# A Panel Estimation of the Relationship Between Trade Liberalization, Economic Growth and $CO_2$ Emissions in BRICS Countries

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**Abstract:** *In the last few years, several studies have found an inverted-U relationship between per capita income and environmental degradation. This relationship, known as the environmental Kuznets curve (EKC), suggests that environmental degradation increases in the early stages of growth, but it eventually decreases as income exceeds a threshold level. However, this paper investigation relationship between per capita CO2 emission, growth economics and trade liberalization based on econometric techniques of unit root test, co-integration and a panel data set during the period 1960-1996 for BRICS countries. Data properties were analyzed to determine their stationarity using the LLC , IPS , ADF and PP unit root tests which indicated that the series are I(1). We find a cointegration relationship between per capita CO2 emission, growth economics and trade liberalization by applying Kao panel cointegration test. The evidence indi cates that in the long-run trade liberalization has a positive significant impact on CO2 emissions and impact of trade liberalization on emissions growth depends on the level of income Our findings suggest that there is a quadratic relationship between relationship between real GDP and CO2 emissions for the region as a whole. The estimated long-run coefficients of real GDP and its square satisfy the EKC hypothesis in all of studied countries. Our estimation shows that the inflection point or optimal point real GDP per capita is about 5269.4 dollars. The results show that on average, sample countries are on the positive side of the inverted U curve. The turning points are very low in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. Thus, our findings suggest that all BRICS countries need to sacrifice economic growth to decrease their emission levels.*

**Keywords**: panel analysis, environmental Kuznets Curve, CO2 emissions, growth economic, trade liberalization

**JEL** Classification: C33, Q43, Q54, O44, O10

## 1. Introduction

The relationship between carbon emissions , GDP and trade liberalization is central to an understanding of the environmental future of the planet and has, as such, been extensively studied. In general, environmental goods and their quality are normally good, denoting that increased earnings from free trade would increase an individual's demand for higher environmental quality. In the early stage of economic development, a small portion of excess income is typically allocated for environmental problems, and thus, at this stage, the industrialization process is likely to be accompanied by environmental problems.

A branch of this literature known as the Environmental Kuznets Curve (or inverted-U shaped curve ,EKC) argues that carbon emissions and GDP are, initially, positive related but that, after a threshold level of income, this relation turns negative. Much of this literature has been cast in a multi-country panel data framework (Burke, 2010). However, most of the previous studies have not taken into account the different levels of income across countries. In this regard this study is an attempt to remedy this limitation by focusing on comparing the relationships between CO2, trade liberalization and economic growth by accounting for level of development.

In the past decade, great efforts have been put into testing the EKC hypothesis by applying different models (linear, parametric, semi-parametric, non-parametric and fuzzy), analyzing various pollutants (SO2, CO2, NH4, etc.) and using various types of data (time series, cross-section and panel). Yet, the exact form of the model remains inconclusive and the results are mixed. This study investigates the question of the existence of an EKC with using a panel data method. The main reason for studying CO2 emissions is that they play a focal role in the current debate on environment protection and sustainable development. CO2 has been recognized by most scientists as a major source of global warming through its greenhouse effects. Pollutants like sulphur oxides or oxides of nitrogen, have a more local impact on the environment. Another reason is that CO2 emissions are directly related to the use of energy, which is an essential factor in the world economy, both for production and consumption. Therefore, the relationship between CO2 emissions and economic growth has important implications for environmental and economic policies.

By applying EKC theory, previous studies have provided a better understanding of the environmental consequences of international trade and suggested that economic growth can improve the environment and that economic growth is necessary for maintaining or improving the quality of the environment. According to the EKC concept, CO2 emissions are expected to have a positive relationship with the level of income or trade liberalization before the EKC threshold and then a negative relationship beyond the threshold. For example, if there is a negative relationship between CO2 emissions and free trade, then CO2 emissions are likely to decrease as the country becomes more exposed to open markets. Similarly, if there is a positive relationship between CO2 emissions and free trade, then the country is not likely to have experienced its optimal level of trade liberalization. The EKC framework implies the existence of an inverted U-shaped relationship between GDP per capita and environmental degradation to be a local pollutant. However, the existence of the EKC for the global pollutant, for example carbon dioxide emissions resulting in problems of international scale, has not been agreed. This study is focused on the trend of CO2 emissions of each country and tries to analyze its relationships with openness and GDP per capita conditional on specific, growth, openness. Determining the existence of the EKC for CO2 as a global pollutant is important. If developing countries have an inverted U-shaped curve, it is likely that the global pollutant can be reduced through international cooperation and financial support. Therefore, this study focuses on the existence of the EKC for BRICS countries.

In this paper, I conduct a series of time series econometric analyses on real GDP, real GDP2 trade liberalization and carbon emissions of the BRICS group: Brazil, Russia, India, China and South Africa. Using recent time series results I inquire as to whether these series are stationary or not and then explore their cointegration properties. I further test for panel cointegration among these variables for the BRICS as a whole. The rest of this paper is organized as follows. Section 2 , 3, 4 and 5 provides a brief review of The Literature on the Environmental Kuznets Curve, relationship between trade and Environmental And the BRICS Importance in The World Economy. Data description and estimation results are covered in Sections 6 Section 7 and 8 discusses the Unit root models and the cointegration test results for the BRICS countries. Section 9 concludes the study.

