ECONOMIC GROWTH AND ENVIRONMENTAL DEGRADATION WITH POSSIBLE IMPLICATIONS FOR CLIMATE CHANGE:

PANEL DATA EVIDIENCE FROM BRIC ECONOMIES

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ABSTRACT

This paper investigates the relation between rapid economic growth and environmental degradation in the BRIC economies. We utilize environmental, macroeconomic and financial variables coupled with Kyoto Protocol indicators based on panel data from 1992 to 2004.To begin with, the long-run equilibrium relationship between economic growth and energy consumption is examined. *Feasible general least squares* procedure (FGLS) is employed to estimate the environmental degradation caused by increases in energy consumption. *Pooled regression analysis* is used to estimate the relationship between energy consumption and growth variables. We study the impact of excessive economic growth rates on energy consumption levels by means of *threshold pooled ordinary least squares* (POLS) method. Moreover, our analysis takes into account the legitimate econometric criticism of the Environmental Kuznets Curve highlighted by Stern (2004). Our findings reveal that higher energy consumption leads to increased CO_2 emissions in the countries under consideration. We determine that energy needs resulting from rapid economic growth are directly contingent upon increased investments, population growth, and trade in energy intensive products. We also find that rapid economic growth further inflates energy consumption levels in the emerging BRIC economies. The results of cointegration analyses also confirm these findings. Finally, the inclusion of the US and Japan as the world's largest energy consumers does not significantly alter the results of our study.

KEYWORDS: CO_2 Emissions, Energy Consumption, Economic Growth, BRIC economies.

JEL CLASSIFICATION: Q40, Q41, Q43, O13, O14

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Acknowledgements: We would like to thank Mr. V. Venkat Sreedhar, Chief Finance Manager, West African Cements (WACEM), Togo, Africa; Dr. Jie He, Assistant Professor, Department of Economics and GREDI, Faculty of Business Administration, University of Sherbrooke, Canada; Prof. Antonio Focacci, University of Bologna, Bologna, Italy; Mr. Alexandre Szklo, Chemical Engineer, Energy Planning Program - COPPE/UFRJ, Brazil, for their discussion on the topic and their invaluable comments and suggestions. We also extend our thanks to Mr. Srivyal Vyyuri, formerly with Ohio State University, USA & Founding member Sphoorti Foundation (www.sphoorti.org), India, for providing some valuable information about key databases. Thanks also to Chase Willett for valuable research assistance. Any remaining errors are ours.

1. Introduction

The race for economic growth in emerging economies such as Brazil, Russia, India, and China (BRIC hereafter) is having a negative impact on proper ecological management in these countries. These rapidly growing economies are emitting high levels of various forms of gases such as CO_2. Increased emissions in these countries are largely the result of escalating levels of energy consumption. Population growth, rapid industrialization, trade in energy intensive products, and an increase in the number of vehicles (as a result of unprecedented economic growth) are the major forces driving energy consumption.

The dramatic levels of economic growth experienced by China and India in the late 1990s have inducted these powers into a veritable league of their own. Together, these two powers constituted 30% of the world's GDP (in $US, constant PPP) in 2003 (World Bank, 2004). In 2006, China experienced growth rates of over 10% while India boasted 9% growth, Russia 7% and Brazil 4% (see Fig. 1).

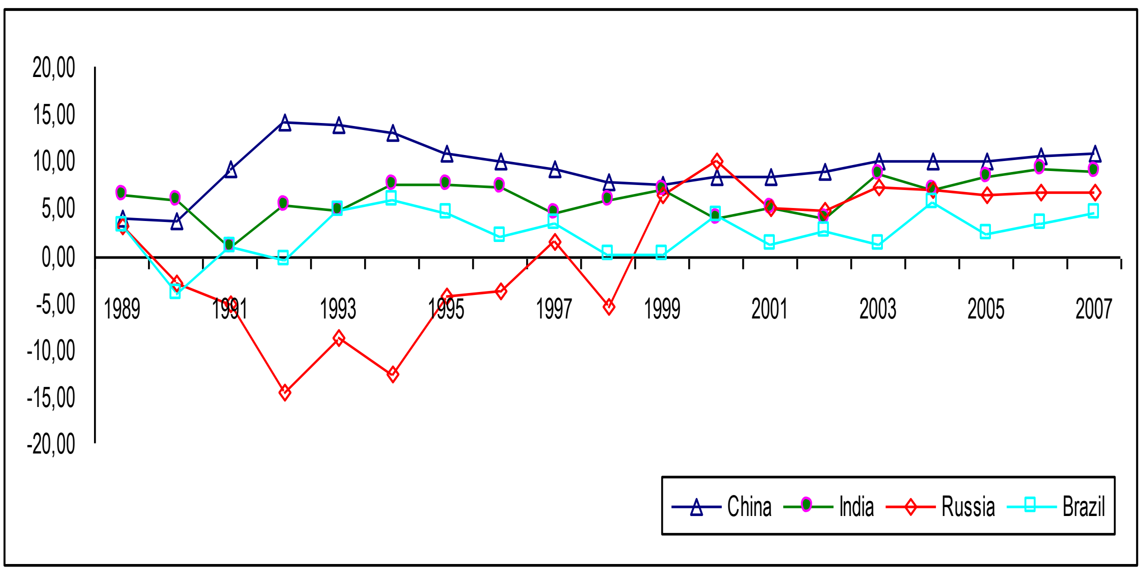

Figure 1: Economic Growth Rates of BRIC Economies

In this context, environmental economists have sent out warnings about the ecological costs of rapid economic growth which leads to an expansion of economic activities. These activities have both direct and indirect effects throughout the domestic and global economies, including an increasing demand for energy consumption. This ever increasing demand for consumable energy, generated by development and industrialization, potentially entails monumental side effects stemming from the increased emissions of harmful gases. These side effects include: global warming, greenhouse effects and deforestation. Environmental degradation also imposes higher costs for the poor by increasing the frequency of health related issues among them (Khan and Sonko 1994, Khan1983, 1997a,b,c,2008). According to a United Nations report, the world's poorest 20% of the population bear most of the burdens associated with environmental degradation. The report further finds that 80% of the world's diseases associated with water, air and land pollution stem from the onset of rapid industrialization (United Nations Report, 1999-00).

Each of the BRIC economies is undergoing a stage of rapid industrialization led by changes in the structure of economic activities, increased investments and high levels of population growth. In short, the positive benefits of rapid economic growth, investment and structural change are also accompanied by some negative externalities. The Environmental Kuznets Curve (EKC) attempts to relate these developments to the environmental statuses of the respective countries. An EKC model predicts that pollution levels increase as the country develops but begin to decrease as rising incomes surpass a certain point. This is illustrated as an inverted-U curve which is a graphic representation of the extended relationship between pollution levels and income. This hypothesis was first proposed by Grossman and Krueger (1992) and restated by them again in 1995. There are many forces driving the relationship between economic growth and environmental degradation. The upward movement of the curve reflects the initial move from an agriculturally-based economy to an industrial-based economy in developing countries. Subsequently, the downward movement of the curve ensues as the economy shifts towards services, increased importation of industrial goods and a general stabilization of growth; that is, as the economy becomes more developed.

