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Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries

Artur Tamazian *, Juan Piñeiro Chousa, Krishna Chaitanya Vadlamannati

Department of Financial Economics and Accounting, University of Santiago de Compostela, Santiago de Compostela, Spain

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ABSTRACT

A vast number of studies addressed the environmental degradation and economic development but not financial development. Moreover, as argued by Stern [2004. The rise and fall of the environmental Kuznets curve. World Development 32, 1419–1439] they present important econometric weaknesses. Using standard reduced-form modeling approach and controlling for country-specific unobserved heterogeneity, we investigate the linkage between not only economic development and environmental quality but also the financial development. Panel data over period 1992–2004 is used. We find that both economic and financial development are determinants of the environmental quality in BRIC economies. We show that higher degree of economic and financial development decreases the environmental degradation. Our analysis suggests that financial liberalization and openness are essential factors for the CO_2 reduction. The adoption of policies directed to financial openness and liberalization to attract higher levels of R&D-related foreign direct investment might reduce the environmental degradation in countries under consideration. In addition, the robustness check trough the inclusion of US and Japan does not alter our main findings.

1. Introduction

Key policy objective of international efforts to mitigate the adverse effects of global climate change is the reduction of global CO_2 emissions. The success of these efforts depends to a large degree on the commitment of the major CO_2 production nations in meeting global emissions targets. In 1990, the major producers of energy-related[1] CO_2 emissions were US 23.00%, Japan 5.72% the OECD group 24.00%, China 11.00%, India 3.00%, Brazil 0.94% and Russian Federation 3.80%. By 2007, US and Japanese emissions came down to 22.00% and 5.00% respectively, while it increased for BRIC economies, China 16.00%, India 5.00%, Brazil 1.15% and Russia 6.00% (World Bank, 2007). However, during the last years these economies have experienced profound structural changes that continue to influence the evolution of regional CO_2 output, with potentially adverse consequences for global mitigation strategies. While there is evidence of declining energy consumption accompanying the development process, for many of these countries it remains unclear what path economic output will follow or whether it is likely to translate into rising CO_2 emissions over the longer term.

In addition, during the last decade the environmental Kuznets curve (EKC) hypothesis has gained increasing popularity in academic and policy circles. Taking the EKC at face value is quite attractive because of its long-run implications that economic growth is good for the environment. Policy makers everywhere are watching with much interest the pros and cons of the EKC hypothesis since the debate have considerable importance for national and international policies. The crucial policy question for them as Barbier (1997) argue is "whether economic growth should continue to be the main priority, with protection of the environment a secondary consideration to be addressed mainly in the future, or whether explicit policies to control environmental degradation at the local, national and global level are urgently required today".

World Bank has long maintained that economic growth is good for both people and the environment. This type of "win-win" situation is based on the view that an immediate benefit of economic growth is a rise in per capita income, which can contribute to alleviate poverty and to clean up the environment. Others such as Beckerman (1992) advocated without reservation economic growth as the most effective solution for curing environmental ills.

On contrary Georgescu-Roegen (1971) and Daly (1977) argue that more economic growth entails more production and

* Corresponding author. Tel.: +34 981 59 44 88x11672; fax: +34 981 56 36 37.
E-mail addresses: artur.tamazian@usc.es (A. Tamazian), efjpch@usc.es (J.P. Chousa), kc_dcm@yahoo.co.in (K.C. Vadlamannati).

[1] Energy-related emissions are those generated through the combustion of fossil fuels. While this is the principal anthropogenic source, other important sources include net deforestation and cement manufacture.

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consumption activities to satisfy human wants, thus causing more waste, more pollution and more pressure on environmental resources. Rothman (1998) asserted that consumption is the principal driving force behind environmental impact and that there is much to be learned by taking a consumption- rather than production-based approach, as earlier studies have predominantly done. Because it is trade that allows for a divergence of production and consumption patterns within a region this leads to a discussion of how to consider the role of trade in the context of the EKC hypothesis. The author then proposes possibilities for more appropriate measures of environmental impacts and considers the results using one such measure. Kolstad and Krautkraemer (1993) point out the fact that there is a dynamic link between the environment, resource use and economic activity. They argue that while resource use (especially energy sources) yield immediate economic benefits, its negative impact on the environment may be observed in the long run.

Consequently, economic growth in excess of the carrying capacity of the environment is counterproductive and detrimental in the long run to human welfare. Not surprisingly, they have advocated that excessive growth should be dismissed in favour or a zero-growth or steady-state economy to prevent future ecological disaster. While the majority of the studies are focused on economic development and environmental degradation, we consider the financial development as another possible determinant of the environmental performance.