## 2. The Literature on the Environmental Kuznets Curve

Carbon dioxide ($CO_2$) is one of the gases in the atmosphere, being uniformly distributed over the earth's surface at a concentration of about 0.033% or 330 ppm. Carbon dioxide is released into the atmosphere when carbon-containing fossil fuels such as oil, natural gas and coal are burned. As a result of the increasing worldwide consumption of fossil fuels, the amount of $CO_2$ in the atmosphere has increased over the past century, now rising at a rate of about 1 ppm per year. Major changes in global climate could result from a continued increase in $CO_2$ concentrations. According to the International Panel on Climate Control (IPCC), $CO_2$ accounts for more than half of global warming. Several econometric studies have estimated the relation between $CO_2$ emissions per capita and per capita GDP growth using cross-country, and often unbalanced, panel data. At the beginning of 1990s, environmentalists voiced their concerns about a potential North American Free Trade Agreement (NAFTA). They argued that the expansion of markets and economic activities, the change of composition of the economy and the decrease of US regulatory standards on environment might lead to more pollution and faster depletion of scarce natural resources. In 1993, Grossman and Krueger presented an empirical paper on the conference of the U.S.–Mexico Free Trade Agreement, illustrating how a reduction in trade barriers generally affects the environment by expanding the scale, altering the composition and changing in the technology of the economy. Grossman and Kruger (1993) constitute the seminal work on the Environmental Kuznets Curve (EKC). They analyzed data for $SO_2$, suspended particulate matter (SPM) and particulates (smoke) for 1977, 1982 and 1988. The data were from Global Environmental Monitoring System (GEMS), which monitors air quality in urban areas throughout the world. Grossman and Kruger did regressions on both random and fixed effects models using a cubic function form. A linear time trend, a variable of openness and dummy variables of location were also included. They found that concentrations of two of the three pollutants, $SO_2$ and particulates, rise with per capita GDP at low levels of national income, and then fall as per capita GDP grows. The turning points for each of them are $4,119 (1985 U.S. dollars) and $5,000 (1985 U.S. dollars). The estimated curves imply an inverted U shaped relationship. Meanwhile, the SPM was found to fall in response to increases in per capita GDP at low levels of economic development. Then after GDP per capita reaches $9,000, economic growth has no further effect on the concentration of SPM. Grossman and Kruger argue that economic growth tends to alleviate pollution problems once a country's per capita income reaches certain level ($4,000 to $5,000 1985 U.S. dollars in this paper). They also predict that, because the free trade agreement with the U.S. and Canada would improve the economic growth of Mexico, whose per capita GDP was already $5,000 (1985 US dollars) at that time, this country would intensify its efforts to alleviate its environmental problems, so that it pollution level would decrease from that point on. In the following decades, many attempts have been made to evaluate the impact of economic growth on environmental quality. The literature is both theoretical and empirical. Theoretical explanations as to why environmental degradation should first increase and then decline with income have focused on three of factors: the effects of scale and structure of the economy; the link between the demand for environmental quality and income; and policies and regulations related to environmental degradation. As income grows, the scale of an economy tends to become larger. As Grossman (1995) suggested, a developing society requires increasing output, therefore more inputs and more natural resources. In addition, more output also implies increased wastes a demission as a by-product of the economic activity, which worsens the environmental quality. This is the so-called scale effect. The structure of the economy also tends to change with the development of the economy. As Panayotou (1993) points out, environmental degradation tends to increase as the structure of the economy changes from rural to urban, from agricultural to industrial. But it starts falling with the second structural change from energy-intensive heavy industry to services and technology-intensive industry. Finally, technological progress leads to the substitution of obsolete and dirty technologies with cleaner ones, which also improves the quality of the environment. This is the technology effect. When the technology effect dominates the scale effect, the pollutant level would increase during the period of first structural change of economy and then decrease during the second stage of structural change. Therefore the inverted U curve comes into being. He (1993) estimated EKCs for SO2, NOx, SPM and deforestation. His study employs only cross sectional data and GDP is in nominal 1985 US dollars. The data on emission for developing countries were estimated from fuel use and fuel mix data. Deforestation was measured as the mean annual rate of deforestation in the mid 1980s. There are 68 counties in the deforestation sample and 54 in the pollution sample. The models for the three pollutants are in logarithmic forms with quadratics in income per capita. For deforestation Panayotou uses a translog function in population density, a dummy variable for tropical countries and income per capita. All the estimated curves are inverted Us. In his results, the turning point for deforestation is $823 per capita. Deforestation rates were significantly greater in tropical countries. Deforestation was also higher in countries with higher population densities. For SO2 emissions the turning point is around $3,000 per capita, for NOx around $5,500 per capita, and for SPM around $4,500 per capita. Some of the theoretical literature has focused on household preferences environmental quality with the pollutant level. If these preferences following the assumption that the damage from extra pollution grows as income grows, then such preferences can be illustrated as an important factor of bending back down of the pollution-growth curve. McConnell (1997) studies the combined effects of preferences; increasing costs of pollution control and the declining value of extra consumption as per capita incomes grow. Applying a method of non-market valuation, McConnell shows that a high-income elasticity of demand for environmental quality is neither necessary nor sufficient for the EKC. Besides preferences, the assimilative capacity of the environment and the cost of abatement are also important influences on the pollution-growth relationship. Others argue that the method of decomposing economic development into its components, and study the bilateral relationship between pollution and each component is only partially right. As Panayotou (1997) points out, "… they focus only on the scale and industrialization effects and ignore the abatement effect of higher incomes." (P.429). In the same paper, the author maintains that the findings from models only including economic growth variables could lead to the unintended and misleading interpretation that some countries can grow out of their environmental problems without the establishment of conscious environmental policies. By taking explicit policy determinants into consideration, Panayotou (1997) finds that better policies, such as more secure property rights and better enforcement of contracts and effective environmental regulations, can help flatten the EKC and reduce the environmental price of economic growth.

