Foreign direct investment and environmental degradation: Further evidence from Brazil and Singapore.

Ioannis Kostakis and Sarantis Lolos and Eleni Sardianou

Department of Home Economics and Ecology Harokopio University, Athens, Greece, Department of Economic and Regional Development Panteion University, Athens, Greece, Department of Home Economics and Ecology Harokopio University, Athens, Greece

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Foreign Direct Investment and Environmental Degradation: Further evidence from Brazil and Singapore

by

Ioannis Kostakis,[1] Sarantis Lolos,[2] Eleni Sardianou[3]

Abstract

This paper assesses empirically the role of foreign direct investment (FDI) inflows on environmental quality, measured by CO2 emissions. The cases of Brazil and Singapore are taken as examples for our empirical investigation, on the grounds of their specific similarities and differences. The empirical analysis is carried out in a multivariate setting, using a variety of models (ARDL, FMOLS, OLS) for the early 1970s to 2010. The results indicate that FDI inflows have lead to environmental degradation in Brazil but not in Singapore. Our findings point to the importance of the sectoral composition of FDI as a determinant of its impact on environmental quality. The analysis is supplemented with an environmental Kuznets curve (EKC), our results showing that the EKC hypothesis holds for the case of Singapore but its validity is marginal in Brazil.

Key words: foreign direct investment; environmental degradation; kuznets curve

JEL classification: Q56; Q43

1. Introduction

The beneficial impact of foreign direct investment (FDI) in stimulating economic growth acquires a more or less universal acceptance. Indeed, empirical evidence reveals that FDI inflow has played an important role in triggering growth in the host countries through innovative activities, technology transfers and spillover effects. However, its impact on environmental quality has not been adequately investigated and the existing evidence on the FDI-environment nexus is inconclusive. In this paper we provide further evidence and a fresh look on the issue.

The FDI-environment relationship is viewed mainly *via* two competing hypotheses: the pollution *heavens* hypothesis and the pollution *haloes* hypothesis. According to the first, more advanced economies implement strict environmental laws while some -mostly developing- countries have lax environmental laws thus attracting “dirty” industries (Levinson, 1996; Zarsky, 1999; Cole and Elliott, 2005; Blanco *et al*., 2012; Hassaballa, 2014). This phenomenon leads to the emergence of specialisation in polluting industries in developing economies and in non-polluting industries in advanced ones. Thus, there is a positive relationship between environmental pollution and foreign direct investment. On the other hand, neo-

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[1] *Address for correspondence*: Ioannis Kostakis, Department of Home Economic and Ecology, Harokopio University, 76 El. Venizelou Str., 176 76 Athens, Greece Tel. +30 210 9549216; e-mail: ikostakis@hua.gr, iekostakis@gmail.com. Thanks are due to George Hondroyiannis for valuable comments and suggestions.

[2] Department of Economic and Regional Development Panteion University 136 Sygrou Ave., 176 71 Athens, Greece Tel. +30 210 920.1855; e-mail: slolos@panteion.gr, sarantislolos@gmail.com

[3] Department of Home Economics and Ecology Harokopio University, Athens, Greece, 76 El. Venizelou Str., 176 76 Athens, Greece Tel. +30 210 9549266; e-mail: esardianou@hua.gr

technology school of thought supports the pollution haloes hypothesis stating that there is a positive relationship between foreign direct investment inflows and environmental quality via technological upgrading and knowledge spillovers (Luiz and Mello, 1999) with a transfer of more environmental friendly technologies from advanced economies to developing countries (Albornoz *et al.*, 2009; Gorg and Strobl, 2005). Thus, there is a negative or neutral relationship between foreign direct investment and environmental pollution in developing countries or that FDI has a positive or neutral relation to clean energy use (Lee, 2013). However, the empirical investigation on the FDI-environment relationship comes out with mixed results.

A positive relationship between aggregate FDI inflows CO_2 emissions is reported by Chung (2014) who verifies the pollution heavens hypothesis for South Korea (2000-2007) and Managi and Jena (2008) for India (1991-2003). Also, for the case of China, Ren *et al*. (2014) analysing the 2000s finds that the large FDI inflows further aggravate CO_2 emissions; Zhang (2011) shows that FDI played a pivotal role in the increase of CO_2 emissions since mid 1980s and Wang and Chen (2014) investigating a panel data set of 287 Chinese cities over the period 2002-2009 find that FDI induces negative environmental externalities. Pao and Tsai (2011) examine the FDI-CO_2 emissions links for the panel of the BRIC (Brazil, Russia, India and China) countries over the period 1992-2007 and they find bidirectional causality between CO_2 emissions and FDI.

A negative impact of FDI on environment is reported by Lee (2013) who investigates the panel of G20 countries from 1971-2009. He finds that there is no direct positive relationship between FDI and CO_2 and since his results differ from those for other studies mostly for developing countries, he concludes that the relationship between FDI and CO_2 emissions can be different for developing and developed countries. Tamazian *et al*. (2009) investigating the panel of BRIC countries over the 1990s come to the conclusion that FDI helps enterprises to promote technology innovation and adopt new technologies and thus increase energy efficiency and advance low carbon economic growth. Thus, increase in FDI inflows are associated with lower levels of per capita CO2 emissions. These findings are in line with List and Co (2000) and He (2006).