Nevertheless, why consider financial development when discussing the relationship between economic growth and environment? The most prominent reason is that financial liberalization and development may attract FDI and higher degrees of R&D investments which in turn can speed up economic growth (Frankel and Romer, 1999), and hence affects the dynamic of the environmental performance. The second reason is that financial development provides developing countries with the motive and opportunity to use new technology, help them with clean and environment-friendly production, and consequently improve global environment at large and enhance regional development sustainability (Birdsall and Wheeler, 1993; Frankel and Rose, 2002). The third reason, contrary to the second one, is that though financial development may enhance economic growth, it may result in more industrial pollution and environmental degradation (Jensen, 1996; World Bank, 2000).[2] Moreover, Stern (2004) presents a critical history of the EKC. According to him the arguments of EKC do not stand firm on strong econometric footing. He pointed out that the major weaknesses associated with the econometric estimations namely, heteroskedasticity, omitted variables bias and critical issues relating to co-integration analysis.

Given these reasons and concerns in the literature, our research tries to fulfill the econometric weakness raised by Stern (2004) while extends the discussion about the importance of financial development in environmental degradation. We limit our focus to BRIC countries, controlling for robustness of results including USA and Japan, as the debate on the pace and level of economic and financial development is mostly pertinent in the context of developing economies. Yet, Goldman Sachs (2003) argues that BRIC economies could become a much larger force in the world economy than G6 in less than 40 years. By 2025 they could account for over half the size of the G6. We use CO_2 emissions as the environmental pollution measure for several reasons. CO_2 emissions, once thought to be a harmless by-product of combustion, are now believed to be the primary greenhouse gas responsible for the problem of global warming (IPCC, 2007). Regulating and monitoring anthropogenic emissions of CO_2 from various economic activities has become a central issue in the ongoing negotiation for an international treaty on global warming (Cline, 1992; Revkin, 2000). Moreover, the scope of its spatial impact makes CO_2 pollution more suitable for country-level aggregate study. Also, we believe that our regression model includes a much larger set of relevant explanatory variables for cross-country CO_2 variation than most other existing studies in the EKC literature. Additionally, the policy recommendations highlighted in this paper are based on the fact that firms in developing countries do not have incentives to invest in pollution-control mechanism because of the weak institutional structure. Therefore, higher economic and financial reforms in future are necessary to strengthen institutional structure which can provide adequate incentives for controlling pollution.

The rest of the paper is organized as follows. Section 2 discusses the importance of economic and financial development for environmental quality. Section 3 presents the empirical design and results. Section 4 concludes.

2. The role of economic and financial development for environmental performance

The main issue of particular interest of this paper is the impact of economic and financial development on the pollution performance relationship. The relationship between the economic development and CO_2 emissions, the most important greenhouse gas implicated in global warming, is widely studied in the literature. As argued by Meadows et al. (1992), far from being a threat to the environment in the long term, economic growth appears to be necessary to maintain or improve the environmental quality.

At the same time, there is a growing concern about the adverse environmental impacts of economic growth (Grove, 1992). This concern has led to a rich stream of research on the notion of environmentally sustainable economic development that explores the tradeoff between economic growth and environmental quality (Anderson, 1992). The dominant view is that the conventional tradeoff between economic growth and environmental quality is not inevitable. In fact, it is possible to mitigate greatly or to even reverse tradeoff through appropriate policy interventions (Antle and Heidebrink, 1995; Grossman and Krueger, 1995; Selden and Song, 1994; Shafik, 1994). This issue is particularly significant for developing countries who, under pressure to achieve accelerated economic growth face the danger of adopting economic policies that run contrary to the objective of their long-term environmental sustainability (Serageldin and Steer, 1994).

The empirical findings for the net impacts of economic development upon environmental quality seem to depend upon characteristics of different pollutants (Shafik and Bandyopadhyay, 1992; Hettige et al., 1992; Birdsall and Wheeler, 1993; Diwan and Shafik, 1992). For example, some air pollutants such as suspended particulate matter, sulfur dioxides, carbon monoxide and oxides of nitrogen, which have relatively significant health and environmental degradation effects, appear in an inverted U-shaped relationship with economic development. Selden and Song (1994) have looked at various air pollutants like SO_2, NO_x and CO and find similar results related to EKC. However, the inflection points were substantially different across studies. In this framework, Holtz-Eakin and Selden (1995) have found that CO_2 emissions did not show the same EKC pattern. Instead, Shafik and Bandyopadhyay (1992) show that the CO_2 emissions have been found to increase monotonically with per capita GDP.