While some economists seek to explain the explanation of the inverted-U growth pollution relationship, others cast doubt on the shape of the curve itself. Dasgupta et al. (2002) examine different EKC scenarios in the recent literature and provide theoretical explanations for different views. Some research shows that the pollution-growth curve rises asymptotically to same maximum pollution level, never coming down again. The EKC curves of some countries or pollutants maintain a high level while others maintain a low level of per capita pollutants. The cumulative effect is inverted U shaped, because the EKC is just a snapshot of a dynamic process. This is the so-called "race-to-the-bottom" curve. Pessimists argue that, even if certain pollutants are reduced as income increases, industrial society continuously creates new, unregulated and potentially toxic pollutants. Then the overall environmental risks from these new pollutants may continue to grow even if some sources of pollution are reduced. Holtz-Eakin and Selden (1995) named it the "new toxics" phenomenon. Meanwhile, some recent research has fostered an optimistic critique of the relationship. They suggest that the level of the curve is actually dropping and shifting to the left, as growth generates less pollution in the early stages of industrialization and pollution begins falling at lower income levels because of the technology overflow and economy globalization. In a comprehensive survey by Stern (1996), the author points out that only a subset of pollutants can apply the model of inverted-U curve, such as sulfur dioxide and suspended particulates. Perman and Stern (2003) is the first paper that raises the point that empirical work on EKC using time series or panel data should consider the issue of non-stationarity.2 They carry out both individual time-series unit root tests by Dickey-Fuller (1973) and panel data tests by Levin and Lin (1993) and by Im et al. (2003) for SO2 and GDP for 74 countries over a span of 31 years. They find that the null hypothesis of unit root could be rejected in only a fraction of all the countries no matter whether the data are transformed into logarithm or remained unchanged. Then applying Levin and Lin (1993) panel unit root tests, Perman and Stern find support for unit root in both variables. The further tests following Im et al. (2003) also confirm this conclusion. Following tests of cointegration provide support for the hypothesis that there is cointegration between emissions per capita and income per capita for each country in the panel. Though the error correction model (ECM) produces an inverted U curve, th heteroscedasticity among the countries shows that the EKC is a problematic concept, a least in the case of sulfur emissions. Perman and Stern (2003) make an important contribution to the empirical EKC research. Huang et al. (2008) considered economic development and greenhouse gas (GHG) emissions, which have been the focus of the Kyoto Protocol. The Protocol attempts to limit increases in GHG emissions among developed countries. They analyzed singlecountry time series and GDP data and found that most of countries do not provide evidence supporting the EKC hypothesis. Akbostanci et al. (2009) investigated the relationship between income and environmental degradation in Turkey. By using a time series model spanning from 1968 to 2003, they found that CO2 emissions and income tend to have a monotonically increasing relationship in the long run. This monotonically increasing relationship implies that the EKC hypothesis does not hold in this case. Galeotti et al. (2009) explained that EKC is not found at all the times relating to CO2. Furthermore this paper makes a significant contribution to the statistical robustness of the EKC by giving a direction. The authors emphasize that theoretical and empirical investigation is clearly organized before the existence and validity of the EKC is established. The review of previous research indicates that there are substantial differences among the countries, suggesting that the hypothesis of the Kuznets curve has a number of weaknesses that need to be addressed.

## 3. Trade and the Environment

While the importance of global warming issues is widely recognized among economists and policy makers, there has so far been little effort attempting to examine environmental performance with including the impact of trade openness (see for example: Ang, 2009; Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012; Tiwari et al. 2013). The trade theory literature generally posits that free trade is welfare-and efficiency-increasing. In a simple Heckscher-Ohlin framework, trade is determined by the relative endowment in factors of production, such as land, capital, and labor. As trade barriers vanish, the economic activity in a given country shifts to the production of goods requiring the factor that is relatively abundant (see, for instance, Burda and Wyplosz 2005). Hence, trade alleviates the pressure on the relatively scarce resource. If that resource is a natural resource, such as land, then trade weakens the demand on nature. In a similar approach, a further stream of argument argues that richer societies place a higher premium on a clean environment, and governments themselves tend to be more capable of acting to tackle pollution (Dasgupta et al., 2002). In this respect, an important role is played by human improvement of markets and technology. Demand for clean energy in conjecture with high investment rates may lead to a virtuous feedback loop by which growth leads to better institutions and technology, which reinforce the demand side for a clean environment (Ayres, 1993; Simon, 1998; Lomborg, 2001). Unsurprisingly, these claims have been highly publicized in the debates on free trade agreements (Stern, 2004). Fears have emerged that trade liberalization might have a disruptive effect on these efforts. Two main sources of worries have emerged. First, the Heckscher-Ohlin framework of efficient trade brakes down if property rights are ill dened. Chichilnisky (1994) shows that when property rights over some natural resources in a given country are not clearly attributed, this country may specialize in the extraction of this resource although there is no technological comparative advantage in doing so. The key insight is that the marginal cost of extraction does not react the true value of these resources as assets. According to Chichilnisky, this explains why developing countries tend to overuse their natural resources, making themselves poorer in the process.

Second, it is feared that trade competition leads to the weakening of existing environmental policies. Trade liberalization exposes and exacerbates institutional failures. Relatively poor countries might be tempted to weaken their environmental regulations to attract foreign investors. Weaker environmental obligations means that producers do not have to internalize the costs of the negative externalities of their business, raising protect margins. By a simple competition effect, arms may be expected to relocate to these areas. This effect is generally referred to as the pollution haven hypothesis which is nothing but a form of pollution outsourcing. Copeland and Taylor (1994) suggest that income may endogenously lead to stricter environmental laws, which in turn dene the structure of trade and domestic production.

Against these grim views, others have argued that trade may vehicle environmentally favourable legislation. For instance, Vogel (1995) suggests that exporters are dependent on the goodwill of the destination markets. Exporting states might thus import stringent regulations in order to ensure the best access for their goods to foreign markets. Sometimes dubbed the California effect, this argument underlines the bargaining struggle between states in the maximization of two parameters: economic welfare and environmental quality (see also Vogel 1997). The empirical evidence for the efficiency, the race to the bottom, or the California effects is mixed. Early studies of the determinant of pollution focused on domestic factors, in particular income. The EKC hypothesis suggests that pollution follows an inversed-U shape as income increases. The theoretical underpinning is that while increased economic activity raises negative by products (such as pollution), wealthier individuals place a higher premium on a clean environment. Furthermore, richer countries are more likely to develop technologies that would satisfy these demands.