However the EKC model has not gone unchallenged. Among others, Stern (2004) presents a critical view of the EKC. According to him, the arguments of EKC do not stand on strong econometric footing. He points out that the major weaknesses associated with the econometric estimation are heteroskedasticity, omitted variables bias, and issues relating to cointegration analysis. In particular, Stern et al. (1996) and Schmalensee et al. (1998) highlight the heteroskedastic regression residuals problem. Taking their arguments into account, we control for heteroskedasticity by using White heteroskedasticity-consistent standard errors and covariance in all our models. We also examine problems of serial correlation by utilizing the Breusch-Godfrey Lagrange Multiplier test. With regard to the omitted variable bias, we run sensitivity analysis in terms of robustness-checks for each model.

Hence, our study attempts to present an econometrically sensible approach to the questions of growth and environment in the context of BRIC economies. We begin by investigating the relationship between CO_2 emissions and energy consumption. We next examine the links between two relationships: energy consumption to economic growth and industrialization to investment activities. We assess econometrically whether or not higher economic growth rates lead to increased energy consumption. In order to further investigate the relevant hypotheses, we test for long-run equilibrium relationships among emissions, energy consumption levels and economic development indicators. Finally, we offer a causal analysis.

We pay special attention to the consequences of the structural shift undergone by the BRIC economies from agricultural to industrial growth. The agricultural sector in India experienced a considerable decline from an 80% share of GDP in the 1950s to around a 25% share by 2007. In China, the decline of the agricultural sector was reflected the drop from a 60% share in GDP to a 25% within the same time period, while the share of industrial output in GDP increased from 20% to over 50%. In Brazil, where industry has traditionally played an integral role, there has been only a modest increase from 38% share of GDP in 1970 to 40% share in 2007 (WDI, 2007). Rapid economic growth has also stimulated an increase in investments within BRIC economies, particularly in the late 1990s. Within the same interval of time, the levels of energy consumption and CO_2

emissions have also drastically increased, exhibiting a *prima facie* relationship between economic growth (i.e. industrialization) and environmental degradation.

The remainder of the paper is organized as follows: section 2 presents the literature review; section 3 outlines the econometric models and data sources; section 4 reports the empirical results and estimates along with our interpretations. Section 5 presents the summary and relevant conclusions.

2. Previous Research Findings

There are a number of studies that examine the link between energy consumption and economic growth. Starting with Kraft and Kraft (1978), a plethora of studies have produced varied conclusions about this relationship (Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Choi, 1985; Erol and Yu, 1987; Nachane, Nadkarni and Karnik, 1988; Abosedra and Baghestani, 1989; Hwang and Gum, 1992 and Bentzen and Engsted, 1993). Unfortunately, *omitted variables bias* seems to characterize the lot. Stern (1993) was the first to advocate *multivariate setting* to understand the relationship between energy consumption and rises in income. Prior to Stern, many authors conducted similar studies on a large-scale sample. For instance, Grossman and Krueger (1991), Lucas et al. (1992), and Shafik and Bandyopadhyay (1992), were the first to apply cross-section time series data to the relationship between economic growth and environmental degradation. Amongst them, Grossman and Krueger (1991) first articulated the environmental degradation and economic growth relation within an Environmental Kuznets Curve model (EKC hereafter). They perform a critical statistical test to examine the hypothesis that greater openness leads to lower environmental standards.

Kolstad and Krautkraemer (1993) point out a dynamic link between the environment, resource use and economic activity. They argue that while resource use (especially energy resources) yields immediate economic benefits, its negative impact on the environment may entail dire ramifications in the long-run. Selecting the period 1971-1991, Tucker (1995) looks at changes in CO_2 versus income in yearly cross-sectional analyses. The study finds that the changes in CO_2 emissions are clearly related to changes in oil prices but does not incorporate them into the analysis. The study by Agras and Chapman (1998) takes into account the *price* of energy. Their study stresses the importance of this element and incorporates it into an econometric EKC framework to test energy-to-income and CO_2- to- income relationships. These long-run, price-to-income models find that income is no longer a relevant indicator of environmental quality or energy demand.

Suri and Chapman (1998) examine the sources of *commercial* energy consumption, which is the root cause of most serious environmental problems. The study finds that while energy requirements for both industrializing and industrialized countries increase due to rises in the exportation of manufactured goods, this trend has been much more significant in the former. As the energy requirements for industrializing countries rise in correlation to increased exportation of manufactured goods, industrialized countries are able to stabilize this trend by importing manufactured goods and by using "Green Technologies" to varying degrees. The exporting of manufactured goods by industrializing countries has thus been an important factor in generating the upward sloping portion of the EKC and imports by industrialized countries have contributed to downward slope.

Bernardini and Galli (1998) examine three fundamental factors that lead to the decline in the use of energy and materials for emerging Asian economies. These three factors are: changes in the structure of final demand, increases in the efficiency of materials and energy use, and the substitution of more efficient materials and fuels. Kadnar (2004), develops a model based on energy consumption patterns, among other things, designed to predict future, short-term fossil fuel energy needs by using the relationship between consumption, population growth and real gross domestic product (GDP) for two situations (zero or no growth and a 5% sustained economic growth). This model was developed for Central Asian economies and obtained mixed results.

Lise and Van Montfort (2006) attempt to reveal the linkages between energy consumption and GDP by undertaking a cointegration analysis for Turkey with annual data from 1970 to 2003. The analysis shows that energy consumption and GDP are cointegrated. This suggests that there is a (possibly bi-directional) causality relationship between the two. In this framework, Soytas and Sari (2007) investigate the long run Granger causality relationship between economic growth, CO_2 emissions and energy consumption in Turkey, controlling for gross fixed capital formation and labor. The most interesting result obtained in the study is that carbon emissions seem to Granger cause energy consumption, but not *vice versa*. Yet this seems counter-intuitive and without theoretical plausibility.

Similarly, Focacci (2005) contributes an empirical analysis of environmental and energy policies in Brazil, China and India. The study includes ratio analysis using two key relationships; namely, the *emission intensity ratio* and the *energy-intensity ratio.* The study presents mixed results with respect to the application of an EKC model for these three economies. It shows that resulting trends in these three countries are different from other developing countries.

The consensus of the research suggests that ever-increasing, world-wide CO_2 emissions seem to be intensifying the problem of environmental degradation *vis a vis* global warming. This trend is highlighted by the Intergovernmental Panel on Climate Change (IPCC, 2007). Since the emissions mainly result from consumption of energy, reduction in energy consumption seems to be the best way of combating this problem. Yet regulating energy consumption can be perceived as incompatible with economic development, and, therefore, environmental considerations are often trumped by the broader economic agenda especially for industrializing economies using largely “Non-Green technologies.” This refocuses attention on the emerging economies of the BRIC group in particular. The crucial question is whether these countries will be able to manage rapid economic growth responsibly in light of the long-run consequences of environmental degradation.