[2] Moreover, since environmental control increases manufacturing cost, pollutant industries and enterprises may be transferred to underdeveloped areas where environmental standards are relatively low, and turn these areas into "pollution havens".

While in this article we strictly explore the existence of EKC, it is worth noting, however, that Goldemberg (1998) argues that environmentally disastrous events may be prevented by leapfrogging the steps followed in the past by industrialized countries incorporating modern and efficient technologies early in the development process.[3] Yet, the main finding of Panayotou (1997) is that the quality of policies and institutions in a country can significantly reduce environmental degradation at low-income levels and speed up improvements at higher-income levels. Policies such as more secure property rights under a rule of law and better enforcement of contracts and effective environmental regulations can help flatten the EKC and reduce the environmental cost of higher economic growth.

Financial development may play a deterministic role in the environmental performance. Greater financial sector development can facilitate more financing at lower costs, including for investment in environmental projects. The ability to raise such financing may be especially important for governments—at the local, state and national levels, since much of environmental protection will be a public sector activity. It, however, also applied to the investment of private firms in required environment-protecting activities. Furthermore, it has been found that better governed firms are more willing to consider environmental considerations. As such, through improved governance, financial sector development can spur greater environmental performance (Claessens and Feijen, 2007). The development of the trading in global pollution rights, for example, has in part been facilitated by greater financial sector development. For instance, Kumbaroglu et al. (2008) argue that emission reductions significantly affect economic and financial systems while induce to technological changes in the energy supply mix. The authors find that economic costs are due to major changes in the technological structure of the energy system. They highlight that the results indicate new technological investments, financial assistance and targeted policies are inevitable for a sustainable evolution of the energy sector. Also, as it was pointed out by Tadesse (2005) financial development induces technological innovations—a major stimulus of productivity—through facilitating capital mobilization and risk sharing. Dasgupta et al. (2001) argues that the environmental regulators in developing countries may explicitly harness financial market forces by introducing structured programs of information release on firms' environmental performance. This indicates that well-developed financial system may provide enough incentive for firms to lower their CO_2 emission.

In this framework, a vast number of studies evidence that capital markets rewards firm with superior environmental performance trough a higher valuation of firms' share. As it is pointed out in Lanoie et al. (1998) the regulators have recently embarked on a deliberate strategy to release information to markets and communities regarding firms' environmental performance in order to enhance incentives for pollution control. Moreover, they find that capital markets react to the release of information, and that large polluters are affected more significantly from such release than smaller polluters. The same results have been found in Dasgupta et al. (2001), who have shown that capital markets in Argentina, Chile, Mexico and the Philippines do react negatively by decreasing the firms' capitalization to citizens' complaints targeted at specific firms, and positively to the announcement of rewards and recognition of superior environmental performance. Recently, Dasgupta et al. (2004) examine the reaction of investors to the publication of the lists of companies that fail to comply with national environmental laws and regulations in Republic of Korea. They find that enterprises appearing on these lists have experienced a significant decline in their market valuation.

Given all these evidences, therefore, financial sector development is likely matter for environmental performance. However, there is still limited empirical evidence on the channels of financial development and environmental performance.

3. Empirical study

The main objective of this paper is to examine whether the economic and financial development along with energy consumption tend to increase the environmental damage or not. To test if the degree of economic and financial development has a systematic relationship with the level of CO_2 emissions in a country, we use panel data and adopt the standard approach used in the existing EKC literature. As argued in Persson et al. (2006), the economic cost of stabilizing the atmospheric concentration of CO_2 will be lower if developing countries adopt policy measures in the first stage of development. Taking their argument, we focused on BRIC countries since they are in their first stage of economic and financial development. The paper covers the period from 1992 to 2004. To our knowledge, the current analysis is the first of this nature performed within BRIC countries.

Similarly to Talukdar and Meisner (2001), we adopted the standard reduced-form modeling approach form. Yet, according to Hsiao (1986) and in order to address with possible country-specific unobserved heterogeneity we use random-effect specification for our empirical model as follows:

$$\begin{aligned} CO_{2it} = {} & \alpha + \beta_1(GDP_{it}) + \beta_2(IS_{it}) + \beta_3(R\&D_{it}) + \beta_4(SMVA_{it}) \\ & + \beta_7 \log(FDI_{it}) + \beta_8(DBA_{it}) + \beta_9(CAC_{it}) + \beta_{10}(FL_{it}) \\ & + \beta_{11}(FO_{it}) + \beta_{12}(EI_{it}) + \beta_{13}(OC_{it}) + \beta_{14}(EC_{it}) + v_i + \varepsilon_{it} \end{aligned} \tag{1}$$