The evidence for trade-related effects on pollution is also disputed. Early research by Leonard (1988) and Tobey (1990) fail to support for a weakening of environmental regulations in wealthy countries. Frankel and Rose (2005) no evidence that trade has a detrimental effect on the environment. Unfortunately, their claims are weakened by using mainly cross-sectional data and using trade openness as their only independent variable. Furthermore, using an instrumental variable (IV) approach with samples as small as 30 observations increases doubts about the strength of their, as the small sample properties of IV models are poor. Grether and De Melo (2004) consider a similar question, but some evidence for trade-related outsourcing of dirty production. Cole (2004)'s study is similar to the analysis performed in this paper; he showed that a trade-related effect for some pollutants but that this effect does not eliminate the EKC. His study however entirely focuses on industrialized countries over a relatively short time span, losing much of the dynamics of the data. Ang (2009), the results of the pollution function are estimated using the variables per capita CO2 emissions, per capita real output and trade openness for the China case during the annual period 1953-2006. Adopting an analytical framework that combines the environmental literature with modern endogenous growth theories, the results indicate that CO2 emissions are negatively related to research intensity, technology transfer and the absorptive capacity of the economy to assimilate foreign technology. The findings also indicate that more energy use, GDP and trade openness tend to cause more CO2 emissions. In the same way, Halicioglu (2009) examines the dynamic causal relationships between CO2 emissions, energy consumption, GDP, and foreign trade in Turkey over the annual period 1960-2005. This research tests the interrelationship between the variables using the bounds testing to cointegration procedure. The finding results indicate that there exist two forms of long-run relationships between the variables. In the first form, CO2 emissions are determined by energy consumption, GDP and foreign trade. In the second form, GDP is determined by CO2 emissions, energy consumption and foreign trade. The Granger causality results suggest that GDP is the most significant variable in explaining the CO2 emissions and it is followed by energy consumption and foreign trade. Moreover, there exists a stable CO2 emissions function. Jalil and Mahmud (2009) extend the same methodology of Halicioglu (2009) for the case of China over the period 1975-2005. This study aims at testing whether EKC relationship between CO2 emissions and per capita real GDP holds in the long run or not using Auto regressive distributed lag (ARDL) methodology. A quadratic relationship between GDP and CO2 emission has been found for the sample period supporting EKC relationship. The results of Granger causality tests indicate one way causality runs through GDP to CO2 emissions. The empirical results also indicate that CO2 emissions are mainly determined by GDP and energy consumption in the long run. Trade has a positive but statistically insignificant impact on CO2 emissions. Recently, Jayanthakumaran et al. (2012) using the bounds testing approach to cointegration and the ARDL methodology to test the long and short-run relationships between growth, energy use, trade openness, and endogenously determined structural breaks for both China and India Using over the annual period 1971-2007. The finding results indicate that CO2 emissions in China were influenced by per capita real GDP, energy consumption and structural changes. A similar causal connection cannot be established for India with regard to structural changes and CO2 emissions, because India's informal economy is much larger than China's informal economy. Moreover, India possesses an extraordinarily large number of micro-enterprises that are low energy consumers and not competitive enough to reach international markets. Understanding these contrasting scenarios is prerequisite to reaching an international agreement on climate change affecting these two countries.

## 4. BRICS Importance in The World Economy

The BRIC acronym, which stands for Brazil, Russia, India and China, originated in a Goldman Sachs(2001) paper– Building Better Global Economic BRICs – as part of an economic modeling exercise to forecast global economic trends over the next half-century. The main finding was that the BRIC countries collectively would play an increasingly important role in the global economy. Another paper by Goldman Sachs (2003) – Dreaming with BRICs: The Path to 2050 – concretised the earlier findings. It predicted that over the next 50 years, the BRIC economies could become a major force in the world economy, and that by 2050 the only industrialised /developed economies among the six-largest global economies would be the US and Japan in US dollar terms. The emerging dynamics over the last decade tend to support the predictions. Starting with a share of a little over 10% in world gross domestic product (GDP) and less than 4% in world trade in 1990, BRICS (with the recent inclusion of South Africa to the forum) in 2010 year constitutes about 25% of world GDP and 15% of world trade. The increase in GDP implies that the economic size of BRICS in terms of its share in world GDP has expanded by 150% in the past two decades. A quick glance at the statistics reveals that in 2011 the BRICS accounted for 25% of global GDP, 30% of global land area and 45% of the world's population. The basic point of commonality among the BRICS countries is that they are regional leaders in their own right and they have fast-growing economies.

In addition, all the BRICS countries are now members of major international and multilateral institutions, such as the World Trade Organisation , the UN, the Group of 20 (G-20) and the UN Framework Convention on Climate Change, and are very active participants therein. There are various other indicators, such as trade openness, current account balance that could make BRICS a formidable force to reckon with in future. The BRICS growing importance for the world economy is reflected by various economic and demographic indicators. These include, but are not limited to, their increasing share in world GDP; share in world trade; trade openness.

## 5. The BRICS Economies

5-1- Share in Global GDP

The BRICS economies, if viewed collectively over the last two decades, have emerged as a force to be reckoned with. This is duly reflected by the increasing share of BRICS in the world GDP. From a share of a little over 10% of the world GDP in 1990, share of BRICS in 2010 commands a share of more than 25%. This implies that the economic size of BRICS in terms of its share in world GDP expanded by 150% in the two decade periods.