3. i. Econometric Models & Data Sources

In this paper, we develop models with which to explain the relationship between pollution (driven mainly but not exclusively, by energy consumption) and energy consumption, which, in turn, is driven by growth variables. First, in order to assess the variables affecting CO_2 and energy consumption, two different relationships are examined using the period from 1992 to 2004:

a. CO_2 **Equation: GLS with Fixed Effects**

$$CO_{2it} = \alpha + \beta_1 \Delta GDP_{it} + \sum_{i=1}^{8} \beta_2 CV_{it} + \varepsilon_{it} \tag{1}$$

Where,
CO_{2it} = Emission in year "t" for country "i"
ΔGDP_{it} = Economic Growth variable in year "t" for country "i"
CV = Control variable in year "t" for country "i"
ε_{it} = Error term

b. Energy Consumption Equation: Pooled Regression Analysis

$$EC_{it} = \alpha + \beta_1 \Delta GDP_{it} + \sum_{i=1}^{8} \beta_2 CV_{it} + \varepsilon_{it} \tag{2}$$

Where,
EC_{it} = Energy Consumption in year "t" for country "i"
ΔGDP_{it} = Economic Growth variable in year "t" for country "i"
CV_{it} = Control variables in year "t" for country "i"
ε_{it} = Error term

Our first dependent variable for equation 1 is CO_2 Emissions. The panel data procedure consists of three estimation sets: *Between Estimates* capture differences between individuals, but ignores any information within them. *Between Estimates* are generally used to estimate long-run coefficients. *Fixed Effects* (FE) estimates assume that the slope of the equation is the same for all individuals but that there are specific intercepts for each of them that would be correlated or uncorrelated with explanatory variables. This procedure is also widely known as the Least Squares Dummy Variables (LSDV) method (Hsiao, 1986)[1]. The third relies on *Random Effects* (RE) estimates.

In order to distinguish between the FE and RE method, we apply a thorough Hausman test for the null hypothesis that the explanatory variables and individual effects are uncorrelated. The fixed effects estimates are consistent with both the null and alternative hypotheses, whereas the random effects estimates are only compatible with the null hypothesis. Therefore, RE method is appropriate if the null hypothesis holds; otherwise FE method can be applied.

It is presumed that ecological problems are largely driven the by emission of toxic gases like CO_2. Higher levels of CO_2 emissions drastically effect the environment. Thus, we take into account the CO_2 emission in kilo tons as the dependent variable which is contributing to the pollution and disturbing the environmental balance. For the second equation, our dependent variable is energy consumption. There are severe environmental threats in most developing economies like India and China because of the growing need for energy. The aforementioned argument hypothesizes that as energy consumption increases, the emission of harmful gases increases. We take into account energy consumption in kilo tons oil equivalent per country. A direct relationship is presumed between energy use and CO_2 emission in developing economies. Environmental degradation almost always hits those living in poverty the hardest (UN HDR, 1998). We acquire the data for both these variables from World Bank's World Development Indicators 2006.

Beginning with the independent variables, we first concentrate on those variables which are common in both models. The energy use in emerging economies is largely due to their rapid growth rates. These higher growth rates are putting increasing pressure on energy consumption, mainly in the form of escalating production needs and higher intermediate input consumption. As emerging markets develop and expand, they release increasing quantities of toxic gases into the atmosphere. Increases in those emissions may eventually be assuaged by rising GDP, increasing the attractiveness of environmental

[1] Early pioneers of this method were Nerlove and Swamy. See Khan(1978) and Khan and Hoshino(1992) for these and other references to the pioneers.

protection as a consumable.However, this is not inevitable without policy interventions. Thus, for the immediate future, the GDP growth rates are positively associated with the energy use emerging countries like BRIC. Productive and industrial activities necessitate liberal supplies of consumable energy; it is the lifeblood of industrial development. As emerging economies continue to grow leading to rises in income and the general progression of the economy into the industrial stage, the need for energy increases nearly exponentially as the emergence of transportation networks, the introduction of various factories and other infrastructural requirements augment this necessity. Due to the lack of data for manufacturing as a function of total industrial production we consider the share of industrial output in the total GDP. Population growth is another key indicator that is taken into consideration especially as it pertains to populations in China and India. The size of population, coupled with the rise in GDP growth and higher per capita income, creates demand for various products leading to an overall increase in energy consumption. The rate of population growth in these countries is also considered. Transportation is also a major contributing factor to energy use. This element becomes even more prevalent as we are considering three of the geographically largest countries in the world. High levels of travel, long-distance travel, public transportation and the number of vehicles in the country typically exacerbate energy demands for these vast and populous giants. In turn, rising incomes generate increased demand for motor vehicles. Vast public transport systems within these countries also heavily contribute to energy consumption dedicated to transportation. We therefore take into consideration all registered vehicles, both commercial & passenger.

Imports including energy imports can have dual effects on energy consumption. The increase in imports can lead to a decline in energy consumption *if* those goods substitute domestically manufactured items which aggravate energy use. Thus, the importation of these manufactured goods can reduce energy requirements for the country. However, there is an opposing argument which states that if the imports including energy imports are utilized in capital-intensive goods production, an increase in energy consumption may result. Thus, the net effect of increases in imports can be either positive or negative for the developing economies of the BRIC. Similarly, we take into account total exports including energy exports, if any, to analyze the effect on energy consumption.

Furthermore, this paper discusses the impact of *Gross Fixed Capital Formation* on investments in capital intensive industries. There is a theory which suggests that the level of capital intensive projects devoted to infrastructure and other industrial sectors swells levels of energy consumption. For example, the GFCF in China, as of 2006, stood at over 40% of GDP, which well surpasses international standards. Massive amounts are spent on infrastructure, creating transportation and electricity-delivery networks which have a substantial impact on energy consumption. Russia, India and Brazil, however, do not demonstrate GFCF to GDP relationships as lofty as that of China's. Finally, we incorporate oil as another important determinant of energy consumption. The colossal demand for oil, which countries like India and China generate, drives unabated growth in energy usage. This is precisely the reason why there was a dramatic increase in energy consumption in the late 1990s. Save for the data concerning the number of registered vehicles and energy intensive imports and exports (which are taken from the UN Stats common database), we gather our information from the World Bank's World Development Indicators (WDI, 2006).

We now look at some of the variables included only in either of the equations like financial market variables and Kyoto Protocol agreements. *Financial market liberalization* examines the effect of the sensitivity of firms engaged in energy production for liberalization. This should eventually lead to an increase of investments by these firms in emerging markets. Here, financial liberalization measures changes in the economy corresponding to relaxing rules and regulations related to private and foreign investments. It does not, however, tell us about the *quality* of investments. Thus, we take the value "0" for the period of *pre-liberalization* and the value "1" for the *post-liberalization* period. We also include two financial market variables; namely, *Stock Market Capitalization* and *value added*. We use the market capitalization ratio as one of the variables measuring the quality of financial liberalization. Many economists have used the market capitalization ratio as an indicator of stock market development under the assumption that stock market size is positively correlated with the ability to mobilize capital and diversify risk. Thus, we should see a positive relationship between higher stock market capitalization and emissions in emerging economies. The value traded actually measures the value of the trading taking place in all firms listed on stock exchanges. Though there are some drawbacks of this ratio, it is a sound estimate of the liquidity position of the stock markets. The major advantage of employing this ratio to analyze stock market development and quality of financial liberalization is that it complements the market capitalization ratio (Levine and Zerov, 1998). Although a particular stock market might be enormous, there may be a very little trading. This is quite common in countries like India, where there are as many as 23 regional stock exchanges which may not witness any trading at all a few days out of the week. Thus, this ratio acts as a complement to the market capitalization ratio in providing more accurate information about a country's financial market development process. The data for financial market liberalization comes from Gupta and Yuan (2005); for stock market variables, we use the database developed by Beck et al. (2000) and Beck and Al-Hussainy (2006). Lastly, as discussed, we introduce two variables related to the Kyoto Protocol which examine the legitimacy of international treaties intended to control emissions by capping levels of energy consumption. We take the value of "0" for the years preceding the signing of the treaty and "1" for the period since. For a separate variable, we ascribe the value of "0" for the years prior to ratification and "1," again, for the period since. We construct these *dummies* based on the information provided by UNFCCC's Kyoto Protocol Background (2007).