On the other hand, Eskeland and Harrison (2003) fail to document a strong positive relationship between FDI to pollutant emissions in some developing countries (Mexico, Morocco, Cote d'Ivoire, Venezuela) over the 80s, while Smarzynska and Wei (2001) investigating 24 transition economies they find some support for the pollution heaven hypothesis but the overall evidence is relatively weak. Aliyu (2005) finds that FDI inflow is not significant in explaining the level of pollution in a panel of fourteen non-OECD countries over the 1990s. Acharyya (2009) provides some empirical support for India (1980-2003) that FDI inflow has caused degradation of air quality as measured by CO_2 emission, though the pollution heaven hypothesis may not be a plausible argument for the upsurge in FDI inflow in the 1990s.

In addition, Merican *et al.* (2007) investigating the impact of aggregate FDI on environmental pollution in ASEAN-5 countries (1970-2001) find that FDI increases CO_2 emissions in Malaysia, Thailand and the Philippines but has beneficial effects on the environment in Indonesia, while it has a neutral effect on CO_2 emissions in Singapore. However, Lee (2009) does not find long-run causality between FDI and CO_2, over the same period for Malaysia. On the other hand, Kivyiro and Arminer (2014) investigate the causal links between CO_2 emissions and aggregate FDI in six Sub Saharan African countries and they find that FDI increases CO_2 emissions in

Kenya and Zimbabwe (pollution haven hypothesis), while the opposite is observed in DR Congo and South Africa (pollution haloes hypothesis). Omri *et al*. (2014) investigate the FDI-CO_2 emissions causality links for a global panel of 54 countries and for regional sub-panels, over the period 1990–2011. They provide evidence of bidirectional causality between FDI inflows and CO_2 for all sub-panels examined, except for the sub-panel of more developed countries (Europe and North Asia). Hoffmann *et al*. (2005) investigating the FDI-CO_2 emissions causality for various panels of 112 countries they conclude that the pollution haven hypothesis is corroborated only with respect to low-income countries and is rejected in the middle and high-income countries.

Finally, empirical studies that allow for sectoral FDI inflows come up with more even conclusions. Xing and Kolstand (2002) examining FDI originating from US over the 1980s they find that the laxity of environmental regulations in host countries is a significant determinant of FDI for heavily polluting industries but it is insignificant for less polluting industries. Blanco *et al.* (2012) study the relationship between FDI and sectoral CO_2 emissions for a sample of 18 Latin American countries over the period 1980-2007 and they find 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. Also, Chandran and Tang, (2013) investigate the transport sector for the ASEAN-5 economies (1970-2008) and they find non significant relationship between FDI and CO_2 emissions. They observe that the long-run influence of FDI on CO_2 emissions varies by country since different sectoral composition of FDI inflows exist in each of these countries. For the case of EU, Lee and Brahmasrene (2013) find that tourism and FDI have high significant positive impact on economic growth, while they both incur a significant negative impact on CO_2 emissions.

The ambiguity of the empirical results among studies on the FDI-environment relationship might arise from differences in scope, approach, institutional setting, data comparability, and level of development and the specific character of FDI in various countries. Studies using FDI data at firm level come up with more detailed results but they are not easily comparable. The issue is further complicated since the scale, regional distribution and sectoral composition of FDI have changed rapidly over time. As discussed in Hassaballa (2014), with reference to UNCTAD data, in the 1950s FDI was directed towards the primary sector and natural resources; since the 1980s, the emphasis was put on the industrial sector and after the 1980s, FDI turned towards services and technology based manufacturing. In developing countries, between the 1980s and the 2000s, the share of the primary sector remained at around 15 percent, while the share of manufacturing decreased from around 53 to 35 percent and that of services increased from around 33 to 50 percent.

Furthermore, FDI data for various countries is available at aggregate level, thus disallowing researchers to test directly the impact of FDI and the relating explanatory factors on environmental degradation. Many researchers carry out comparative studies, looking at groups of countries with similar geographical or development characteristics (eg ASEAN, European countries) and try to infer the relationship between FDI and the quality of the environment. The empirical findings, mostly mixed, come up with *post hoc* explanations of the FDI impact on the environment, attributing it to factors such as the use of ‘dirty’-‘clean’ technologies in manufacturing and the role of environmental standards and regulation.

Instead, we investigate empirically the FDI-CO_2 nexus, starting from a working hypothesis that the sectoral composition of FDI matters. We chose to analyse two economies, Brazil and Singapore, knowing in advance their specific common characteristics and differences. In particular, a large amount of FDI is directed not only to each of these economies but also to their geographical region and we expect it to affect the environment significantly. On the other hand, Brazil is a developing economy while Singapore has achieved a high level of GDP. In addition, the composition of FDI inflows in the two countries is very different since in Brazil it is directed mostly to industry (also 'dirty' industries) while in Singapore it is to a great extend directed to the tertiary sector. Hence, we bring out the polluting / non-polluting divide of the FDI effect on environment, expecting to detect an FDI impact on environmental degradation in Brazil but not in Singapore.