Table 1: Overview of BRICS, 1990 and 2010

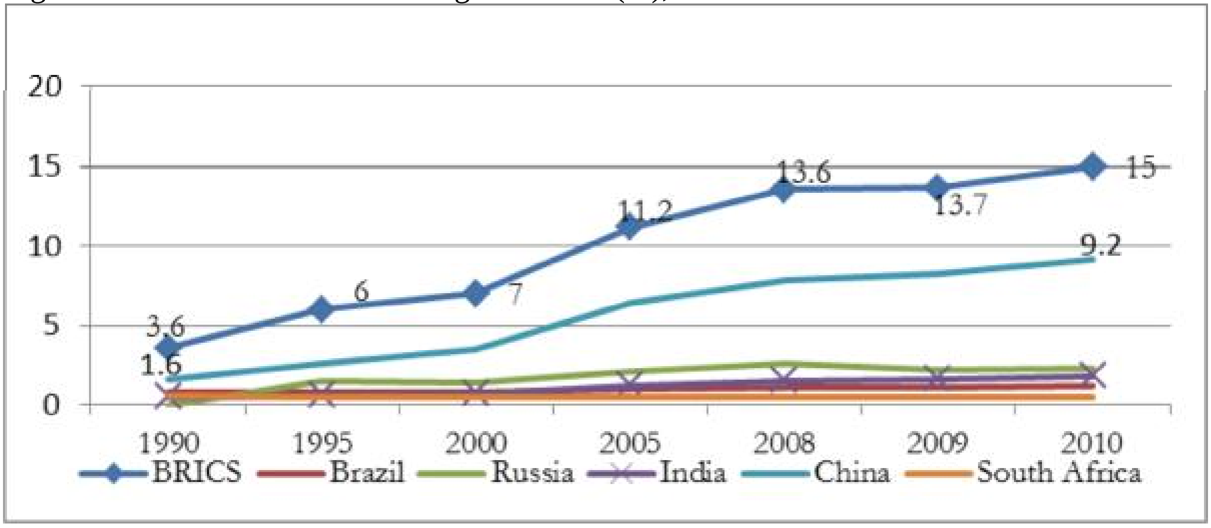
| Country | GDP (PPP ) | Rank in world | GDP ($ ) | | Share in world GDP (%) | | Per capita GDP ($) | |
|---|---|---|---|---|---|---|---|---|
| | | | 1990 | 2010 | 1990 | 2010 | 1990 | 2010 |
| Brazil | 2,172 | 8 | 508 | 2,090 | 3.3 | 2.9 | 3,464 | 10,816 |
| Russia | 2,223 | 6 | - | 1,465 | - | 3 | - | 10,437 |
| India | 4,060 | 4 | 326 | 1,538 | 3.1 | 5.4 | 378 | 1,265 |
| China | 10,086 | 2 | 390 | 5,878 | 3.9 | 13.6 | 341 | 4,382 |
| South Africa | 524 | 26 | 112 | 357 | 0.9 | 0.7 | 5,456 | 7,158 |

Source: IMF (International Monetary Fund) database, adapted from The BRICS Report 2012. India: Oxford University Press, 2012.

5-2- Share in global trade

As in the case of their share in world GDP, the BRICS share in world trade has also improved significantly over the last two decades, from 3.6% to over 15%. The primary contribution to this in terms of value has come from China, whose share has increased from less than 2% to over 9%. This is, however, not to argue that other BRICS countries have not contributed. Their shares have also increased, with Brazil's share rising from 0.8% to 1.2%; Russia's from 1.5% to 2.3%; and India's from 0.5% to 1.8%. South Africa is the only country in the group whose share in world trade has remained constant over the last two decades.

Figure 1: Trend in BRICS share in global trade (%), 1990–2010




Source: UNCTAD, adapted from The BRICS Report 2012. India: Oxford University Press, 2012.

Trade appears to have played a significant role in boosting the economic growth prospects of these countries. There is evidence to suggest that trade liberalization has been seen and used as a tool for promoting economic growth and facilitating development in all the BRICS countries.

Table 2: Global integration and evolution of BRICS economies

| Indicators | Year | BRICS economies | | | | |
|---|---|---|---|---|---|---|
| | | Brazil | Russia | India | China | South Africa |
| Trade openness | 1990 | 6.9 | - | 6.9 | 17.4 | 24.3 |
| | 2010 | 11.2 | 30.3 | 21.7 | 29.5 | 27.9 |
| Current account balance (% of GDP) | 1990 | 0.8 | - | -1.2 | 1.3 | 1.4 |
| | 2010 | -2.3 | 4.9 | -3.2 | 5.2 | -2.8 |

Source: IMF, UNCTAD & World Bank, adapted from The BRICS Report 2012. India: Oxford University Press, 2012.

BRICS countries have become more open, reflected by indicators such as trends in trade openness, current account balance and forex reserves, among others. In most of these parameters, BRICS countries have performed reasonably well, as reflected by Table 2. The rising GDP and forex reserves, increasing share in global trade, and trade openness augurs well for the group as a whole. They have bolstered the BRICS economic and political status at the global level and have helped BRICS countries to play a bigger role, as evidenced in the aftermath of the global crisis periods.

5-3- Climate change

Climate change has emerged as one of the priority issues of the 21st century and has been highlighted as a human crisis. For the BRICS countries, climate change is also a development challenge and a key governance issue, especially given its social and economic impacts. Climate change is related closely to industrialization and urbanization. Adaptation and mitigation efforts at domestic country level include factors such as financing, technology transfer, promoting clean development mechanisms, R&D, and the sharing of knowledge. All of these require greater international co-operation. The BRICS countries have already shown leadership in the climate change sphere through the commitments they made at Copenhagen, even in the absence of a legally binding agreement. Brazil committed itself to reducing its carbon emissions by 39% by 2020; Russia committed itself to reducing its emissions by between 15% and 25% from 1990 levels; India pledged to reduce its emissions by up to 25% below 2005 levels per unit of GDP; China committed itself to a reduction by 45% per unit of GDP, also from 2005 levels; while South Africa committed itself to cutting its emissions growth by 34%. Considering that currently the BRICS countries are among the leading greenhouse gas emitters, and also considering their development challenges, their commitment shows leadership and a sense of international responsibility. However, the BRICS countries still expect the principle of common but differentiated responsibility to apply. In Copenhagen, the BRICS member played an important role in the achievement of the four key decisions reached during the conference:

• agreeing to begin the second commitment period of the Kyoto Protocol in 2013, although not in a legally binding form, as commitments had not yet been written or ratified but the specifics of the commitments were due to be discussed in 2012;

• launching the Durban Platform to ensure the establishment of a legal agreement by 2020;

• adopting guidelines for reporting implementation progress; and

• approving the governing instruments for the Green Climate Fund.

## 6. Methodology and Empirical Results

*6-1-* The model and data

To conduct our empirical analysis and investigate the relationship between CO2 emissions, Trade Liberalization and economic growth which is a synthesis of the EKC and Liberalization literatures, we need the following variables for all studied BRICS countries:

- CO2 emission (CO);
- Trade Liberalization (L);
- Per capita real GDP (GDP).