where CO_2 indicates CO_2 emission per capita in country i at time t; ΔGDP_{it} the GDP per capita growth rate in country i at time t; IS_{it} the industry share as percentage of GDP in country i at time t; $R\&D_{it}$ the gross domestic expenditure in research and development as percentage of GDP in country i at time t. Theses set of variables are conforming the economic development. Moreover, $SMVA_{it}$ indicates stock market value added computed as total shares traded on the stock market exchange to GDP in country i at time t; FDI_{it} the degree of foreign direct investment in country i at time t; DBA_{it} the ratio of deposit money bank assets to GDP in country i at time t; CAC_{it} the capital account convertibility in country i at time t; FL_{it} the financial liberalization dummy in country i at time t; Fo_{it} the financial openness in country i at time t. This subset of variables defines financial development, while EI_{it} defines the energy imports in country i at time t; OC_{it} the oil consumption in country i at time t; EC_{it} the energy consumption in country at time t are the control variables. v_i and ε_{it} indicate the country-specific random effect and random error term, respectively. The detailed explanation and sources of the variables is in Annex 1.

Analogically, we test whether U-shaped effect may be confirmed for BRIC economies or not. The specification for the latter purpose is as follows:

$$\begin{aligned} CO_{2it} = {} & \alpha + \beta_1(GDP_{it}) + \beta_2(GDP_{it})^2 + \beta_3(IS_{it}) \\ & + \beta_4(R\&D_{it}) + \beta_5(SMVA_{it}) + \beta_6 \log(FDI_{it}) \\ & + \beta_7(DBA_{it}) + \beta_8(CAC_{it}) + \beta_9(FL_{it}) + \beta_{10}(FO_{it}) \\ & + \beta_{11}(EI_{it}) + \beta_{12}(OC_{it}) + \beta_{13}(EC_{it}) + v_i + \varepsilon_{it} \end{aligned} \tag{2}$$

where the definitions of the variables are the same as that for the first equation. We added GDP per capita growth rate squared values in country i at time t, $(GDP_{it})^2$, to confirm whether the

[3] An interesting reading for Brazilian case is Machado and Schaeffer (2006).

U-shaped relationship between CO_2 and economic growth exists or not.

Also, one of the referees suggested that the control variables, i.e., energy and oil consumption used in our study may explain most of the CO_2 emissions, and the other variables could be threat as a noise. To address this issue and similarly to the Eqs. (1) and (2), we performed regressions excluding the control variables. Then, our specification is as follows:

$$CO_{2it} = \alpha + \beta_1(GDP_{it}) + \beta_2(IS_{it}) + \beta_3(R\&D_{it}) + \beta_4(SMVA_{it}) + \beta_5 \log(FDI_{it}) + \beta_6(DBA_{it}) + \beta_7(CAC_{it}) + \beta_8(FL_{it}) + \beta_9(FO_{it}) + v_i + \varepsilon_{it} \quad (3)$$

and

$$CO_{2it} = \alpha + \beta_1(GDP_{it}) + \beta_2(GDP_{it})^2 + \beta_3(IS_{it}) + \beta_4(R\&D_{it}) + \beta_5(SMVA_{it}) + \beta_6 \log(FDI_{it}) + \beta_7(DBA_{it}) + \beta_8(CAC_{it}) + \beta_9(FL_{it}) + \beta_{10}(FO_{it}) + v_i + \varepsilon_{it} \quad (4)$$

where the definitions of the variables remain the same.

Hence, the rationale of our selected variables is discussed below.

(a) *Economic development*: In the framework of economic development, Azomahou et al. (2006) find evidence that supports a stable relationship between CO_2 emissions per capita and GDP per capita over time. Sun (2006) argues that GDP rates must be used in CO_2 emission forecasting. However, not only GDP rate defines the economic development. The industry share is also a key source of production and industrial activities. Rapid industrialization, transportation networks and other infrastructure requirements needs sustained energy sources. The importance of change in economic structure and, therefore, the industry importance as determinant of environmental degradation is well documented in Grossman and Krueger (1995), Westbrook (1995), Suri and Chapman (1998), Panayotou 1998 and Talukdar and Meisner (2001). In addition, Grossman and Krueger (1995), Selden and Song (1994), Holtz-Eakin and Sleden (1995) and Panayotou (1998) argue that the population growth rate is a key indicator in determining environmental degradation. The size of population coupled with rise in GDP growth and higher per capita income leads to an increase in demand and, therefore, in an increase in energy consumption. Hamilton and Turton (2002) argue that per capita income and population growth are the main two factors increasing carbon emissions in OECD countries.