Finally, in order to further support our findings, we incorporate in the analysis a link between environmental pollution and the level of development, i.e. an Environmental Kuznets Curve, since substantial environmental effects are primarily related to GDP rather than to FDI. We think that, in future, if we have at our disposal disaggregated FDI data we can assess the possible impact of FDI inflows on the environment even without embarking into econometric work.

The rest of the paper is organised as follows: Section 2 presents the main features of the economies of Brazil and Singapore in relation to the focus of our study. Section 3 presents the empirical methodology and data, whereas the empirical findings are presented and discussed in Section 4. Finally, Section 5 summarizes the results and concludes the issue.

2. Snapshot features of the Brazil and Singapore economies

Brazil is one of the biggest countries in the world with Latin American social and political characteristics, belonging to BRICS along with Russia, India, China and South Africa. Its rapid economic growth, especially during the 2000s, has attracted the attention of economists and investors. This remarkable achievement in Brazil's growth rate can be attributed to its extended industrial base and to the fact that the country has become one of the top mining and agricultural world powerhouses (Tollefson, 2010). However, Salvo *et al.* (2015) show that Brazil has not only become a big exporter of energy intensive primary goods, but also, the pollution and emissions of its exports have risen.

A relatively large amount of FDI inflows is been directed to Latin America, while Brazil has received the highest level of FDI inflow compared to other countries in the region. Over the last decades, FDI inflow has played an important role in country's economic performance. According to United Nation Conference on Trade and Development (UNCTAD), Brazil encourages foreign direct investment reaching the fifth-most attractive country for foreign capital inflow for the period 2012-2014 (Veiga, 2004; Jadhav, 2012). The high level of foreign capital inflows in Brazil is related to economic stability, trade liberalization and natural and agricultural resources such as energy, metallurgy and steel, mineral extraction, food industry and others (Castro *et al*., 2013). Nevertheless, while Brazil is generally considered a friendly environment for investment, there is a complex tax-system and regulatory requirements. Furthermore, the macroeconomic difficulties of Brazil during the 1980s caused a drastic reduction in infrastructure investment leading to a radical transformation of technology, regulation and organizational models of management all over the country (Veiga, 2004).

Also, according to CDIAC (Carbon Dioxide Information Analysis Centre) Brazil is among the four countries in Latin America, along with Argentina, Mexico and

Venezuela. Also, Mexico and Brazil alone account for 52.7 percent of the 2008 regional emissions and belong in the list of top 20 highest fossil-fuel CO_2 emitting countries (Marland *et al.*, 2008).

Singapore is a small Asian country -one of the smallest in the world- with an extended service sector, having also achieved a remarkable economic growth. Singapore belongs to the countries with the highest per capita income, while its average GDP growth reached 5 percent in recent period. Also, the growth of energy demand in Asia is expected to be higher than the global growth rate leading to several challenges among policymakers in managing the issue of climate change. The investigation of the Kuznets hypothesis is a dominant topic for researchers and policymakers for Asian countries. In addition, the effect of FDI on environment has received considerable attention among economists. Singapore has attracted nearly 44 percent of the total FDI inflows among the ASEAN-10 economies (Chandram and Tang, 2013).

It is interesting to note the sectoral composition of FDI in Singapore compared to the other countries in the region. According to Chandran and Tang (2013), about 60 percent of Singapore's FDI is attracted by the service sector, while in Malaysia 50 percent of FDI inflow concentrates on the manufacturing sector. With the exception of Singapore, the annual growth in road transport energy consumption increased at high rates over the period 1971-2008 in ASEAN-5 (Malaysia, 6.7 percent; Thailand, 6.6 percent; Indonesia, 6.3 percent). Also Merican *et al.*, (2007) do not detect an apparent impact of aggregate FDI on environmental pollution in Singapore (1970-2001) ascribing it to the dominance of FDI in the tertiary sector.

Table 1 presents the average statistics of variables of interest for Brazil and Singapore for the time period -and sub-periods- under investigation.

Over the whole 1975-2010 period, the per capita real GDP in Brazil is almost *five* times lower than that in Singapore, about as much as the difference in per capita energy use; while the respective FDI inflow as percent of GDP is about *eight* times lower to that of Singapore, about as much as the difference in CO_2 emissions per capita. According to the average per capita figures (1975-2010), the economy of Brazil compared to Singapore is less developed and uses less energy, attracts less FDI finance and has a cleaner environment.

Table 1: Means of variables of interest

Country	(period)	Real GDP per capita (US dollars)	CO_2 Emissions per capita (metric tons oil equivalent)	Energy use per capita (kt of oil equivalent)	FDI inflow (percent of GDP)
Brazil	(1975-2010)	4,280	1.62	1,020	1.60
	(1975-1984)	3,807	1.41	888	1.10
	(1985-1994)	4,102	1.44	962	0.45
	(1995-2010)	4,686	1.86	1,138	2.62
Singapore	(1975-2010)	19,111	11.79	4,056	12.00
	(1975-1984)	9,178	12.58	1,986	7.09
	(1985-1994)	16,011	14.55	3,816	9.98
	(1995-2010)	27,061	9.59	5,472	10.37

Source: World Bank Indicators and UNCTADstat databases.