We collect data from World Bank Development Indicators (WDI). Our data are annual and cover the period 1960-2012 for the following BRICS countries: Brazil, Russia, India, China, and South Africa. We empirically investigate the following model based on variables in bottom model:

$$CO_{2it} = \alpha_1 + \alpha_2\, GDP_{it} + \alpha_3 GDP_{it}^2 + \alpha_4 L_{it} + \varepsilon_t \qquad (1)$$

Environmental quality is proxied by CO2 emission per capita (Marland et al, 2010). Economic activity is proxied by GDP per capita of these regions (Maddison, 2009). L, a measure of trade liberalization, was measured as the sum of imports and exports as a share of total GDP in a given year.

To test the presence of EKC, the equation (1) which is derived from the relationships between pollution levels and GDP and Openness will be used. Pollution levels are expected to increase with growing income up to a threshold level beyond which pollution levels are expected to decrease with higher income levels. The combination of these two effects, ($\alpha_2 >0$) and ($\alpha_3<0$) in Model (1), creates the inverted U-shaped relationship between per capita CO2 emissions and GDP. In an attempt to broaden the concept of EKC, we investigate the relationship between environmental quality and trade liberalization. This is motivated by the fact that at early stages of economic development, free trade leads to an increase in real income, and at the same time, it increase the pollution level because environmental quality is regarded as a luxury good and not a normal good. However, as the country achieves a certain level of GDP, the increased income from free trade encourages consumers to increase their demand for a clean environment and then an attempt is made to reduce environmental damage through increasing clean production and eventually to improve environmental quality (Galeotti and Lanza, 1999). Therefore, the expected sign of $\alpha_4$ is mixed depending on the level of economic development stage of a country. For the case of developed countries, this sign is expected to be negative as they cease to produce certain pollution intensive goods and begin to import these from other countries with less restrictive environmental protection laws. But for the case of developing countries, this sign expectation is reversed as they tend to have dirty industries with heavy share of pollutants (Grossman and Krueger, 1995). It means also that an increase in trade openness will increase pollution due to a comparative advantage in dirty production under weaker environmental regulations (Jayanthakumaran et al. 2012) In what follows, we start by testing for unit roots in our variables. If these variables are nonstationary in our country panel, we investigate the existence of long run co-integration relationships and investigate their magnitude. Finally, we estimate panel error correction models based above model.

The data set is a unbalanced panel of 5 BRICS countries over the annual period 1960-2012. The BRICS countries included in the sample are: Brazil, Russia, India, China and South Africa.

Table 3 shows some descriptive statistics. Our overall data-set contains 984 observations for all variables, and for each country we have 115 observations available. Russia GDP per capita is the highest, followed by Brazil and South Africa. A similar pattern is found concerning GDP per capita.

Table-3
Descriptive statistics

| | GDP_BRAZIL | GDP_CHINA | GDP_INDIA | GDP_RUSSIA | GDP_AFRICA |
|---|---|---|---|---|---|
| Mean | 4568.334 | 1364.965 | 630.8584 | 4862.352 | 3237.878 |
| Media | 4403.812 | 1122.285 | 576.9295 | 4634.314 | 3108.044 |
| Maximum | 5721.290 | 3120.930 | 1085.729 | 6649.402 | 3825.094 |
| Minimum | 3911.571 | 452.7224 | 389.8141 | 3300.036 | 2903.200 |
| Std.Dev | 519.7677 | 807.5910 | 213.1174 | 1154.133 | 318.4666 |
| Skewness | 0.89 | 0.77 | 0.73 | 0.14 | 0.78 |
| Kurtosis | 2.74 | 2.44 | 2.37 | 1.57 | 2.04 |
| Sum | 105071.7 | 31394.19 | 14509.74 | 111834.1 | 74471.19 |
| Sum Sq.Dev | 5943486 | 14348470 | 999218.6 | 29304524 | 2231261 |
| Observation | 23 | 23 | 23 | 23 | 23 |

Source: authors calculated

## 7. Empirical results

*7-1-* Unit root tests

We begin our empirical analysis by testing for unit roots in the Carbon Emissions (CO) measured in kilotonnes, Trade Liberalization (L) and GDP per-capita. The implementation of unit root tests for both each series and the panel data is mainly due to the proven fact that individual tests have low power when they are applied to short series, while panel tests increase the power of contrasts (Perman and Stern, 1999).

In this paper we apply the LLC, Breitung, IPS, ADF, PP test. The results of the LLC, Breitung, IPS, ADF, PP panel unit root tests are presented in Table 4. The LLC, Breitung, IPS, ADF, PP statistics for the levels of Carbon Emissions (CO) measured in kilotonnes, Trade Liberalization (L) and GDP per-capita do not reject the null hypothesis of a unit root. However, we take the first difference of each of the variables. Therefore, we conclude that CO, L and GDP per-capita are each integrated of order one or I(1) and the variables are no stationary in the level for 5 countries. In the next stage, we will test whether there is a long-run equilibrium relationship among these three variables.

**Table 4- Results - Panel Unit Root Test (p-values), BRICS, 1960-2012**

| Variable / Method | CO | | L | | GDP | |
|---|---|---|---|---|---|---|
| | Without Trend | With Trend | Without Trend | With Trend | Without Trend | With Trend |
| H0: Unit root (common unit root process) | | | | | | |
| **LLC *t*** | **3.568** | **2.544** | **2.587** | **-0.258** | **7.976** | **6.823** |
| Level | (0.999) | (0.994) | (0.99) | (0.398) | (1.000) | (1.000) |
| First difference | -5.143* | -4.376* | -2.617 | -10.826* | -0.852 | -4.606* |
| | (0.000) | (0.000) | (0.000) * | (0.000) | (0.197) | (0.000) |
| **Breitung t-test** | ---------- | **1.227** | -------- | **1.115** | ---------- | **7.059** |
| Level | | (0.89) | | (0.867) | | (1.000) |
| First difference | ---------- | -0.887 | ---------- | -9.598* | ---------- | -2.365* |
| | | (0.187) | | (0.000) | | (0.009) |
| H0: Unit root (individual unit root process) | | | | | | |
| **IPS t-stat** | ---------- | **2.377** | ---------- | **-1.331** | ---------- | **6.114** |
| Level | | (0.99) | | (0.091) | | (1.000) |
| First difference | ---------- | -4.79* | ---------- | -12.124* | ---------- | -4.572* |
| | | (0.000) | | (0.000) | | (0.000) |
| **ADF-MW $\chi 2$** | **5.169** | **9.255** | **2.602** | **18.55** | **0.633** | **3.877** |
| Level | (0.879) | (0.508) | (0.989) | (0.046)** | (1.000) | (0.952) |
| First difference | 67.72* | 47.17* | 220* | 123.10* | 45.19 * | 44.67* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| **PP - MW $\chi 2$** | **3.845** | **12.36** | **2.653** | **22.57** | **0.688** | **3.594** |
| Level | (0.954) | (0.261) | (0.988) | (0.012) ** | (1000) | (0.963) |
| First difference | 70.005* | 47.53* | 308.11* | 377.51* | 52.04* | 44.86* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |

*,**: Null hypothesis rejected at 1% and 5% significant level

Source: authors calculated

7-2- Panel Cointegration Approach results

Taking into account these results, we conclude that the series are integrated of order one and proceed to test for cointegration. Thus the second stage involves testing for the existence of a long-run equilibrium relationship among Carbon Emissions (CO) measured in kilotonnes, Trade Liberalization (L) and GDP per-capita within a trivariate framework. Based on Kao's (1999) ADF test statistics reported in Table 5, According Table 5, we find that arbon Emissions (CO) measured in kilotonnes, Trade Liberalization (L) and GDP per-capita are cointegrated within the panel of these 5 countries.

Table 5- Results of Kao's Residual Cointegration Test

| | t-Statistic | Prob. |
|---|---|---|
| ADF | -1.592 | 0.0557 |

Source: author's estimations

Next given that the Kao test indicates cointegration, we can now estimate the long-run coefficients of the panel model. A central assumption in random effects estimation is the assumption that the random effects are uncorrelated with the explanatory variables. One common method for testing this assumption is to employ a Hausman (1978) test to compare the fixed and random effects estimates of coefficients. The Hausman test is frequently used in order to choose between the fixed effects and the random effects specification. The results of Husman test are presented in Table 6. Based on the Hausman test, the null hypothesis is rejected at the 1% significance. However this outcome suggests that fixed effect models are more appropriate, for all the following extensions, we present fixed effect regressions.

Table 6- Description of the Hausman test

| Hausman Test | $X^2$ . Statistic | P-values |
|---|---|---|
| Cross-section random | 62.362 | 0.0000 |

Source: authors' estimations

The results on the long-run coefficients are reported in Table 7. The empirical results reveal that in the long run that all of the coefficients are significant affect at %10.

## 8. Results

The equation (2) is estimated by the Panel Data methods. The time period covered in the estimations is 1960-2012 across BRICS Countries. Data are obtained from the World Bank's 2012 World Development Indicators' (WDI's) CD-Rom and Penn World Table (http://pwt.econ.upenn.edu/php_site/pwt63/pwt63_form.php).

In this paper, we analysis and investigate the relationship between CO 2 emissions, Trade Liberalization and economic growth which is a synthesis of the EKC and Liberalization literatures for BRICS Countries. In equation (2) we report the estimated coefficients of model using unbalance Panel method with period fixed effects. The Panel consists of 208 observations with 5 countries over the period 1960-2012.

$$\begin{aligned} \mathrm{Co}_{it} &= \underset{(3.734)}{0.932} + \underset{(6.262)}{0.00176}(\mathrm{GDP}_{it}) - \underset{(-4.455)}{0.000000167}(\mathrm{GDP}_{it}^2) + \underset{(1.667)}{0.0108}\mathrm{L}_{it} \\ \mathrm{R}^2 &= 0.96 \end{aligned} \qquad (2)$$

In parenthesis are presented the t-statistics. They show that all coefficients are statistically significant at 10 percent. Thus, the relationship between Trade Liberalization and CO2 emissions is positive except. However the positive coefficient of trade liberalization in the first area, indicate a positive effect of trade liberalization on pollution. The positive coefficient of liberalization effect that is represented by the sum of imports and exports as a share of total GDP has shown that BRICS countries has comparative advantage in dirty goods . This result indicates strong that a 1% increase in trade liberalization degree increases CO2 emissions per capita by 1.08% in BRICS Countries. Thus, free trade is bad for the environment. This can be explained by the fact that when the real per capita GDP is low, as in the case of the Developing countries, environmental concern is overshadowed by the pursuit of growth, which is the main objective of the economic policy. To this succeeds a second stage characterized by a slower degradation of the environment even when income increases. This fact can be explained by the realization by middle income countries to bracket, the environmental problem. This awareness may take the form of financial efforts allocated to the cleaning of water or air, grants or the creation of institutions that handle these cases. It can also take the form of new tax provisions requiring polluters to pay a certain fee, according to the principle of “polluter payers” or a variant of such a principle. Whatever its form, an effort should make lower the rate of degradation of the environment as this could be perceived by the above estimated equation. On average, over the studied BRICS countries, there is a positive relationship between CO2 emissions and real GDP per capita and a negative relationship between CO2 emissions and real GDP per capita quadratic: a 1% increase in real GDP per capita increases CO2 emissions per capita by 0.176% in the BRICS region. Taken together, our results are supportive of the EKC hypothesis in the BRICS region: the level of CO2 emissions first increases with income, stabilizes, and then declines. Thus, there appears to be an inverted U-shaped relationship between CO2 emissions per capita and real GDP per capita in the BRICS region when taken as a whole. The inflection point characterizing the end of the first phase and the beginning of the second must verify the following condition:

$$\frac{\delta \mathrm{Co}_{\mathrm{it}}}{\delta \mathrm{GDP}_{\mathrm{it}}} = \alpha_2 + 2\alpha_3 = 0$$

which corresponds to a real GDP per capita equal to $\frac{\alpha_2}{-2\alpha_3}$. For this, $\alpha_2$ and $\alpha_3$ must be of opposite sign. Our estimation shows that the inflection point or optimal point real GDP per capita is amounts to 5269.4. The result shows that mean all countries from the sample are on the positive side of the inverted U curve (see table 6 in the appendix).