c. Threshold Pooled Regression Analysis:

In the third stage, our study introduces *pooled threshold regression analysis* which utilizes interactive dummy variable(s). The idea here is to develop a more in-depth understanding of the relationship between economic growth and energy consumption. Therefore, we include three different levels of GDP growth rates (see scenarios – 1 & 2) and analyze their impact on levels of energy consumption. First, we create a dummy variable for higher GDP growth rates which assumes the value of one when the rate exceeds 25%, 50% and 75% of its respective average value in separate models. Otherwise, we set the value at zero. Next, we introduce these dummy values together with the *actual* GDP growth rates. The basic premise is to consider only the higher GDP growth rates while ignoring the years of low growth rates. This will reveal whether the higher GDP growth rates share a positive relationship or otherwise with energy consumption. The three different levels of GDP growth rates are identified by GDP Interactive Dummy $(ID_{GDP_{it}})$ which is expressed as follows:

$$EC_{it} = \alpha + \beta_1 ID_{GDP_{it}} + \sum_{i=1}^{8} \beta_2 CV_{it} + \varepsilon_{it} \qquad (3)$$

Scenario – 1:

GDP growth rate in year "t" *x* 1 (IF) GDP growth rate is > 50% of its mean value
GDP growth rate in year "t" *x* 1 (IF) GDP growth rate is > 75% of its mean value
GDP growth rate in year "t" *x* 1 (IF) GDP growth rate is > 100% of its mean value

Scenario – 2:

GDP growth rate in year "t" *x* 0 (IF) GDP growth rate is < 50% of its mean value
GDP growth rate in year "t" *x* 0 (IF) GDP growth rate is < 75% of its mean value
GDP growth rate in year "t" *x* 0 (IF) GDP growth rate is < 100% of its mean value

In order to ensure that the model specified is correct and is free from serial correlation, our study employs the Durbin Watson test. We wanted to further ensure that there are, indeed, no errors associated with serial correlation. Hence, we also utilize an alternative method named the Breusch-Godfrey LM test.

d. Cointegration Test:

Using cointegration analysis, we investigate next the possibility of long-run relationships between the variables. If the variables that we are using in the study are found to be cointegrated, it will provide statistical evidence for the existence of such a relationship. Although a set of economic time- series may not be stationary, there may still exist some linear combinations of the variables which exhibit a dynamic equilibrium in the long run (Engle and Granger, 1987). We employ the maximum-likelihood test established by Johansen and Juselius (1990) and Johansen (1991) to check for these occurrences. More specifically, if Y_t is a vector of n stochastic variables, then there exists a p-lag vector auto regression with Gaussian errors of the following form:

$$\Delta Y_t = K + \Gamma_1 \Delta Y_{t-1} + ... + \Gamma_{p-1} \Delta Y_{t-p+1} + \Pi Y_{t-1} + \mu_t \quad (4)$$

Where Γ_1, ... Γ_{p-1} and Π are coefficient matrices, Y_t is a vector of white noise process and K contains all deterministic elements.

The primary reason for conducting Johansen's cointegration tests is to determine the rank (r) of matrix Γ_k. In the present application, there are three possible outcomes. First, it can be of full rank (r=n). This implies that the variables are stationary processes and contradicts the previous notion of non-stationarity. Second, the rank of k can be zero $(r = 0)$, indicating that there is no long-run relationship among the variables. For instance, when Γ_k is of either full rank or zero rank, it will be appropriate to estimate the model in either levels or first differences, respectively. Finally, in intermediate cases, when there are at most r cointegrating vectors $0 \le r \le n$ (i.e., reduced rank), the implication is that there are $(n - r)$ common stochastic trends. The cointegration procedure yields two likelihood ratio test statistics, referred to as the *maximum eigenvalue test* $(\lambda_{\max})$ and the *trace test* (λ_{trace}). The number of lags used in the vector auto-regression is chosen based on the evidence provided by Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC).

e. Granger Causality: VECM

If the two variables specified share a long-run relationship with each other, then the next immediate step is to examine causality. If two or more variables are cointegrated, there is causality in at least one direction (Engel and Granger 1987). We proceed to determine whether the variable X *Granger* causes Y or vice-versa, using the Vector Error Correction Model (VECM). According to Engle and Granger (1987), if two variables are cointegrated, then a more comprehensive test of causality (which has become known as an Error-Correction Model (ECM)) should be adopted. The VECM restricts the tendency of the endogenous variables to converge with their cointegrating relationships in the long-run while allowing for a wide range of short-run dynamics (Granger Causality). The cointegration term is *error correction* since the deviation from long-run equilibrium is corrected gradually through a series of partial, short-run adjustments. The exact representation of VECM is:

$$\Delta Y_t = \sum_{f=1}^{k-1} \Gamma_1 \Delta Y_{t-f} + \theta \ \varphi \ \Delta Y_{t-k} + \upsilon + \eta_t \qquad (5)$$

Where $\theta \ \varphi \ \Delta Y_{t-k}$ denotes Error Correction Term and 'Δ' stands for first difference. First order differenced variables in equation 4 are now stationary, and, therefore, the OLS method gives consistent estimates (Enders, 1995).

4. Empirical Results

We now turn towards the empirical results and estimates for the equations concerning CO_2 emissions and energy consumption for the BRIC economies as well as for the US and Japan. First, we introduce the results of the CO_2 emissions-to-energy consumption relationship for all the economies in our study (see table 1). As explained before, we distinguish between fixed effects and random effects methods of panel data using the Hausman test. For this study, the Hausman test indicates that the fixed effects estimates are consistent with both the null and alternative hypotheses, whereas the random effects estimates are only compatible with the null hypothesis. Therefore, FE method is applied.

In the following section, we examine the relationship between economic growth and energy consumption for, first, the BRIC economies and, then, for the US and Japan. This equation involves four models. Model 2, the standard model, deals exclusively with the BRIC economies and includes all variables, while Model 2A tests for the robustness of the standard model (see table 2).

We next present standard model 3, which incorporates the US and Japan with the BRIC economies. Likewise, we incorporate model 3A to check for the robustness of results from model 3 (see table 2). In the final phase, we discuss the results derived from threshold pooled regression analysis dealing with higher economic growth and energy consumption. Here, we have six models; three with the BRIC economies exclusively (models 4, 5 and 6 – reported in table 3), and three incorporating the US and Japan (models 7, 8 and 9 – presented in table 4).

We begin with the analysis presented in table 1 which shows that economic growth undoubtedly contributes to increased CO_2 emissions. This has statistical significance at a 10% confidence level. The implication, here, is that economic growth is, in fact, a major contributor to environmental degradation not only in the BRIC economies but in the US and Japan as well.

Table 1: Results of CO_2 equation function

Dependent Variable: CO_2 Emissions

Variables	Standard Model 1
C	-7219253 * (148034)
Economic Growth Rate	25788.1 *** (14354.05)
Energy Imports	153341.6 * (34474.32)
Energy Exports	-8688.81 (15678.96)
Oil Consumption	1157755 * (189096.1)
Kyoto Protocol Ratification	465895.7 * (172388.5)
Kyoto Protocol Signatory	-156657.2 (140247.8)
Share of Industry in GDP	-9957.11 (11648.95)
Energy Consumption	0.7297895 * (0.19686)
Financial Liberalization	-1046642 * (341315.8)
Stock Market Value Added	490670.1 *

	(171868.0)
Stock Market Capitalization	-995259 ** (426240.1)
R-squared	0.9517
Hausman Test	Chi2(10)= 44.49
Wald Test	Chi2= 1300.72
Total no. observations	72

Note: * Significant at 1% confidence level; ** Significant at 5% confidence level; *** Significant at 10% confidence level. White heteroscedasticity-consistent standard errors are reported in parenthesis.

