of the variables unemployment rate and FDI. In the previous paragraphs, we mentioned how unemployment rate can affect pollution. In reality, unemployment could have reverse causality with pollution and hence, there could exist bi-directional causality between unemployment rate and pollution (Lan et al., 2012; Cole et al., 2008). Intuitively, foreign investors may not want to invest in a region or a country that is already polluted and thus, may provide less opportunity for employment. Some past studies have pointed out the endogeneity of FDI while analyzing the relationship between FDI and pollution (Wang et al., 2013; Bao et al., 2011; Liang, 2008). Similar to unemployment rate, FDI could also have reverse causality since more polluted countries or regions may be less attractive for foreign investment thus, resulting in less FDI in the polluted countries.

To empirically test the endogeneity issues related with these variables, we carry out Davidson and Mackinnon test (Davidson and Mackinnon, 1993) by using one-period lagged unemployment rate and FDI stock as the instruments. The Davidson and Mackinnon test

[4] Barro and Lee (2013)'s data on educational attainment in Latin American countries show that the variable is quite stable over time. Paradiso et al. (2013) mention that simple linear interpolation to construct annual data using stable variable does not create problems or distortions. Many studies (Paradiso et al., 2013; Park, 2010; Vogl, 2016) have used the linear interpolation technique to obtain annual data. However, as a robustness check, we also tried cubic spline interpolation for human capital and the results were very similar. We have not reported these results for the purpose of brevity and are available upon request.

[5] We acknowledge one of the reviewers for suggesting examination of panel cointegration methodology, given its increasing use in the recent literature, as a robustness check. To this end, we carried out various panel unit root and cointegration tests. However, the test results do not provide plausible statistical evidence for pursuing the panel cointegration approach. Nevertheless, we report the test results in the appendix.

tests the null hypothesis that OLS estimator would yield the consistent estimates against the alternative that OLS estimator is inconsistent and the instrumental variable technique is appropriate. Hence, rejection of the null hypothesis would be suggestive of the endogeneity of the regressors in question.

Because of high variation in the values of variables between countries[6] as shown in Table 2, the results obtained by including all countries may only render the average scenario of PHH and EKC for the Latin American countries. Hence, to obtain more realistic results, we divide countries into two groups based on average income level and re-estimate the models for each group. We categorize the countries into two groups based on mean income (GDP per capita) where countries with average per capita GDP lower than $3550 (constant 2005 US$) are included in one group (Group 1) and the remaining into the other (Group 2). The average income for Latin American countries as a whole is $3547 (Table 1).

4. Results and discussion

Table 3 presents results from both fixed and random effects models. The Davidson and Mackinnon test suggests the endogeneity of unemployment rate and FDI (p-values <0.05 in both cases). Moreover, the Hausman specification test for fixed versus random effects yields a p-value to be greater than 0.05, suggesting that random effects estimates are consistent and efficient. Hence, the random effect model with instrumental variables is selected as the final model for further inferences.

The model R-square is quite high (0.749) which indicates that about three-quarter of variation in the pollution emission is explained by the explanatory variables included in the model. All of the estimated coefficients are statistically significant ($p < 0.05$) except that of physical capital. FDI stock is found to have a positive effect, which indicates that increase in FDI stock would increase pollution (CO_2 emissions) in Latin America, thus supporting the pollution haven hypothesis for the region. The coefficient of 0.036 for FDI suggests that every 1% increase in FDI stock will lead to a 0.036% increase in pollution. As FDI is considered as an engine of economic growth in developing countries, these countries need to focus on attracting clean and energy efficient industries through FDI to reduce pollution. This would contribute to the economic growth in these countries without having negative impact on the environment.

The coefficients for GDP per capita and the square of GDP per capita are statistically significant at the one percent level with a positive and a negative sign, respectively. This indicates that income has an inverted-U shape relationship with pollution and thus, supports environmental Kuznets curve hypothesis for Latin America. Intuitively, GDP per capita at first increases pollution, and then decreases it after a certain level of income is attained. Using the coefficient values obtained for income and square of income from the third column of Table 3, the turning point of income for the inverse-U curve is estimated to be US $3158 (in constant 2005 US$). Different studies have come up with different levels of income turning points for different countries. For instance, Rashid (2009) finds this turning point for CO_2 emission to be US $32,045 for United States and US $2751 for BRIC (Brazil, Russia, India, and China) countries; Aslanidis and Iranzo (2009) find this to be US $9912 for 77 non-OECD countries. Similarly, the turning point for SO_2 emission is found to be US $1200 for China (Liang, 2008); US $3137 for 55 developed and developing countries (Panayotou, 1993); US $5648 for OECD sub-sample and $3401 for non-OECD sub-sample (Halkos, 2003). This threshold level of income as a turning point of the inverse-U curve is very sensitive to the functional form used, countries included, control variables used in the model, type of pollutant used, and the methodology employed (Harbaugh et al., 2002; He and Richard, 2010). Hence, precautions should be taken while generalizing this value for policy implications.