(b) *Financial development*: Several studies highlighted the importance of capital markets as a main pillar of financial development. Hamilton (1995), Klassen and McLaughlin (1996) and Lanoie et al. (1998) found evidence that capital markets reward firms with higher environmental performance through a higher valuation of firms' equities. This argument suggests that the more-developed financial capital markets are likely to enjoy a better environmental quality than that of a country with less-developed capital markets (Dasgupta et al., 2001). Consequently, we used stock market value added as an indicator of capital markets across countries under consideration. At the same time, the literature has recognized the importance of FDI impact in the environmental performance (Rock, 1996; Chua, 1999). However, the impact of FDI on environmental degradation is controversial. Eskeland and Harrison (2003) use a panel data set on US outbound direct investment to four countries and find little support for the pollution haven hypothesis. Also, they find foreign plants are significantly more energy efficient and use cleaner types of energy than the domestic-owned plants. Wang and Yanhong (2007) find similar results in a study examining firm level pollution discharge in more than 1000 firms in China. Liang (2006) found a negative correlation between FDI and air pollution, suggesting that the overall effect of FDI may be beneficial to the environment. This finding supports the argument that FDI in developing countries are more likely to act as conditional factor for advanced, and cleaner, environmental technologies. On contrary, Xing and Kolstad (2002) report a positive association between the amount of sulfur emissions in a host country and inflows of US FDI in heavily polluting industries.

Similarly to Creane et al. (2007), we used deposit money bank assets to GDP as determinant of financial development. Yet, one of the banking system development indicators is the capital account liberalization process which usually increases the efficiency level of the financial system by weeding out inefficient financial institutions and creating greater pressure for a reform of the financial infrastructure (Stiglitz, 2000; Claessens et al., 2001). Klein and Olivei (2001) find that capital account liberalization is statistically significant for financial development and economic growth in a cross-section study over 1986–1995. They argue that the countries with open capital accounts had significantly a greater increase in financial development in contrast with countries presenting account restrictions. Moreover, Frankel and Rose (2005) find that openness is at least as likely to help the environment, for a given level of income, as to hurt it. Therefore, such an improvement in financial infrastructure, based on the openness of capital account, may contribute to the efficient technological use and, therefore affect not only the financial development itself but the environmental degradation as well.

(c) *Energy control variables*: Finally, we decompose net energy imports variable to assess the individual effects of energy imports and exports on energy consumption. This is because the role of energy imports has a double edge impact on energy consumption (Shafik and Bandyopadhyay, 1992; Suri and Chapman, 1998). Increase in energy imports lead to decline in energy consumption if those goods are used to replace the manufactured goods which are produced domestically which consume high energy levels. Thus, imported manufacturing goods replacing domestic production would reduce the energy consumption. On contrary if the energy imports are utilized in capital intensive goods production it leads to increase in energy consumption adding to the existing production levels. Therefore, the net effect of increase in energy imports can be either positive or negative. We also include total energy exports as developing countries are largely engaged in energy production and are used for the purpose of exports resulting in increase in energy consumption.

3.1. Empirical results

The empirical results and estimates for equation on per capita CO_2 emission for BRIC countries are presented in this subsection. First, we discuss the results for per capita CO_2 emission vs. economic and financial development along with energy consumption control variables in the model 1 (see Table 1). Then we discuss the EKC or curvilinear relationship between economic growth and CO_2 emission in BRIC countries (see Table 1; model 2). The results in the Table 1 (see model 3) deals with economic and financial development and energy control variables and per capita CO_2 emissions for the panel of US, Japan and BRIC countries are presented. Moreover, the results for curvilinear effect of economic growth and CO_2 per capita emission for USA, Japan and BRIC countries is attached in Table 1 (see model 4).

The results for BRIC panel show that the economic development addressed by GDP growth rate, industry share and R&D expenditure has significant impact on per capita CO_2 emissions. The GDP growth rate has 1% significant and positive effect on per capita CO_2 emissions. For every 1% increase in GDP growth rate the per capita CO_2 emissions are increasing by 0.01%. Similarly, we