We find a very strong positive relationship between energy intensive imports and energy consumption. This relationship is statistically significant at a 1% confidence level. This substantiates the claim that ever increasing energy imports are directly contributing to higher levels of pollution by engendering inflated levels of energy consumption. This correlation is evinced by all the economies under consideration (excluding Russia) which have been growing since the early 1990s. However, there is no statistical significance for energy *exports*.

As expected, we find the influence of oil consumption on CO_2 emissions to be in line with our hypothesis. The demand for oil is one of the most prominent aspects driving energy consumption in all of the BRIC economies. The same holds for the US and Japan. In fact, this relationship exhibits a strong positive association with statistical significance at 1%. Similarly, we find that energy consumption in general has a greater impact on CO_2 emissions. Therefore, it appears that energy consumption is a major generator of CO_2 emissions. This relationship exhibits statistical significance at a 1% confidence level.

We now turn to the Kyoto protocol agreements. Here we find mixed results. We conclude that the mere ratification of the Protocols has absolutely no statistical significance for the reduction of CO_2 emissions. Simply being signatory to a treaty does not necessarily ensure a country's compliance with the dictates of that agreement. Ratification of the Kyoto Protocols can be considered an integral first step towards the moderation of CO_2 emissions, however, ensuring the implementation of policies which will carry out this agenda is a much more difficult enterprise when emerging economies face the overarching needs of development. All of the BRIC economies, excluding Russia, have signed the protocol but have yet to specify any legitimate implementation of the treaty's directives (UNFCCC's Kyoto Protocol Background, 2007). On the other hand, if the country ratifies the protocol then there is an obligation to take some steps to cut the emissions. We find that this variable with CO_2 is significant at 1% confidence level, giving support to our argument.

Now we focus on financial markets and their role in boosting CO_2 emissions. We find that the liberalization process of financial markets in this relationship has a negative sign and a statistical significance of 1%. This could be attributed to the fact that the mere opening up of markets does not necessarily attract investment by firms. Rather, it is the *quality* of openness which correlates to investment and, therefore, development. In regard to this, we find that stock market capitalization also bears a negative sign and has a statistical significance of 5%. We can attribute this negative behavior to the lack of disclosure of the amount of trading which has taken place in the markets. Stock market capitalization only shows the *total value* of the shares listed in the market. But, it does not speak to the *number* of stocks traded or the value of each of those traded stocks (Levine and Zerov, 1998). This is surely misleading. Thus, although it may be a better model than a simple financial liberalization dummy, it still retains drawbacks of its own. However, this argument is nullified when we encounter a robust statistical relationship between stock market value added and CO_2 emissions; an association which proves that the *quality* of financial liberalization, in fact, matters. A key reason why we include this ratio is that it acts as a compliment to the market capitalization ratio in providing more accurate information about a country's financial market development. Here we observe a very strong, positive relationship which is statistically significant at a 1% confidence level.

Table 2: Panel Data Results of Energy Consumption

Dependent Variable: Log(Energy Consumption)

Variables	Standard Model MODEL - 2	Robustness Check MODEL – 2A	Standard Model MODEL - 3	Robustness Check MODEL – 3A
C	1.949527 * (0.3692)	1.655679 * (0.3622)	1.245597 * (0.3209)	1.085857 * (0.3009)
Economic Growth Rate	0.002785 *** (0.0016)	0.003560 ** (0.0016)	0.004017 * (0.0012)	0.004849 * (0.0012)
Investments	0.006274 ** (0.0026)	0.004089 *** (0.0022)	0.006069 * (0.0021)	0.004714 ** (0.0019)
Share of Industry	-0.001945 ** (0.0008)	-0.001992 ** (0.0007)	-0.002437 ** (0.0009)	-0.002459 * (0.0009)
Rate of Growth of Population	0.054150 ** (0.0246)	0.067299 * (0.0223)	0.014033 (0.0113)	0.011585 (0.0093)

Total Registered Vehicles	3.92E-07 (9.36E-)	3.78E-07 (8.21E-)	-1.90E-07 (2.02E-)	-1.17E-06 ** (4.78E-)
Energy Imports	0.039049 ** (0.0156)	0.026133 *** (0.0142)	0.011333 * (0.0039)	0.010291 * (0.0036)
Energy Exports	0.004764 (0.0033)	0.006485 ** (0.0025)	0.002717 (0.0025)	0.003838 ** (0.0019)
Energy Production	2.94E-07 * (8.00E-)	2.38E-07 * (7.98E-)	1.36E-07 * (4.49E-)	8.63E-08 ** (4.20E-)
Log (Energy Consumption (t-1))	0.822051 * (0.0331)	0.846928 * (0.0326)	0.891554 * (0.0276)	0.906834 * (0.0262)
Oil Consumption	-----	1.82E-05 ** (7.89E-)	----	1.38E-05 * (5.92E-)
R-squared	0.996211	0.996309	0.995378	0.995427
Adjusted R-squared	0.996024	0.996123	0.995288	0.995333
F-statistic	5349.052	5352.905	11074.98	10640.67
Prob(F-statistic)	0.000000	0.000000	0.000000	0.000000
Durbin-Watson stat	1.752025	2.018356	1.643517	1.638105
Total no. observations	48	48	72	72

Note: ***** Significant at 1% confidence level; ****** Significant at 5% confidence level ******* Significant at 10% confidence level. White heteroscedasticity-consistent standard errors are reported in parenthesis.

The results presented in model 2 are as expected: the economic growth variable exerts a positive pressure on energy consumption. An increase of 1% in GDP growth rates for BRIC economies leads to an increase of 0.28% in energy consumption. This is statistically significant at a 10% confidence level. We also look at the *individual* effects of GDP growth rates on energy consumption. We find that all countries exhibit a statistically significant relationship in this context. The growth rates of India, China and Brazil, in particular, demonstrate very strong associations with energy consumption. Russia also displays statistical significance in this relationship yet its coefficient value is much lower compared to those of its counterparts[2].

An interesting point to note here is the negative association of the share of industry in GDP for the BRIC economies. This aside, we notice that there has actually been a gradual *decline* in industry share of GDP for Russia and Brazil and only a modest *increase* for India from 23% in 1992 to 26% in 2004 (still much lower than its BRIC counterparts). In China, industry share of GDP increased from 43% in 1992 to 48% in

[2] The individual coefficient value for India is 99% with 1% confidence level followed by China: 70% with 5% confidence level; Brazil: 63% with 5% confidence level; and Russia: 22% with 5% confidence level.

1996 only to decline to 45% in 2004. Thus the China factor may be counterbalanced by the modest shares of industry in the other BRIC economies.

Furthermore, we find that higher levels of investments in BRIC economies are directly contributing to increased energy consumption in those countries. The relationship is positive with statistical significance at 5%. Investments begin to rise when there is a boom in economic growth. In turn, investments stimulated by economic growth are exerting pressure on energy demands and, therefore, are increasing energy consumption.