Table 3
Fixed and random effects estimation for the full sample.

Variables	Fixed effect	Random effect
FDI	0.025**	0.036***
	(2.21)	(3.28)
GDP	3.254***	3.352***
	(6.28)	(6.68)
GDP^2	-0.206***	−0.208***
	(−6.45)	(−6.76)
Energy	0.753***	0.766***
	(13.39)	(13.83)
Capital	0.065**	0.026
	(1.91)	(1.16)
Popden	0.26**	0.166**
	(2.57)	(2.22)
Unemp	−0.112***	−0.117***
	(−5.15)	(−5.73)
HC	0.07	0.142**
	(0.92)	(2.05)
Constant	−20.241***	−20.102***
	(−8.77)	(−9.30)
Wald Chi^2	10,872	1511
	0.000	0.000
R^2	0.616	0.749
Hausman FE Vs RE		11.93
		(0.154)
D-M exogeneity		
FDI	4.070	
	(0.044)	
Unemp	4.068	
	(0.044)	

Note: The values in parentheses for the coefficient estimates are Z-statistics for both fixed and random effects. The values in parentheses for Hausman test and Davidson Mackinnon test are p-values. Davidson and Mackinnon test for exogeneity cannot be performed for random effects estimation. ** and *** indicate significant at 5% and 1% levels, respectively.

The estimated coefficient for energy is significant and positive indicating detrimental impact of energy intensive production to the environmental health. The coefficient for energy consumption is quite high (0.766), which suggests that the increased level of pollution is highly attributed by excessive consumption of energy. These results are consistent with our expectations. Hence, these findings suggest that in order to reduce pollution, countries may need to focus on adopting energy-saving and environment-friendly technologies.

The population density variable has a significant and positively signed coefficient, which indicates that densely populated areas will be more polluted. This might be because pollution will be less visible in a densely populated area and opposition to such plants is less likely to occur which will lead to more pollution. The estimated coefficient for unemployment rate is significant with negative sign and contradicts to the findings by Lan et al. (2012) and Cole et al. (2008). Intuitively, if there are less industries and production activities, there will be less pollution but the unemployment rate will increase. This suggests that in Latin American countries, policies that aim to increase employment may succeed, but likely at the cost of environmental health.

Estimation results for two groups[7] of countries separated on the basis of average per capita income are presented in Table 4. The coefficients for FDI are significant at the 1% level in both cases suggesting that pollution haven hypothesis applies to both group of countries. The coefficients for GDP and square of GDP are significant for low-income group (Group 1) but not significant for high-income group (Group 2) of countries. For Group 1 countries, the sign for GDP is negative and that for square of GDP is positive, which does not validate the EKC hypothesis. Moreover, the estimated coefficients for all other variables (energy, population density, capital, unemployment rate, and

[6] For example, average per capita GDP varies from as low as $946 (Bolivia) to as high as $6929 (Mexico).

[7] Countries in low-income group consist of Bolivia, Colombia, Honduras, Nicaragua, Paraguay, and Peru. Remaining eight countries are grouped under high-income countries.

Table 4
Random effects estimation by income group.

Variables	Group 1 Income < $3550	Group 2 Income > $3550
FDI	0.215***	0.026***
	(8.61)	(3.91)
GDP	−6.918***	−3.673
	(−3.76)	(−1.74)
GDP2	0.483***	0.182
	(3.88)	(1.45)
Energy	0.360***	1.625***
	(3.33)	(33.40)
Capital	−0.054***	−0.046***
	(−5.40)	(−5.27)
Popden	−0.115***	0.013
	(−3.23)	(0.51)
Unemp	−0.313***	−0.123***
	(−5.74)	(−3.82)
HC	−0.473***	0.418***
	(−2.83)	(7.67)
Constant	20.885***	7.320
	(3.06)	(0.82)
F-test/Wald chi-2	644.72	4377.03
	(0.000)	(0.000)
R^2	0.792	0.951

Note: The values in parentheses for the coefficient estimates are t-statistics for group 1 countries and Z-statistics for group 2 countries. ** and *** indicate significant at 5% and 1% levels, respectively.

human capital) are statistically significant. For Group 2 countries, the estimated coefficients for all other variables except that for population density are statistically significant.