Table 1
Results of CO_2 equation function

Variables	BRIC panel		US, Japan and BRIC panel	
	Model–1	Model–2	Model–3	Model–4
Constant	1.106 (1.42)	0.343 (1.05)	−7.789* (0.34)	−7.941* (0.33)
Economic development variables				
Economic growth rate	0.010* (0.00)	0.009* (0.00)	0.020* (0.00)	0.021* (0.00)
Economic growth rate squared	–	−0.001 (0.00)	–	−0.001* (0.00)
Industry share in GDP	0.007* (0.00)	0.008* (0.00)	0.008* (0.00)	0.010* (0.00)
R&D expenditure	−0.037*** (0.08)	−0.009 (0.04)	−0.064** (0.03)	−0.051* (0.02)
Financial development variables				
Stock market value added	−0.001 (0.06)	−0.053* (0.02)	−0.034** (0.02)	−0.111* (0.01)
Log (FDI Stock)	−0.045* (0.01)	0.003** (0.00)	−0.095* (0.01)	−0.002* (0.00)
Deposit money bank assets/GDP	0.002** (0.00)	−0.030** (0.07)	−0.001* (0.00)	0.045* (0.03)
Capital account convertibility	−0.030* (0.01)	−0.031* (0.01)	−0.034* (0.01)	−0.038* (0.011)
Financial liberalization	−0.025*** (0.06)	−0.025** (0.03)	−0.456* (0.10)	−0.436* (0.09)
Financial openness	0.001*** (0.00)	0.001 (0.00)	−0.001** (0.00)	−0.001** (0.00)
Control variables				
Net energy imports	6.21E-07* (1.55E−07)	5.50E-07* (1.10E−07)	6.64E-07* (1.01E−07)	6.49E-07* (9.35E−08)
Log (Oil consumption)	0.216* (0.07)	0.256* (0.08)	0.703* (0.05)	0.772* (0.05)
Log (Energy consumption)	0.180** (0.10)	0.148** (0.07)	0.281* (0.05)	0.261* (0.05)
Adjust. R^2	0.9786	0.9780	0.9820	0.9817
F-statistic	2755.54	2516.03	11035.54	13765.14
Prob (*F*-statistic)	0.0000	0.0000	0.0000	0.0000
Total no. observations	52	52	78	78

Dependent variable: log (per capita CO_2 emissions).
White heteroskedasticity-consistent standard errors are reported in parenthesis.
* Significant at 1% confidence level.
** Significant at 5% confidence level.
*** Significant at 10% confidence level.

find that if the share of industry in GDP increased by 1% it leads to 0.70% increase in per capita CO_2 emissions. We also find that R&D expenditure is associated with low per capita CO_2 emissions, suggesting that higher rates of R&D expenditure decrease the CO_2 emissions. The interpretation and statistical significance of these results remains inalterable across both panels (see models 1 and 3, Table 1).

The relationship between financial development and environmental quality is controversial. There are studies that show FDI inflows lead to increase in environmental degradation (Cole and Elliot, 2005; Feridun, 2006). Our results show that increase in FDI inflows are associated with lower levels of per capita CO_2 emissions. These findings are in line with List and Co (2000), He (2002), Soysa and Neumayer (2004) and Liang and Guoyong (2006), who show that increase in FDI leads to decline in CO_2 emissions. Same is the case with financial liberalization and capital account convertibility. For every 1% increase in financial liberalization leads to 0.025% decline in per capita CO_2 emissions. Similarly, a 1% increase in capital account convertibility there is a 0.03% decline in per capita CO_2 emissions. On the other hand, we find that financial openness in BRIC economies may increase per capita CO_2 emissions. However, when we include US and Japan in the regression, the effect of financial openness becomes positive. This finding is very important, because higher levels of financial liberalization in BRIC countries may attract FDI inflows which in turn encourage R&D investments possibly leading to higher technological energy-related efficiencies, and therefore lower emissions. For instance, Machado and Schaeffer (2006) suggests that to achieve a sustainable development one of the key factors for Brazil is to compete successfully by being an attractive place for investment while promote technological innovation and more dynamic markets, to dematerialize its economy and to upgrade exports. In this sense, Goldemberg (1998) argues that most technological research and development occurs within the OECD countries. The author sustain that the transfer of technology from industrialized countries to developing countries is, therefore, likely to be a necessary condition for mitigating climate change and improve other environmental conditions. Yet, Blanford (2008) shows that R&D expenditure increases the probability of technological advance. Given all of this, our results advocate that the degree of financial development is a key factor in decreasing environmental degradation (see model 1 and 3, Table 1).

Regarding the energy consumption control variables, we find that higher levels in energy consumption increase per capita CO_2 emissions. The net energy imports exert positive impact on per capita CO_2 emissions. This is due to higher energy-intensive imports of Brazil, China and India. The energy imports of Brazil, China and India surged during post 1990s. Though it is statistically significant at 1% confidence level, the coefficient value remains very low. Similarly, we see that when oil consumption is increased by 1%, it is leading to 0.21% increase in per capita CO_2 emissions. China and India drives more than 35% of oil consumption in the world. In comparison to 1% growth rate in oil consumption of industrialized countries, the growth rate of oil use in China and India is around 7.5% and 5.5% per annum respectively[4] (see model 1 and 3, Table 1).