We find a very strong positive relationship between energy intensive imports and energy consumption. A 1% increase in energy intensive imports leads to a corresponding 4% increase in energy consumption. This correlation is statistically significant at a 5% confidence level. A similar trend can be observed in the case of energy intensive *exports*. However, the rate of growth of energy intensive exports is much lower compared to imports. Consequently, this relationship is weak with a 15% confidence level.

We now examine the relationships of other variables; namely, population growth and number of vehicles. We find that population growth exhibits a positive relationship with energy consumption and has statistical significance at a 5% confidence level. Energy consumption, therefore, is also driven by population growth in the BRIC economies, especially in India, China and Brazil. However, although we find a positive sign for *number of vehicles*, we could not find any statistical significance at an acceptable level.

Energy *production*, which is on the rise for all of these economies, also has a positive impact on energy consumption and is statistically significant with a 1% confidence level. We also examined energy consumption from previous years to assess any impact it might have on current levels. We find the result to be positive and robust with statistical significance of 1%.

Next, in order to check for the robustness of the results, we introduce *oil consumption* into the model 2A. We find that oil consumption has a positive relationship with energy consumption levels in BRIC economies. It is statistically significant at a 5% level.

In the next model, 2B[3], we introduce the *lagged value* of economic growth rate. We find that the economic growth of previous years does not make any impact on current energy consumption levels. But the most important thing about these robustness checks is that results related to the standard model are found to be quite robust while the signs and significance levels remain unchanged.

In the third model, we introduce the US and Japan. We find that although the results do not change dramatically, economic growth rate remains a significant factor for energy consumption with statistical significance of 1%. We also find that the statistical significance of investments in the standard model is 1%, but results related to industry share remain the same, as was the case for the BRIC economies. Here, we find a *negative* association with statistical significance at a 5% confidence level.

Another significant aspect of these results is the impact of population growth on energy consumption. When we introduce the US and Japan, we find that the relationship becomes statistically *insignificant*. Given the negative rate of population growth in Japan and a very low rate of growth in the US, this relationship is not unexpected. We do find that energy intensive imports make a strong impact on energy consumption levels when we bring the US and Japan into the equation (statistically significant at a 1% confidence level). However, like the previous model, we could not determine any relationship with energy *exports*. Still, we find positive and very strong associations with energy production and lagged value of energy consumption (both significant at 1% confidence levels).

Introducing the oil consumption variable, we observe it having a positive impact on energy consumption levels. This is statistically significant at a 5% level. As before, we also find energy-intensive exports turning statistically significant at 5%. Furthermore, *number of vehicles* now bears negative sign while remaining statistically significant. This is largely due to the fact that there was either stagnant or decreased rates of growth in the number of registered vehicles in the US and Japan during the study period. In the final model, 3B[4], we introduce lagged value of GDP growth rate and find it to be statistically *insignificant*. The adjusted R square values for both models are, however, highly

[3] The results of 2B model are not reported here. The detailed results are provided upon request.
[4] The results of 3B model are not reported here. The detailed results are provided upon request.

significant. The Durbin Watson statistics show that the models do not suffer from serial correlation.

Table 3 gives us three different models that capture the impact of increase in GDP growth rates for BRIC economies (US and Japan excluded). We find that whenever the GDP growth rate of respective BRIC economies crosses 50% and 75% of their particular mean values, there is no acceptable statistical significance. However, when we introduce a GDP growth rate greater than 100% of their respective mean values, we find positive results with statistical significance at 10%. The results are robust compared to our previous model 3.

Table 3: Pooled Threshold regression estimates for BRIC economies

Dependent Variable: Log(Energy Consumption)

Variables	MODEL - 4 Economic Growth rate > 50% of Mean Value	MODEL – 5 Economic Growth rate > 75% of Mean Value	MODEL – 6 Economic Growth rate > 100% of Mean Value
C	2.201954 * (0.4397)	2.042454 * (0.4344)	1.928191 * (0.3931)
Economic Growth Rate	-3.06E-05 (0.0011)	0.001451 (0.0014)	0.003230 *** (0.0018)
Investments	0.008012 * (0.0019)	0.007340 * (0.0019)	0.007607 * (0.0018)
Share of Industry	-0.002381 ** (0.0009)	-0.002348 ** (0.0009)	-0.002458 * (0.0008)
Rate of Growth of Population	0.099990 * (0.0242)	0.102243 * (0.0229)	0.095838 * (0.0223)
Total Registered Vehicles	1.42E-06 *** (9.18E-)	1.39E-06 *** (8.63E-)	1.08E-06 (7.67E-)
Energy Imports	0.035086 ** (0.0153)	0.028505 *** (0.0159)	0.026772 ** (0.0135)
Energy Exports	0.009332 * (0.0027)	0.009003 * (0.0025)	0.008504 * (0.0026)
Energy Production	3.55E-07 * (8.82E-)	3.36E-07 * (8.79E-)	3.08E-07 * (8.12E-)
Log (Energy Consumption (t-1))	0.791398 * (0.0384)	0.805367 * (0.0378)	0.816284 * (0.0339)
Oil Consumption	8.33E-06 (7.95E-)	1.10E-05 (7.77E-)	1.16E-05 (7.68E-)
R-squared	0.997066	0.998087	0.996120
Adjusted R-squared	0.998614	0.998740	0.998682
F-statistic	3958.170	4048.623	4201.630
Prob(F-statistic)	0.000000	0.000000	0.000000
Durbin-Watson stat	2.032311	2.001794	2.073112
Total no. observations	48	48	48

Note: * Significant at 1% confidence level; ** Significant at 5% confidence level *** Significant at 10% confidence level. White heteroscedasticity-consistent standard errors are reported in parenthesis.

Our study uncovers a nuanced relationship between population growth and energy consumption. Based on our findings, each percentage point of GDP growth rates may propagate a 0.28% increase in energy consumption levels. When we introduce a GDP growth rate greater than 50% and 75% of the mean values, we find no statistical significance, yet the coefficient value of GDP growth greater than 100% of the mean value is 0.32% and significant, which, in fact, is higher than the coefficient value in standard model 2. This shows that whenever the GDP growth rate exceeds the mean values by 100%, its effect on energy consumption increases.

We now discuss our final model, in which we incorporate the US and Japan into the pooled threshold regression analysis to address the robustness of our results. The results are quite different from those from the earlier model. When we introduce the two new countries into the study, we find that the GDP growth rate at all levels is positive and significant at 1%. This proves that when we control for highly developed countries, the results change, implying that the findings are sensitive to sample size and stage of development.