Looking at the developments over time, GDP, CO_2 emissions and energy use in Brazil register low and more or less smooth increases, while the ratio FDI/GDP is higher at the beginning (1975-1984) and especially in the end of the period under review (1995-2010). The picture in Singapore is very different. The variables that are expected to affect environmental degradation (energy use, ratio FDI/GDP and especially GDP) are on a strong ascending path, while CO_2 emissions follow an inverse U-shape path.

3. Model specification and data

The emphasis of our empirical investigation is on the impact of foreign direct investment (FDI) on the environment, as reflected in CO_2 emissions. Our analysis is carried out in a multivariate setting incorporating in one equation variables responsible for CO_2 emissions, such as the Environmental Kuznets Curve (EKC) hypothesis and energy use. Thus, we examine empirically the dynamic relationship between environmental degradation (CO_2 emissions) and FDI, energy use and EKC hypothesis (GDP and GDP^2), since the relevant results in the literature appear controversial and ambiguous.

The Environmental Kuznets Curve (EKC) hypothesis is a theoretical tool depicting the relationship between environmental and economic variables. Following the pioneering work of Grossman and Krueger (1991) who found evidence of an inverted U-shaped relationship between real income and environmental degradation, the empirical evidence provided since then appears to be mixed (Ren *et al.*, 2014; Stern, 2004; Dinda, 2004), although the majority of research points to the validity of the EKC hypothesis.

In particular, there are studies that provide empirical support of the validity of the EKC hypothesis, such as Tamazian *et al.* (2009) and Pao and Tsai (2011) investigating the panel of BRIC countries (Brazil, Russia, India and China) over the 1990s and the period 1980–2007 respectively verify the existence of the EKC hypothesis, while the Kuznets hypothesis is also verified for the case of Brazil (Pao and Tsai, 2011a). Also Selden and Song (1994) for 30 economies (1952-1985), Panayotou (1993) for 66 developing and developed economies (1980-1990), Ansuategi (2003) for 21 European economies (1987-1992), Tang and Tan (2015) for Vietnam (1976-2009), Monseratte *et al.* (2016) for Brazil (1971-2011).

However, there are studies that fail to obtain an inverted U-shaped relationship between real income and environmental degradation, such as Holtz-Eakin and Selden (1995) for 130 countries (1951-1986), Unruh and Moomaw (1998) for 16 countries (1950-1992), Friedl and Getzner (2003) for Austria (1960-1999), Shao *et al*. (2011) for China (1994-2009), Vincent (1997) and Saboori and Suleiman (2013) for Malaysia (1970s-1990s) and (1980-2009) respectively.

On the other hand, Kivyiro and Arminer (2014) analyzing in a multivariate setting the EKC hypothesis in six Sub Saharan African countries (Republic of Congo, Democratic Republic of Congo, Kenya, South Africa, Zambia and Zimbabwe) verify it for three of them (DRC, Kenya and Zimbabwe). Also, Omri *et al.* (2014) analyzing sub-panels of 54 countries find that CO_2 emissions are positively linked to economic growth only for the Middle Eastern, North African, and sub-Saharan panels. The finding that countries in the early stages of economic development are more polluting seems to validate the EKC hypothesis, which is also confirmed by the results of Narayan and Narayan (2010) who obtain mixed results for 43 developing economies (1980-2004).

Also, FDI may or may not lead to an increase in CO_2 emissions through its impact on energy use. The empirical results of the impact of FDI on energy use are mixed (Elliott *et al*., 2013; Amimu, 2005; Mielnik and Goldemberg, 2002). Recent studies on the examination of the causal links between CO_2 emissions and energy use in a multivariate setting for a panel of BRIC countries (Pao and Tsai, 2011) point to a strong unidirectional causality running from energy consumption to CO_2 emissions and to bidirectional causality in the two variables for the case of Brazil 1980-2007 (Pao and Tsai, 2011a). Finally, Kivyiro and Arminer (2014) examine the case in six Sub Saharan African countries and they observe that the larger the role of energy intensive sectors is these economies; the more likely energy consumption is to Granger cause CO_2 emissions. For the US, Soytas *et al*. (2007) find that income does not Granger cause carbon emissions in the long run, but energy use does.

Data for our empirical investigation is obtained from the published dataset statistics of the World Development Indicators of the World Bank and UNCTADstat databases. The level of *CO_2 emissions* is a measure of environmental degradation and it is the most important greenhouse gas.[4] It is measured in thousand metric tons per capita. Real *GDP* per capita is measured in constant (2005) US dollars. Foreign direct investment inflow is the sum of equity capital, reinvestment of earnings, other long-term capital and short-term capital as shown in the balance of payments. The *FDI* variable is expressed as percent of GDP. *Energy use* is the consumption of primary energy forms before transformation to other end use fuels and it is measured in thousands metric tons of oil equivalent per capita.