The results for curvilinear effect between GDP growth rate and per capita CO_2 emissions show that after controlling for other factors, the results confirm the existence of curvilinear relationship. The curvilinear results show that as economic growth rate is accelerated its negative impact on per capita CO_2 emissions decreases (see model 2 and 4, Table 1). These results support EKC theory that pollution levels increase as the countries develop, but

[4] For more information see: http://www.iags.org/futureofoil.html.

Table 2
Environmental degradation equation function

Variables	BRIC panel		US, Japan and BRIC panel	
	Model–5	Model–6	Model–7	Model–8
Constant	0.876* (0.12)	0.854* (0.13)	1.110* (0.11)	1.085* (0.11)
Economic development variables				
Economic growth rate	0.001* (0.002)	0.002* (0.001)	0.030** (0.001)	0.003*** (0.002)
Economic growth rate squared	–	−0.001** (0.002)	–	−0.0004** (0.001)
Industry share in GDP	0.005* (0.001)	0.005* (0.001)	0.004* (0.001)	0.006* (0.001)
R&D expenditure	−0.11** (0.06)	−0.10*** (0.05)	−0.068 (0.04)	−0.302* (0.08)
Financial development variables				
Stock market value added	−0.102*** (0.05)	−0.010*** (0.05)	−0.071* (0.02)	−0.066* (0.01)
Log (FDI Stock)	−0.033* (0.01)	−0.031** (0.01)	−0.034* (0.01)	−0.023** (0.01)
Deposit money bank assets/GDP	−0.001* (0.00)	−0.001** (0.00)	−0.001 (0.00)	−0.001 (0.00)
Capital account convertibility	−0.014** (0.005)	−0.014* (0.004)	−0.012** (0.005)	−0.015* (0.005)
Financial liberalization	−0.062** (0.02)	−0.054** (0.03)	−0.066* (0.02)	−0.049*** (0.03)
Financial openness	−0.001 (0.001)	−0.001 (0.001)	−0.001 (0.00)	−0.001** (0.00)
Adjust. R^2	0.7261	0.6629	0.6294	0.6595
F-statistic	5.33	5.02	9.30	10.29
Prob (*F*-statistic)	0.0001	0.0001	0.0000	0.0000
Total no. observations	52	52	78	78

Dependent variable: per capita CO_2 emissions.
White heteroskedasticity-consistent standard errors are reported in parenthesis.
* Significant at 1% confidence level.
** Significant at 5% confidence level.
*** Significant at 10% confidence level.

begin to decrease as rising incomes pass beyond a threshold. Our results are similar to obtained in Kraft and Kraft (1978) and Grossman and Krueger (1992), who show an inverted-U curve relationship between pollution levels and income. Thus, as economies develop along with financial liberalization and development the energy-related efficiencies are improved, and this in turn reduces energy consumption levels and hence lower CO_2 emissions (see models 2 and 4, Table 1). This suggests that there is a need to further increase the degree of financial and economic development in BRIC countries to achieve lower environmental degradation in terms of CO_2 emissions.

Following the suggestion of one of the referees, we analyze the nexus between growth-finance and environmental degradation excluding the control variables since they may be overall determinants of the previous empirical evidence. The results from Table 2 suggest that excluding energy-related variables do not alter the results significantly. We observe the curvilinear effect while the indicators related to economic and financial development are statistically significant.

More concretely, the estimates of economic development-related variables are statistically significant and have expected signs which are in accordance with the results obtained in Table 1. Specially, the results from model 5 and 6 (see Table 2) show that R&D expenditure is important in BRIC countries to reduce the environmental degradation. Yet, higher industry share leads to higher CO_2 emissions. Regarding financial system development, we observe that all related variables (see Table 2) are statistically significant and lead to lower the environmental degradation. Only financial openness in models 5–7 shows statistical insignificance, which confirms the relative importance of the control variables, though the signs in the models 7 and 8 remain as expected. This financial openness variable becomes significant at 5% confidence level when we interact BRIC countries with Japan and USA (see model 8, Table 2). The estimates are statistically consistent and efficient. The adjusted R^2 suffered a reduction but its range goes from 62.94% (model 5) to 72.61% (model 8) which confirms the goodness of fit of the statistical models. Again, the overall results are similar to those obtained in Table 1. Consequently, our interpretation of the financial and economic development as determinants for environmental disclosure still applies even excluding the control variables.