Table 4: Pooled Threshold regression estimates for entire sample

Dependent Variable: Log(Energy Consumption)

Variables	MODEL - 7 Economic Growth rate > 50% of Mean Value	MODEL – 8 Economic Growth rate > 75% of Mean Value	MODEL – 9 Economic Growth rate > 100% of Mean Value
C	1.454842 * (0.3627)	1.304477 * (0.3549)	1.269866 * (0.3322)
Economic Growth Rate	0.002159 ** (0.0010)	0.003597 * (0.0013)	0.006325 * (0.0020)
Investments	0.009170 * (0.0019)	0.002704 (0.0019)	0.008916 * (0.0017)
Share of Industry	-0.002969 ** (0.0011)	-0.003263 * (0.0012)	-0.003080 * (0.0010)
Rate of Growth of Population	0.028858 ** (0.0121)	-0.030952 *** (0.0184)	0.034598 * (0.0103)
Total Registered Vehicles	-3.48E-07 (4.65E-)	-1.15E-07 (6.75E-)	-6.37E-07 (4.45E-)
Energy Imports	0.013900 * (0.0045)	2.19E-07 (1.64E-)	0.012832 * (0.0040)
Energy Exports	0.004717 (0.0032)	-3.56E-07 ** (1.54E-)	0.004524 *** (0.0027)
Energy Production	1.71E-07 * (5.05E-)	2.17E-07 * (7.12E-)	1.44E-07 * (4.62E-)
Log (Energy Consumption (t-1))	0.868747 * (0.0307)	0.902249 * (0.0251)	0.884097 * (0.0281)
Oil Consumption	1.65E-06 (6.35E-)	-1.31E-05 (9.05E-)	5.74E-06 (5.98E-)
R-squared	0.995153	0.995185	0.998258
Adjusted R-squared	0.995014	0.996051	0.998137
F-statistic	7194.912	7476.898	8216.807
Prob(F-statistic)	0.000000	0.000000	0.000000
Durbin-Watson stat	1.589257	1.501027	1.704111
Total no. observations	72	72	72

Note: * Significant at 1% confidence level; ** Significant at 5% confidence level *** Significant at 10% confidence level; White heteroscedasticity-consistent standard errors are considered.

We find that GDP growth greater than 50% of the respective mean values has a lower coefficient value compared to the actual GDP growth mentioned in the standard model 3. Whenever the GDP growth rates surpass 50% of the mean values, its impact on energy consumption is 0.22% compared to 0.40% of the actual GDP growth of standard model 3 (table 4). The same can be found for GDP growth rates above 75% of their mean values. However, when we introduce GDP growth rates higher than 100% of the mean values, we find that its coefficient value of 0.63% is much higher than the coefficient value presented in standard model 3. The results of all other variables included in both the models are similar to that of model 3, mentioned above. The adjusted R square values for all models' range stood at 99% which indicates that the overall significance is high. The Durbin Watson statistics also show that none suffer from serial correlation.

We now apply cointegration tests[5] between CO_2 and energy consumption, and economic development and energy consumption to detect any possible long-run equilibrium relation between the series for BRIC countries. The cointegration test reflects the statistical implication of the existence of a long-run relationship between economic variables. The test stipulates that if variables are integrated in the same order, a linear combination of the variables will also be integrated in that same order.

Table 5: Johansen Co-integration Test for CO_2 and Energy Consumption

Country	Equations	Trace Statistic	Critical Value at 5%	Critical Value at 1%	Max –Eigen Statistic	Critical Value at 5%	Critical Value at 1%
Brazil	None	15.43499	15.41 *	20.04	8.782496	14.07 *	18.63
	At most 1	6.652494	3.76 *	6.65	6.652494	3.76 *	6.65
Russia	None	27.35696	15.41 *	20.04 **	22.44670	14.07 *	18.63 **
	At most 1	4.910257	3.76 *	6.65	4.910257	3.76 *	6.65
India	None	18.87460	15.41 *	20.04	14.82855	14.07 *	18.63
	At most 1	4.046047	3.76 *	6.65	4.046047	3.76 *	6.65
China	None	34.67281	15.41 *	20.04 **	24.10295	14.07 *	18.63 **
	At most 1	10.56986	3.76 *	6.65 **	10.56986	3.76 *	6.65 **
Observations	32						
Lags Interval (in first differences)	1 to 1						

Note: * Indicates cointegrating equation(s) at the 5% level; ** Indicates cointegrating equation(s) at the 1% level. Linear deterministic trend is considered.

[5] It is worth noting that for cointegration analysis our dataset increase the number of observations for CO_2, Economic Development and Energy Consumption variables. The time period range is 1970 to 2005.

The null of no cointegrating vector can be rejected for all BRIC countries (see Table 5) as the empirical findings reinforce the conclusions about the presence of long run relationships and the existence of a linear combination between CO_2 and energy consumption. Furthermore, we find that there are two cointegrating equations for almost all of the countries, excepting Brazil and India. This leads to the conclusion that there is a very strong, long-run equilibrium relationship between CO_2 and energy consumption.

Once the presence of long run relationship between CO_2 and energy consumption is confirmed we discuss the cointegration analysis for energy consumption and economic development.

Table 6: Johansen Cointegration Test for Energy Consumption & Economic Development

Country	Equations	Trace Statistic	Critical Value at 5%	Critical Value at 1%	Max –Eigen Statistic	Critical Value at 5%	Critical Value at 1%
Brazil	None	15.50641	15.41 *	20.04	9.615369	14.07	18.63
	At most 1	5.891044	3.76 *	6.65	5.891044	3.76 *	6.65
Russia	None	24.99580	15.41 *	20.04 *	21.59137	14.07 *	18.63
	At most 1	3.404431	3.76 *	6.65	3.404431	3.76	6.65
India	None	17.32465	15.41 *	20.04	17.27031	14.07 *	18.63
	At most 1	0.054340	3.76	6.65	0.054340	3.76	6.65
China	None	9.444051	15.41	20.04	9.246200	14.07	18.63
	At most 1	0.197851	3.76	6.65	0.197851	3.76	6.65
Observations	32						
Lags Interval (in first differences)	1 to 1						

Note: * Indicates cointegrating equation(s) at the 5% level; ** Indicates cointegrating equation(s) at the 1% level. Linear deterministic trend is considered.

In this case, the null of no cointegrating vector cannot be rejected for all countries excepting China (see table 6). For China, we do not find a long-run equilibrium relationship between energy consumption and economic growth. While using around 10 lags we still could not find any long-run association. However, for the other countries, we find at least one cointegrating equation, either statistically significant at a 5% and/or 1% confidence level. We find that trace and max-eigenvalue tests show at least one cointegrating equation for Brazil, Russia and India yet none for China. The empirical results support the presence of a long-run relationship and a linear combination between CO_2 emissions and energy consumption for all the BRIC economies. Nevertheless, the same cannot be confirmed in the case of China when it comes to the energy consumption and economic development relationship.

We now shift our focus towards estimating the short run relationship of those combinations in which we have found long run equilibrium and linear combinations. For this purpose, we apply Vector Error Correction Model (VECM) as discussed earlier. This model is useful in restricting the long-run tendency of the endogenous variables to converge with their cointegrating relationships while allowing for a wide range of short-run dynamics (Granger Causality). Thus, it foresees any deviations from long-run equilibrium. It is then rectified gradually through a series of partial short-run adjustments. In table 7, we take into account the equation relating CO_2 emissions and energy consumption for BRIC countries.