4. Empirical model and methodology

Following the discussion of the previous Section 3.1, the relationship between per capita CO_2 emissions and its determinants (the EKC hypothesis, energy use as well as FDI) is depicted in the following model specification:

$$CO_{2t} = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 E_t + \beta_4 F_t + \varepsilon_t \qquad (1)$$

All variables are expressed in natural logarithms. CO_2 is the per capita carbon dioxide emissions (lnco$_2$); Y is real GDP per capita (lngdp); Y^2 is the square of real GDP per capita (lngdp^2); E is energy use per capita (lnen); F is foreign direct investment inflow as a percent of GDP (lnfdi); ε is the residual term assumed to be normally distributed and white noise. The expected sing of the equation parameters are $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$ and $\beta_4 > 0$ or $\beta_4 < 0$, respectively.

The main econometric approach that we implemented to Equation (1) was the ARDL (Autoregressive Distributed Lag) methodology (Pesaran and Smith, 1995) which has many econometric advantages. Firstly, it does not require establishing the order of integration of the variables. Second, this technique is applicable regardless of whether the independent variables are I(0) or I(1). These characteristics inform us whether the ARDL methodology is free of pretesting issues. Third, long-run and short-run effects of regressors on dependent variable are estimated simultaneously, allowing for the interpretation of the different aspects of the research goal. Fourth, bounds testing approach has better properties for small samples. Finally, all variables are assumed to be endogenous thus avoiding endogeneity problems in the estimations.

Equation (1) shows the long-run association among the underlying variables. The implementation of the ARDL approach requires that short-run dynamics have to be included into the long-run specification. This is shown in the following Equation (2).

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[4] A coherent justification for using CO_2 emissions as a proxy for pollution is presented, among others, in Hoffmann *et al*. (2005) and Hassaballa (2013).

$$\Delta CO_{2t} = \beta_0 + \sum_{\kappa=1}^{n} \beta_1 \Delta CO_{2,t-k} + \sum_{\kappa=1}^{n} \beta_2 \Delta Y_{t-k} + \sum_{\kappa=1}^{n} \beta_3 \Delta Y_{t-k}^2 + \sum_{\kappa=1}^{n} \beta_4 \Delta E_{t-k} + \sum_{\kappa=1}^{n} \beta_5 \Delta F_{t-k} + \lambda_1 CO_{2,t-1} + \lambda_2 Y_{t-1} + \lambda_3 Y_{t-1}^2 + \lambda_4 E_{t-1} + \lambda_5 F_{t-1} + \varepsilon_t \quad (2)$$

The null hypothesis of Equation (2) is based on the F-statistic for jointly significance of the parameters λ_is ($H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$ against $H_1: \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq 0$). The test for the existence of a long-run relationship is based on two sets of critical values for a given level of significance, the lower bounds (LCB) and upper bounds critical values (UCB) respectively. Also, Δ (or *d* in the definition of variables) denotes the change vector, CO_2, Y, Y^2, E and F are endogenous variables; $\beta_i s$ are the estimated parameters of the equation while ε is the residual term.

In addition, in case that all variables of interest are integrated of order one I(1), Phillips-Hansen FMOLS (Fully Modified Ordinarily Least Squares) and simple OLS methodologies can be also used. Then, Equation (1) indicates the long-run covariates estimations. The FMOLS technique is preferable when explanatory variables are endogenous since it takes endogeneity issues into consideration, thus leading to more robust estimations.

5. Empirical findings

The requirement to carry out time series analysis is that variables have to be stationary with a zero mean and finite variance, since non-stationary variables may lead to spurious results (Granger and Newbold, 1974).

Table 2: Unit root test results

Variables	Tests			
	ADF	KPSS	PP	DF - GLS
Brazil				
$lnco_2$	-1.703(0)	0.129(4) **	-1.842(1)	-1.718(0)
$dlnco_2$	-4.351(0)***	0.062(0)	-4.351(0)***	-4.469(0)***
lngdp	+0.709(5)	0.143(3)**	-1.574(0)	-1.752(0)
dlngdp	-5.886(4)***	0.095(3)	-5.618(8)***	-3.097(1)**
$lngdp^2$	-1.149(0)	0.146(3)**	-1.489(0)	-1.698(0)
$dlngdp^2$	-5.098(0)***	0.097(3)	-5.561(8)***	-4.739(0)**
lnen	-0.585(5)	0.154(4)**	-1.403(1)	-1.501(5)
dlnen	-3.382(5)*	0.061(2)	-4.583(4)***	-3.531(4)**
lnfdi	-2.210(0)	0.128(4)*	-2.149(3)	-2.289(0)
dlnfdi	-6.336(0)***	0.054(0)	-6.349(1)***	-6.528(0)***
Singapore				
$lnco_2$	1.432(2)	0.188(5)**	-0.300(1)	-0.927(4)
$dlnco_2$	-8.594(1)***	0.126(7)	-7.957(3)***	-1.789(3)
lngdp	-2.045(0)	0.221(4)***	-2.025(2)	-1.539(0)
dlngdp	-6.147(1)***	0.099(8)	-5.274(7)***	-5.559(1)***
$lngdp^2$	-2.193(0)	0.209(4)**	-2.181(2)	-1.852(0)
$dlngdp^2$	-6.140(1)***	0.096(8)	-5.267(7)***	-5.660(1)***
lnen	-2.239(0)	0.144(4)*	-2.328(2)	-2.194(0)
dlnen	-6.190(0)***	0.053(3)	-6.195(2)***	-6.068(0)***
lnfdi	-5.451(1)***	0.148(12)***	-6.996(13)***	-5.588(0)***
dlnfdi	-6.129(4)***	0.500(38)***	-27.319(37)***	-6.243(1)***

Notes: All regressions include an intercept and a linear trend in the levels and in the first differences; the signs (***), (**) and (*) represent the 1%, 5% and 10% significance level respectively; numbers in *parenthesis* show the optimal lag order for ADF, PP and DF-GLS and bandwidth for KPSS test.