The results for human capital variable deserve more explanation. We find that the estimated coefficient for human capital has a negative sign for Group 1 countries indicating reduction of pollution with an increase in human capital in these countries. For Group 2 countries, however, the sign of the estimated coefficient for human capital is positive, suggesting higher level of pollution with increased level of human capital in high-income countries. These findings confirm to those reported in previous studies. For instance, our finding of a negative association between human capital and pollution for low-income group coincides with that of Lan et al. (2012) for China. Intuitively, as country's stock of human capital expands, or specifically, as people become more educated, the demand for and adoption of cleaner production technology may rise, thus reducing pollution emissions. Similarly, the positive association between human capital and pollution for high-income group is consistent with Cole et al. (2005)'s study[8] for the UK manufacturing sector. These findings thus demonstrate the differential impacts of human capital on environmental pollution across levels of economic growth.

5. Conclusion

To our knowledge, this is the first study that examines the relationship between foreign direct investment (FDI), environmental pollution, and income at a panel level for Latin American countries. Using annual country level data from 1980 to 2010 for 14 Latin American countries, we estimate and compare panel fixed versus random effects models for correct specification and take into account endogeneity issues related to FDI and unemployment rate. Such an econometrically justified model is then used to test the validity of pollution haven hypothesis and environmental Kuznets curve hypothesis for Latin America. We find that FDI is positively related with pollution, which supports the pollution haven hypothesis for this region. The estimated marginal effects show that every one percent increase in FDI leads to a 0.036 percent increase in pollution. Moreover, we find significant positive and negative coefficients for per capita GDP and square of per capita GDP, respectively, which validate the environmental Kuznets curve hypothesis for Latin America. However, analyzing these effects further by dividing counties into two groups based on average per capita GDP validates only the PHH but not the EKC hypothesis. As expected, the EKC estimation results are sensitive to the countries included in the model. Interestingly, impact of human capital on pollution emission is different across income groups. Results show that pollution is negatively correlated with human capital in low-income countries and is positively correlated in high-income countries.

We find that pollution emission in Latin America is positively correlated with FDI and energy. As FDI is considered as an engine of economic growth in developing countries, the Latin American nations need to focus on attracting clean and energy efficient industries through FDI. Such a policy has potential to improve environmental health while enhancing economic growth in this region. Moreover, policies for increasing human capital are also likely to contribute to pollution reduction, especially in countries on the low-income spectrum.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eneco.2017.04.001.

References

Acharyya, Joysri, 2009. FDI, growth, and the environment: evidence from India on CO2 emission during the last two decades. J. Econ. Dev. 34, 43–58.
Aslanidis, Nektarios, Iranzo, Susana, 2009. Environment and development: is there a Kuznets curve for CO2 emissions? Appl. Econ. 41 (6), 803–810.
Baek, Jungho, Kim, Hyun Seok, 2013. Is economic growth good or bad for the environment? Empirical evidence from Korea. Energy Econ. 36 (2013), 744–749.
Bao, Qun, Chen, Yuanyuan, Song, Ligang, 2011. Foreign direct investment and environmental pollution in China: a simultaneous equations estimation. Environ. Dev. Econ. 16, 71–92.
Barro, Robert J., Lee, Jong-Wha, 2001. International data on educational attainment: updates and implications. Oxf. Econ. Pap. 53, 541–563.
Barro, Robert J., Lee, Jong-Wha, 2013. A new data set of educational attainment in the world, 1950–2010. J. Dev. Econ. 104, 184–198.
Bayindir-Upmann, Thorsten, Raith, Matthias G., 2005. Unemployment and pollution: is one policy suited for two problems? Econ. Rec. 81, 378–393.
Bhattarai, Madhusudan, Hammig, Michael, 2001. Institutions and the environmental Kuznets curve for deforestation: a cross-country analysis for Latin America, Africa and Asia. World Dev. 29, 995–1010.
Bitzer, Jurgen, Gorg, Holger, 2009. Foreign direct investment, competition and industry performance. World Econ. 32 (2), 221–233.
Blanco, Luisa, Gonzalez, Fidel, Ruiz, Isabel, 2011. The Impact of FDI on CO2 Emissions in Latin America. Pepperdine University, School of Public Policy Working Papers, Paper 28 (Available at http://digitalcommons.pepperdine.edu/sppworkingpapers/28).
Boden, T.A., Marland, G., Andres, R.J., 2011. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. http://dx.doi.org/10.3334/CDIAC/00001_V2011.
Cohen, Daniel, Soto, Marcelo, 2007. Growth and human capital: good data, good results. J. Econ. Growth 12, 51–76.
Cole, Matthew A., Elliott, Robert J.R., Shimamoto, Kenichi, 2005. Industrial characteristics, environmental regulations, and air pollution: an analysis of the UK manufacturing sector. J. Environ. Econ. Manag. 50, 121–143.
Cole, Matthew A., Elliott, Robert J.R., Wu, Shanshan, 2008. Industrial activity and the environment in China: an industry-level analysis. China Econ. Rev. 19, 393–408.
Davidson, R., MacKinnon, J.G., 1993. Estimation and Inference in Econometrics. Oxford University Press, New York.
Eskeland, Gunnar S., Harrison, Ann E., 2003. Moving to greener pastures? Multinationals and the pollution haven hypothesis. J. Dev. Econ. 70, 1–23.
Fodha, Mouez, Zaghdoud, Oussama, 2010. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energ Policy 38 (2), 1150–1156.
Friedl, Birgit, Getzner, Michael, 2003. Determinants of CO_2 emissions in a small open economy. Ecol. Econ. 45, 133–148.
Grossman, Gene M., Krueger, Alan B., 1991. Environmental Impacts of a North American Free Trade Agreement. No. w3914. National Bureau of Economic Research.