Table 7: VECM for CO_2 & Energy Consumption

Countries	Variables	Constant	CointEq1	D(CO_2 (-1))	D (Energy Consumption(-1))
Brazil	CO_2 (-1)	-53.02445 (1486.45)	-0.688724 * (0.24646)	0.137703 (0.27300)	-0.804176 (0.65575)
	Energy Consumption (-1)	296.5997 (577.441)	-0.250313 * (0.09574)	0.140682 (0.10605)	-0.323592 (0.25474)
Russia	CO_2 (-1)	-1964.867 (12675.2)	0.513114 * (0.54385)	-0.851993 (0.37095)	1.420745 (1.11152)
	Energy Consumption (-1)	-932.9997 (3282.23)	0.488982 (0.14083)	-0.248069 (0.09606)	0.189665 (0.28783)
India	CO_2 (-1)	1784.912 (2577.32)	-0.719663 * (0.33359)	-0.360088 (0.16027)	1.055197 (1.06086)
	Energy Consumption (-1)	596.7519 (805.059)	0.182910 * (0.10420)	-0.088303 (0.05006)	-0.005136 (0.33137)
China	CO_2 (-1)	2600.567 (18870.0)	-0.589748 * (0.24209)	0.907249 (0.24016)	-0.448615 (0.50980)
	Energy Consumption (-1)	8270.292 (6459.42)	0.193185 * (0.08287)	0.047532 (0.08221)	0.246731 (0.17451)
Observations	32				
Lags interval (in first differences)	1 to 1				

Note: ***** Significant at 5% confidence level

The empirical findings for the BRIC countries suggest two different scenarios. First, we find that there is a significant short-run relationship between economic growth and environmental degradation contributing towards climate change for all countries in the sample. This relationship is statistically significant at a 5% confidence level. Second, excluding Russia, we find bi-directional causality. For Russia, we find a uni-directional causal relationship flowing from energy consumption to CO_2 emissions, which means that the latter is influencing the former and not vice a versa. Again, these results are consistent to the cointegration results in which we found two cointegrating equations for all countries. Thus, from the Granger causality results (Vector Error Correction Model*)*, it is evident that there is a uni-directional Granger-causality for Russia and bi-directional causality for the rest of the countries. Hence, it suggests that overall energy consumption and CO_2 emissions are strongly correlated.

We now take a look at an equation relating energy consumption and economic development for Brazil, Russia and India. We exclude China because we did not find any long run relationship between energy consumption & economic development.

Table 8: VECM for Energy Consumption & Economic Development

Countries	Variables	Constant	Coint.Eq1	D (Energy Consumption(-1))	D (Economic Development (-1)
Brazil	Energy Consumption (-1)	119.7854 (552.473)	0.179798 (0.18567)	0.162178 (0.29049)	-13.82528 (7.36798)
	Economic Development(-1)	-4.399451 (18.6088)	0.018257 * (0.00625)	0.008566 (0.00978)	-0.400055 (0.24817)
Russia	Energy Consumption (-1)	-774.6795 (3355.34)	-0.159044 * (0.06883)	-0.392512 (0.14533)	-12.37936 (3.84900)
	Economic Development(-1)	0.725840 (170.825)	0.011717 * (0.00350)	0.003394 (0.00740)	-0.068590 (0.19596)
India	Energy Consumption (-1)	1027.951 (726.135)	-1.043784 * (0.23611)	-0.016881 (0.16967)	-94.60456 (50.0674)
	Economic Development(-1)	3.520862 (2.69468)	0.000328 (0.00088)	-8.18E-05 (0.00063)	0.551026 (0.18580)
Observations	32				
Lags interval (in first differences)	1 to 1				

Note: * Significant at 5% confidence level

The empirical findings show that there is a uni-directional causal relation for Brazil and India and a bi-directional relation for Russia. The findings are statistically significant at a 5% confidence level. Interestingly, for the first model in VECM, we find bi-directional causality for Brazil and India and uni-directional causality for Russia. In the second model, we find that the causal relationships are opposite to the first model. The Granger causality results here show that there is no bi-directional causality for both Brazil and India. However, there is definitely uni-directional causality between economic development and energy consumption. Thus, it confirms that economic growth contributes to energy consumption levels. These results are consistent with our findings in earlier models (see models 1 to 6).

5. Summary and Conclusions

While existing studies have focused on the effects of economic growth on environmental degradation, this study adopts an alternative approach. We examine BRIC economies using the period 1992 to 2004 to reveal whether the decline in environmental quality in BRIC economies is due to increased energy consumption resulting from rapid economic growth. Moreover, our analysis also attempts seriously address the econometric criticisms of the EKC highlighted by Stern (2004).

More specifically, we use various environmental, macro economic and financial variables, along with dummy indicators proxied for Kyoto Protocol treaties, to examine the effects of energy consumption on CO_2 emissions. The influences of domestic demand, dependence on energy and investment activities on energy consumption are also taken into consideration.

The results suggest that growth in energy consumption has a significant impact on the CO_2 emissions contributing to global warming in the countries under consideration. In the first place, high levels of energy consumption are driven by rapid economic growth, international trade in energy intensive goods, growth of domestic demand for energy and the number of registered vehicles. This implies that higher rates of economic growth may be harmful to the environment unless technological structure is conducive to minimizing such impact and improves enough in time to reverse the trend. We find the results to be robust. When the US and Japan are included in the analysis, we observe slightly different results. This suggests that our analyses are sample sensitive and subject to the countries' respective stages of development.

In addition, we examine the possible long-run relationships between CO_2 emissions, energy consumption and economic growth by introducing cointegration tests followed by causality analysis using the Vector Error Correction Method. These results signify a long-run equilibrium and causal association between CO_2 emissions and energy consumption all of the countries. However, we could not find the same relationship for China concerning energy consumption and economic growth.

Our overall findings carry an important message. Given the current growth strategies of BRIC countries, perhaps reductions in energy consumption are implausible given of the negative effects it might entail for economic growth. However, adoption of appropriate technologies and price incentives may be necessary in order to avoid a serious environmental debacle. Over time, rapidly emerging economies in India, China and Brazil, which are extremely dependent on energy, may experience a subsequent balancing-out of ecological concerns and economic development.However, given the urgency of the climate change issues, a change in development strategies may be necessary(Khan 2008).

Future research can also address other substantive aspects highlighted by Stern (2002) related to the analysis of the proximate factors driving changes in pollution emissions, energy efficiency and decomposition of sulfur emissions. This in turn requires a detailed sectoral examination which could be helpful for the policy makers in these countries to frame an “inclusive environment quality led growth policies” in light of the findings here and in Khan(2008).

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APPENDIX

Appendix– 1: Variables Description and data sources

Research Variable	Indicators	Data Source
a. Dependent Variables		
Environment Disturbances - Emissions	CO_2 Emission in Kilo Tons tonnes oil equivalent	WDI
Energy Consumption	Energy Use in Kilo tonnes oil equivalent per country	WDI
b. Independent Variables		
c. i. Macroeconomic & Energy Variables		
Growth of market size	ΔGDP/GDP per country	WDI
Industrialization	Share of Industrial Output in GDP per country	WDI
Population	Rate of Growth of Population per country	WDI
Registered Vehicles	Registered vehicles (both commercial & passenger) in 1000s	UN Statistics
Energy Imports	Share of Total Energy Imports/GDP	UN Statistics
Energy Exports	Share of Total Energy Exports/GDP	UN Statistics
Gross Fixed Capital Formation	GFCF as percentage of GDP	WDI
Oil Consumption	Oil consumption in barrels oil equivalent per country	WDI
d. ii. Financial Variables		
Initiation of Financial Liberalization process	The value "0" for pre liberalization period and take the value "1" for post liberalization period.	Nandini Gupta & Kathy Yuan, 2005
Stock Market Capitalization	Total value of all the listed shares / GDP	Thorsten Beck & Ed Al-Hussainy, 2006
Stock Market Value Traded	Total value addition of stocks traded in market / GDP	Thorsten Beck & Ed Al-Hussainy, 2006
e. iii. Kyoto Protocol Agreement Variables		
Signatory *Ratification*	*Takes the value of "0" for the years before signing the treaty and "1" afterwards.* *Takes the value of "0" for the years before ratification of the signed treaty and "1" afterwards.*	UNFCCC's Kyoto Protocol Background document, 2007

Note: WDI: World Development Indicators 2006; World Bank. & UN Stats: UN Statistical database 2006.