Given the size of our samples we performed several unit root tests. In particular, were implemented the ADF (Augmented Dickey Fuller) unit root test, the KPSS (Kwiatkowski, Phillips, Schmidt, Shin) null stationary test, the PP (Phillips and Perron test) and the DFGLS (Dickey-Fuller Generalized Least Square) unit root tests to examine the order of integration of each series on its natural logarithm in levels and first differences.

As shown in Table 2, the null hypothesis for the existence of a unit root cannot be rejected for all variables in both countries except for the FDI variable (lnfdi) in the case of Singapore. Similarly, the KPSS test also shows that the variables $lnco_2$, lngdp, $lngdp^2$, lnen and lnfdi are integrated of order one I(1) in Brazil, while the variable lnfdi is found to be I(0) -stationary in level- in Singapore.

Subsequently, having found that none of the variables are integrated of order more than one we employ the bound test analysis of the ARDL methodology for both countries. This approach has the advantage of being applicable even if the variables are a combination of I(1) and I(0) integrated variables. For Brazil we also performed the OLS and FMOLS methodologies since all variables are integrated of order one.

5.1 Brazil

The ARDL[5] long-run estimations for the Brazilian economy together with the diagnostic tests are presented in Table 3a. To examine the robustness of our estimations we also present the results of the OLS and Phillips-Hansen FMOLS estimations that have been carried out.

The diagnostic tests of the ARDL model confirm the absence of serial correlation and heteroskedasticity and pass the test of normality and functional form at 5 percent level of significance. The OLS and FMOLS models also pass the statistical tests.[6]

The empirical results show a positive and statistically significant relationship between the foreign direct investment and CO_2 emissions variables. Our finding indicates that a higher share of FDI to GDP leads to a worsening of environmental quality confirming the pollution havens hypothesis in the case of Brazil. This finding is also verified by the results of the other empirical models of Table 3a (OLS, FMOLS) and it should be related to the composition of FDI in favour of polluting sectors. Indeed, Blanco *et al*. (2012) showed that in Latin America only the FDI inflows to “dirty industries” lead to environmental degradation.

Our results do not allow verifying the EKC hypothesis, i.e. the non-linear relationship between economic growth and environmental degradation over the period 1975-2010. The coefficients of GDP and GDP^2 are not statistical significant (in all three models), although they have the expected positive and negative signs respectively. According to our ARDL model the estimated turning point of the Brazilian GDP variable (lngdp) is 3.37, while its highest value of 3.71 is achieved towards the end of the period under study. For the OLS and FMOLS models the turning points (around 3.64) are very close to the highest value achieved (3.71). It seems, therefore, that the Brazilian economy may be on the verge of achieving an inverted-U relationship between economic development and environmental pollution. Note that the study of Pao and Tsai (2011a) verifies the EKC hypothesis for Brazil (1980-2007). Likewise, the EKC hypothesis is verified for the panel of BRIC

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[5] ARDL (2,2,0,0,2,0) is selected on the base of the Schwarz Bayesian criterion.

[6] In the OLS, the serial correlation and normality tests are not passed at 5 percent level of confidence.

countries by Tamazian *et al*. (2009) and Pao and Tsai (2011). Judging from our findings and the results of these studies we may conclude that the validity of the EKC hypothesis for Brazil is marginal.

Finally, the long-run elasticity estimate of CO_2 emissions with respect to energy use is positive and significant at the 5 percent level of confidence. This finding indicates that higher energy consumption will result in more CO_2 emissions and a more polluted environment in Brazil, in line with Pao and Tsai (2011a) who detect bidirectional causality between energy consumption and CO_2 emissions over the period 1980-2007. However, the expansion of renewable energy would enhance Brazil's economic growth and curb the deterioration of the environment (Pao and Fu, 2013).