4. Summary and conclusion

While most empirical studies have focused on the effects of economic growth on environmental performance, this paper also addressed the impact of financial development on environmental degradation. We examine BRIC economies to show whether or not higher degrees of economic and financial development lead to higher CO_2 per capita emissions. As a measure of robustness, we introduce and examine behavior of results considering USA and Japan. Energy and oil consumption as well as energy imports are used as control indicators. Our analysis attempts to fulfill the econometric criticism of the EKC theory highlighted by Stern (2004).

We show that the economic development decreases the environmental degradation with higher levels of economic growth. This finding confirms empirically the EKC existence for the countries under consideration.

In addition, while the majority of the existing research is focused on consequences of economic growth on environmental degradation, we show that financial development might play a determinant role for environmental disclosure in developing economies. Our findings show that financial development is associated with decline in CO_2 per capita emissions. Particularly, we find that capital market and banking sector development along with higher levels of FDI help to achieve lower CO_2 per capita emissions. In this sense, it is noteworthy that the government can help the markets by establishing a strong policy framework that creates long-term value for greenhouse gas emissions reductions and consistently supports the development of new technologies that lead to a less carbon-intensive economy. Moreover, well-developed capital markets are very important;

because firms can reduce the liquidity risk and can mobilize the funds required which is extremely useful in developing technology in the long run.

Our overall results suggest some important policy recommendations. We believe that policies directed to financial openness and liberalization to attract higher levels of R&D-related foreign direct investment can decrease the environmental degradation. Our results supports the findings of Copeland and Taylor (2004) who claims that it would be unwise for countries to use trade protection as a means to improve their environment. This is important because the higher degree of economic and financial openness strengthen the institutional framework creating incentives for the firms to act upon. Therefore, addressing these issues might lead to higher energy efficiencies through technological advances as suggested by Blanford (2008) and possibly reduce the CO_2 emissions in BRIC countries.

Finally, we recognize that the technological change, R&D investment, environmental degradation and growth are not simply related. While our results pretend to be only an empirical evidence, it is worth noting that we were handicapped to capture the effects of R&D because we did not have the aggregate private sector; public sector and foreign firm level data on R&D spending and their investments in development of technologies. Yet, it is beyond the scope of this study to find exact mechanism through which financial system development leading to technological development through technological choice of the firms. Here, we would like to highlight that in the last two decades there has emerged a large macro-economic literature that builds on the above concepts to produce models of overall economic growth based on technological change (Romer, 1994; Grossman and Helpman, 1994; Solow, 2000). Our argument with respect to financial development and environment degradation is that higher degree of financial system development and openness prop up technological innovations by increasing spending on energy conservation R&D which results in energy efficiency and hence it may lower emissions.

We hope that other researchers will use our results and methodology to get improved insights into the economic-finance and environment nexus in other developing countries.

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Annex 1. : data description

Indicator	Source
Environment degradation is per capita CO_2 emission in kilo tons tonnes oil equivalent	WDI
Economic growth	WDI
Industrialization is the share of industrial output in GDP per country	WDI
R&D expenditure[1] is the gross domestic expenditure on R&D as percentage of GDP	OECD (2006)
Financial liberalization[2]	Gupta and Yuan, 2008
Stock market value traded is the total value addition of stocks traded in market divided by GDP	Data are taken from the updated version (as for August, 2007) of Beck et al. (2000)
Financial openness is defined as (foreign assets+foreign liabilities)/GDP	WDI
Capital account convertibility index	Chinn and Ito (2008)
FDI inflows stock	UNCTAD
Deposit money bank assets is the ratio of deposit money bank assets to GDP	Data are taken from the updated version (as for August, 2007) of Beck et al. (2000)
Energy consumption is the energy consumed in kilo tons tonnes oil equivalent	WDI
Oil consumption is the oil consumption in barrels oil equivalent per country	WDI
Net energy imports is the share of total energy imports divided by GDP	UN Stats

Note: [1]The R&D data for Brasil are taken from Red Iberoamericana de Indicadores de Ciencia y Tecnología. Principales Indicadores y Tecnología, 2005. For the period 1997–1999 we used interpolation method.

[2]The data for China and Japan are taken from Bekaert, Harvey and Lundblad (2005). Russian data were taken from EBRD Transition Report, 2005.

WDI: World Development Indicators, 2006; UN Stats: UN Statistical database, 2006; UNCTAD: United Nations Commission for Trade and Development, 2007.

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