[8] Cole et al. (2005) used share of value added that is paid to skilled workers as a measure of human capital intensity. Moreover, their findings were robust to alternative measures of human capital intensity as well as functional forms used.

Grossman, Gene M., Krueger, Alan B., 1995. Economic growth and the environment. Q. J. Econ. 110, 353–377.

Halkos, George E., 2003. Environmental Kuznets curve for sulfur: evidence using GMM estimation and random coefficient panel data models. Environ. Dev. Econ. 8, 581–601.

Harbaugh, William T., Levinson, Arik, Wilson, David Molloy, 2002. Reexamining the empirical evidence for an environmental Kuznets curve. Rev. Econ. Stat. 84, 541–551.

Hausman, J.A., 1978. Specification tests in econometrics. Econometrica J. Econ. Soc. 1251–1271.

He, Jie, 2006. Pollution haven hypothesis and environmental impacts of foreign direct investment: the case of industrial emission of sulphur dioxide in Chinese provinces. Ecol. Econ. 60, 228–245.

He, Jie, Richard, Patrick, 2010. Environmental Kuznets curve for CO_2 in Canada. Ecol. Econ. 69, 1083–1093.

Hoffmann, Robert, et al., 2005. FDI and pollution: a Granger causality test using panel data. J. Int. Dev. 17, 311–317.

Holtz-Eakin, Douglas, Selden, Thomas M., 1995. Stoking the fires? CO_2 emissions and economic growth. J. Public Econ. 57, 85–101.

Hubler, Michael, Keller, Andreas, 2010. Energy savings via FDI? Empirical evidence from developing countries. Environ. Dev. Econ. 15, 59–80.

Iwata, Hiroki, Okada, Keisuke, Samreth, Sovannroeun, 2010. Empirical study on the environmental Kuznets curve for CO_2 in France: the role of nuclear energy. Energ Policy 38, 4057–4063.

Jaffe, Adam B., Peterson, Steven R., 1995. Environmental regulation and the competitiveness of U.S. manufacturing: what does the evidence tell us? J. Econ. Lit. XXXIII, 132–163.

Kanjilal, Kakali, Ghosh, Sajal, 2013. Environmental Kuznet's curve for India: evidence from tests for cointegration with unknown structural breaks. Energ Policy 56, 509–515.

Lan, Jing, Kakinaka, Makoto, Huang, Xianguo, 2012. Foreign direct investment, human capital, and environmental pollution in China. Environ. Resour. Econ. 51, 255–275.

Letchumanan, Raman, Kodama, Fumio, 2000. Reconciling the conflict between the ‘pollution-haven’ hypothesis and an emerging trajectory of international technology transfer. Res. Policy 29, 59–79.

Liang, Feng Helen, 2008. Does foreign investment harm the host country's environment? Evidence from China. Available at SSRN. http://ssrn.com/abstract=1479864.