Table 3a: Long-run estimates for Brazil, 1975-2010

Methodology / Independent variables	ARDL (2,2,0,0,2,0)	OLS	FMOLS
c	-21.733	-19.633	-21.789
	(-0.668)	(-1.239)	(-1.044)
lngdp	10.519	12.424	13.472
	(0.596)	(1.396)	(1.177)
$lngdp^2$	-1.561	-1.710	-1.851
	(-0.650)	(-1.392)	(-1.181)
lnfdi	0.053***	0.024***	0.025***
	(3.556)	(4.553)	(4.542)
lnen	1.414*	0.910**	0.844*
	(1.801)	(2.180)	(1.810)
diagnostic tests			
Serial correlation	0.219	12.266	
	[0.640]	[0.010]	
Functional form	1.888	0.510	
	[0.169]	[0.614]	
Normality	1.352	8.365	4.343
	[0.509]	[0.026]	[0.114]
Heteroskedasticity	0.965	1.402	
	[0.326]	[0.252]	
R^2-adj.	0.98	0.91	0.92
DW statistic	2.08	0.79	0.88
F-statistic	123.70***	64.54***	
AI criterion	104.22	-4.83	
SB criterion	95.06	-4.56	
HQ criterion		-4.47	

Notes: The signs (***), (**) and (*) represent the 1%, 5% and 10% significance level respectively; numbers in *parenthesis* are the t-ratios; numbers in *brackets* are the p-values; AI is the Akaike Information criterion; SB is the Schwarz Bayesian criterion; HQ is the Hannan Quinn criterion.

The short-run estimation results depicting the error-correction representation along with several diagnostic tests are shown in Table 3b.

Table 3b: Error correction representation for the model of Brazil

Independent variables \ Methodology	ARDL(2,2,0,0,2,0)	OLS	FMOLS
dc	-5.292 (-0.661)	-	-
$dlnco_2(-1)$	0.609*** (3.320)	0.615*** (3.192)	0.614*** (3.129)
dlngdp	4.818 0.687)	6.976 (0.656)	9.491 (0.879)
dlngdp(-1)	0.431* (1.992)	0.293 (1.496)	0.314 (1.582)
$dlngdp^2$	-0.624 (-0.644)	-0.922 (-0.652)	-1.271 (-0.849)
dlnfdi	0.002** (2.061)	0.001 (0.933)	0.004 (0.942)
dlnen	0.941*** (3.151)	1.093*** (4.129)	1.120*** (4.260)
dlnen(-1)	-1.259*** (-3.383)	-1.105*** (-3.127)	-1.146*** (-3.150)
ecm(-1)	-0.399*** (-2.944)	-0.285** (-2.000)	-0.281** (-1.995)
diagnostic tests			
R^2-adj.	0.838	0.802	0.802
S.E.	0.010	0.010	0.010
DW statistic	2.075	1.80	1.79
AI criterion	104.218	-6.11	-6.11
Eq. Log-Likelihood	116.218	112.87	112.82
SB criterion	95.060	-5.71	-5.70
F-Stat. (9,24)	12.613***	12.686***	12.638***
Functional form		0.296 [0.769]	0.374 [0.712]
Serial Correlation		0.274 [0.763]	0.268 [0.767]
Heteroskedasticity		0.323 [0.949]	0.306 [0.957]

Notes: The signs (***), (**) and (*) represent the 1%, 5% and 10% significance level respectively; numbers in *parenthesis* are the t-ratios; numbers in *brackets* are the p-values; AI is the Akaike Information criterion; SB is the Schwarz Bayesian criterion.

The error correction representation for the ARDL model for Brazil has high explanatory power. The coefficient of lag of real GDP variable is statistically significant indicating that there is a positive short-run effect of per capita economic growth on environmental degradation, while the coefficient of GDP^2 is not significant. Thus, an inverse-U relationship between economic performance and environmental degradation is not verified in the short-run. Furthermore, the results indicate that energy use has a significant short-run effect on CO_2 emissions. Also, there is an indication of a significant positive short-run relationship between FDI inflow and environmental pollution for the ARDL model but not for the OLS and the FMOLS models. However, the actual importance of this relationship in the short-run is limited since it usually takes time for these effects to manifest themselves.

Finally, the error-correction term has the expected negative and highly significant sign, indicating that real GDP, GDP^2, FDI ratio and energy use are cointegrated. In the ARDL model, the absolute value of the coefficient of the error-correction term indicates that about 40 percent (less for OLS and FMOLS) of disequilibrium in the CO_2 emissions variable is offset by short-run adjustment in each time of period.

5.2 Singapore

The ARDL methodology is also used for the model for Singapore. For estimating both the long and short-run effect of the regressors on environmental degradation, the bounds testing approach to cointegration was employed (Pesaran *et al*. 2001). The long-run estimation of the model for Singapore is shown in Tables 4a.

Table 4a: Long-run coefficients of the ARDL model for Singapore

Independent variables	ARDL(1,2,0,2,0)
c	-50.459
	(-0.409)
lngdp	23.559***
	(4.268)
$lngdp^2$	-2.986***
	(-3.878)
lnfdi	-0.165
	(-1.242)
lnen	1.621***
	(3.947)
diagnostic tests	
Serial correlation	0.331
	[0.565]
Functional form	0.404
	[0.764]
Normality	0.304
	[0.585]
Heteroskedasticity	0.110
	[0.740]

Notes: The signs (***), (**) and (*) represent the 1%, 5% and 10% level of significance respectively; numbers in *parenthesis* are the t-ratios; numbers in *brackets* are the p-values.