List, John A., Co, Catherine Y., 2000. The effects of environmental regulations on foreign direct investment. J. Environ. Econ. Manag. 40, 1–20.

Mani, Muthukumara, Wheeler, David, 1998. In search of pollution havens? Dirty industry in the world economy, 1960 to 1995. J. Environ. Dev. 7, 215–247.

Mart, Inmaculada, Bengochea-Morancho, Aurelia, 2003. Testing for an environmental Kuznets curve in Latin-American countries. Rev. Anál. Econ. Econ. Anal. Rev. 18, 3–26.

Narayan, Paresh Kumar, Narayan, Seema, 2010. Carbon dioxide emissions and economic growth: panel data evidence from developing countries. Energ Policy 38, 661–666.

Nasir, Muhammad, Rehman, Faiz Ur, 2011. Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energ Policy 39, 1857–1864.

Onafowora, Olugbenga A., Owoye, Oluwole, 2014. Bounds testing approach to analysis of the environment Kuznets curve hypothesis. Energy Econ. 44 (2014), 47–62.

Organization for Economic Co-operation and Development (OECD), 2002. Foreign Direct Investment for Development: Maximizing Benefits, Minimizing Costs.

Panayotou, T., 1993. Empirical tests and policy analysis of environmental degradation at different stages of economic development. Working Paper WP238, Technology and Employment Programme. International Labor Office, Geneva.

Paradiso, Antonio, Kumar, Saten, Bhaskara Rao, B., 2013. The growth effects of education in Australia. Appl. Econ. 45, 3843–3852.

Park, Jungsoo, 2010. Projection of long-term Total factor productivity growth for 12 Asian economies. Asian Development Bank Economics Working Paper Series 227.

Rashid, S., 2009. The Environmental Kuznets Curve Case for the USA and the BRIC Countries. (Master's thesis). Georgia Institute of Technology.

Saboori, Behnaz, Sulaiman, Jamalludin, Mohd, Saidatulakmal, 2012. Economic growth and CO_2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energ Policy 51, 184–191.

Selden, Thomas M., Song, Daqing, 1994. Environmental quality and development: is there a Kuznets curve for air pollution emissions? J. Environ. Econ. Manag. 27, 147–162.

Shafik, Nemat, 1994. Economic development and environmental quality: an econometric analysis. Oxford Economic Papers, pp. 757–773.

Shafik, Nemat, Bandyopadhyay, Sushenjit, 1992. Economic Growth and Environmental Quality: Time Series and Cross Country Evidence. 904 World Bank-free PDF.

Soytas, Ugur, Sari, Ramazan, Ewing, Bradley T., 2007. Energy consumption, income, and carbon emissions in the United States. Ecol. Econ. 62, 482–489.

Spatareanu, Mariana, 2007. Searching for pollution havens: the impact of environmental regulations on foreign direct investment. J. Environ. Dev. 16, 161–182.

Stern, David I., Common, Michael S., 2001. Is there an environmental Kuznets curve for sulfur? J. Environ. Econ. Manag. 41 (2), 162–178.

United Nations Conference on Trade and Development (UNCTAD), 2012. World Investment Report 2012: Towards a New Generation of Investment Policies. New York and Geneva: Available at:. http://unctad.org/en/PublicationsLibrary/wir2012_embargoed_en.pdf.

Vincent, Jeffrey R., 1997. Testing for environmental Kuznets curves within a developing country. Environ. Dev. Econ. 2, 417–431.

Vogl, T.S., 2016. Differential fertility, human capital, and development. Rev. Econ. Stud. 83: 365–401. http://dx.doi.org/10.1093/restud/rdv026.

Wacker, Konstantin M., 2011. The impact of foreign direct investment on developing countries' terms of trade. No. 2011, 06. Working Paper/World Institute for Development Economics Research.

Waldkirch, Andreas, Gopinath, Munisamy, 2008. Pollution control and foreign direct investment in Mexico: an industry-level analysis. Environ. Resour. Econ. 41, 289–313.

Wang, Danny T., et al., 2013. When does FDI matter? The roles of local institutions and ethnic origins of FDI. Int. Bus. Rev. 22, 450–465.

World Development Indicators, The World Bank, 2011. Available at:. http://data.worldbank.org/indicator.

Yang, Hao-Yen, 2001. Trade liberalization and pollution: a general equilibrium analysis of carbon dioxide emissions in Taiwan. Econ. Model. 18, 435–454.