Our model passes all diagnostic tests. The results indicate that foreign direct investment inflows do not affect environmental quality, since the impact of FDI ratio on CO_2 emissions is statistically insignificant. Thus, neither the pollution haloes nor the pollution havens hypothesis is confirmed for Singapore. This finding can be attributed to the fact that a great amount -nearly 60 percent- of Singapore's FDI inflows is directed to the service sector. Our result is in agreement with that of other studies (Merican *et al*., 2007; Blanco *et al*. 2012; Chandram and Tang, 2013) which relate the sectoral composition of FDI with its environmental impact. It seems to be the case that the composition of the FDI inflow with respect to its impact on environmental degradation matters. However, the amount of FDI inflow does not affect the environment as far as it is directed to no polluting sectors (e.g. services) or technologies. By the same token, the study by Lee (2013) for the G20 countries comes up with a neutral effect of FDI on the environment.

The long-run results confirm the EKC hypothesis for Singapore at 1 percent level of significance. The statistically significant positive coefficients of lngdp together with the negative coefficient of $lngdp^2$ with respect to CO_2 emissions provide evidence of a non-lineal relationship between economic growth and environmental emissions. The turning point of the GDP variable (lngdp) is 3.94 compared to its highest value of 4.55 indicating that the results obtained in the estimations show that the hypothesis postulated for the Environmental Kuznets Curve is supported for

Singapore. Our result is in accordance to that of other studies, such as Tang and Tan (2015), Pao and Tsai (2011), Tamazian *et al.* (2009) to mention some recent ones.

Finally, the elasticity of CO_2 emissions per capita with respect to the energy use is positive and significant at 1 percent level of confidence. This finding is in line with that of the majority of empirical studies and indicates that higher energy use results in environmental degradation in Singapore.

The error correction model for Singapore is shown in Table 4b. The relevant tests verify normality and confirm the absence of heteroskedasticity, serial correlation and functional misspecification.

Table 4b: Error correction representation for the ARDL model for Singapore

Independent variables	ARDL(2,2,0,2,0)
dc	-29.355***
	(-3.556)
dlngdp	13.705***
	(3.372)
$dlngdp^2$	-1.737***
	(-3.209)
dlnfdi	-0.096
	(-1.435)
dlnen	0.406*
	(1.747)
dlnen(-1)	-0.645**
	(-2.618)
ecm(-1)	-0.582***
	(-3.492)
Diagnostics tests	
R^2-adj.	0.528
S.E.	0.066
DW-statistic	1.959
AI criterion	45.606
SB criterion	38.237
Eq. Log-Likelihood	54.606
F-stat (7,30)	4.521***

Notes: The signs (***), (**) and (*) represent the 1%, 5% and 10% significance level respectively; numbers in *parenthesis* are the t-ratios; AI is the Akaike Information criterion; SB is the Schwarz Bayesian criterion.

The positive coefficient of GDP together with the negative coefficient of GDP^2 supports the validity of the EKC hypothesis in the short-run, although the importance of this relationship is more meaningful for the longer term. Also, the link of energy use to CO_2 emissions is statistically significant at 5 percent level of confidence. However, as in the case of the long-run model, FDI inflows seem not to affect the environment in the short-run. Finally, the error correction term is statistically significant (at 1 percent level of confidence) and has a high value of around 60 percent indicating a fast speed of adjustment in the long-run equilibrium.

6. Concluding remarks

In this study we investigate empirically the role of foreign direct investment inflows on environmental quality, as measured by CO_2 emissions. The cases of Brazil and Singapore are taken as examples in our empirical investigation on the grounds of their similarities and differences. The two economies have a common characteristic in that they have received large amounts of FDI since the 1970s. On the other hand, Brazil is still a developing economy, while Singapore has achieved a high level of development. In addition, the composition of FDI and of GDP is very different in the two economies, since in Brazil it has to do mostly with industrial sectors and in Singapore mostly with services and clean technologies. The empirical analysis is carried out in a multivariate setting, using an autoregressive distributed lag (ARDL) model as well as other estimation techniques (OLS, FMOLS), covering the period from the early 1970s to 2010.

Our findings indicate that FDI inflows have an adverse effect on CO_2 emissions in Brazil but not in Singapore, which can be explained by the different FDI composition in the two economies. On the other hand, the Environmental Kuznets hypothesis, i.e. the inverted-U relationship between GDP and CO_2 emissions is confirmed in the case of Singapore but its validity is marginal in Brazil, which can be attributed to the different GDP composition in the two economies. These supplementary results indicate that the composition of FDI and of GDP is a significant determinant of environmental quality. Finally, as expected, energy use seems to burden the quality of the environment in both countries.

Our empirical results are useful in that they bring out the role of the composition of FDI as an important determinant of its impact on environmental quality. We thus offer a rationale to the results of many studies in the relevant literature. In particular, empirical studies covering the case of low-income countries show that FDI (mostly directed to 'dirty' sectors) causes environmental degradation, while in the case of wealthier economies FDI (mostly directed to 'clean' sectors) is not related to environmental pollution. The same applies to the results of studies investigating the relationship between the level of development and environmental quality.

The research of the FDI-environment relationship is much constrained because of the difficulty in obtaining the necessary data. The non-availability of disaggregated FDI data does not allow researchers to investigate in a direct way the impact of FDI on environmental degradation. More emphasis should be put to the construction of more detailed FDI data.

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