## 9. Conclusion

The question of sustainability of growth in BRICS Countries has become of crucial economic importance. It’s obvious that a specific study for the relationship between growth, trade liberalization and environmental degradation in the BRICS Countries becomes central for policymakers. The pattern of sustainability for the region must be examined.

Our article had two aims. First, we investigate the existence of EKC in the BRICS region in the matter of Carbon dioxide. Second, we in this paper explore the relationship between economic growth, trade liberalization and emissions of CO2 by implementing unit root tests and panel cointegration techniques to investigate the relationship between carbon dioxide emissions, trade liberalization, and real GDP per capita for 5 BRICS countries over the period 1960–2012.

Several Studies have examined the relationship between Environmental quality and Growth. The basic idea behind the Environmental Kuznets Curve (EKC) is that economic growth degraded environment quality in a first stage. But the picture change until a turning point and environmental quality is growth improves the Environmental Quality. Since that environmental quality is a U shaped curve. Three theoretical explanations are provided in order to explain this dynamics. Firstly, Growth impacts tastes of economic agents to a more environmental friendly products and production process. Citizen and consumers’ awareness about environment induce a big change in the Market dynamics. Secondly, Innovation and technological change lead to use more friendly technologies and process following the market opportunities. Thirdly, economic growth leads to the set up of organizations, institutions and capacities in order to manage environmental problems. This new setting improves the situation through their action in order to enhance democratic decision-making, secure property rights, enforce contracts and act as ramparts against corruption.

Our results show that in the long run, trade liberalization has a positive significant impact on CO2 emissions. However, if a country's income level is not high enough for it to care about the environment, then trade liberalization is likely to be an important factor influencing the deterioration of the quality of the environment. Thus, the level of a country's economic development had considerable influence on CO2 emissions. More interestingly, we show that real GDP exhibits a quadratic relationship with CO2 emissions. Taken together, our findings support an inverted U-shape pattern associated with the Environmental Kuznets Curve (EKC) hypothesis for the BRICS region: CO2 emissions increase with real GDP, stabilize, and then decrease. We find a turning point at $5269.4 in the estimated result, but the EKC turning points are highest of average real GDP per capita level in BRICS countries. Thus, our findings suggest that all BRICS countries need to sacrifice economic growth to decrease their emission levels as they may achieve CO2 emissions reduction via energy conservation without negative long run effects on economic growth.

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**Table 1a: Panel unit root tests for the carbon dioxide emissions (1960-2012)**

Group unit root test: Summary
Series: CO_BR, CO_CH, CO_IN, CO_RU, CO_SO
Date: 10/08/13 Time: 17:05
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 1
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | 2.54422 | 0.9945 | 5 | 210 |
| Breitung t-stat | 1.22750 | 0.8902 | 5 | 205 |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | 2.37734 | 0.9913 | 5 | 210 |
| ADF - Fisher Chi-square | 9.25553 | 0.5080 | 5 | 210 |
| PP - Fisher Chi-square | 12.3603 | 0.2617 | 5 | 213 |

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: CO_BR, CO_CH, CO_IN, CO_RU, CO_SO
Date: 10/08/13 Time: 17:05
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 1
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | 3.56872 | 0.9998 | 5 | 210 |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 5.16928 | 0.8796 | 5 | 210 |
| PP - Fisher Chi-square | 3.84501 | 0.9541 | 5 | 213 |

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

**Table 1b: Panel unit root tests for 1st difference the carbon dioxide emissions (1960-2012)**

Group unit root test: Summary
Series: CO_BR, CO_CH, CO_IN, CO_RU, CO_SO
Date: 10/08/13 Time: 17:06
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 1
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -5.14353 | 0.0000 | 5 | 207 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 67.7229 | 0.0000 | 5 | 207 |
| PP - Fisher Chi-square | 70.0050 | 0.0000 | 5 | 208 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: CO_BR, CO_CH, CO_IN, CO_RU, CO_SO
Date: 10/08/13 Time: 17:06
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -4.37464 | 0.0000 | 5 | 208 |
| Breitung t-stat | -0.88771 | 0.1873 | 5 | 203 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | -4.79039 | 0.0000 | 5 | 208 |
| ADF - Fisher Chi-square | 47.1751 | 0.0000 | 5 | 208 |
| PP - Fisher Chi-square | 47.5394 | 0.0000 | 5 | 208 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

**Table 2a: Panel unit root tests for real GDP per capita (1960-2012)**

Group unit root test: Summary
Series: GDP_BR, GDP_CH, GDP_IN, GDP_RU, GDP_SO
Date: 10/08/13 Time: 17:07
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 5
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | 7.97669 | 1.0000 | 5 | 223 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 0.63372 | 1.0000 | 5 | 223 |
| PP - Fisher Chi-square | 0.68876 | 1.0000 | 5 | 230 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: GDP_BR, GDP_CH, GDP_IN, GDP_RU, GDP_SO
Date: 10/08/13 Time: 17:07
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 5
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | 6.82338 | 1.0000 | 5 | 224 |
| Breitung t-stat | 7.05927 | 1.0000 | 5 | 219 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | 6.11482 | 1.0000 | 5 | 224 |
| ADF - Fisher Chi-square | 3.87715 | 0.9527 | 5 | 224 |
| PP - Fisher Chi-square | 3.59482 | 0.9638 | 5 | 230 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

**Table 2b: Panel unit root tests for 1st difference real GDP per capita (1960-2012)**

Group unit root test: Summary
Series: GDP_BR, GDP_CH, GDP_IN, GDP_RU, GDP_SO
Date: 10/08/13 Time: 17:08
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 3
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -0.85210 | 0.1971 | 5 | 222 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 45.1932 | 0.0000 | 5 | 222 |
| PP - Fisher Chi-square | 52.0404 | 0.0000 | 5 | 225 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: GDP_BR, GDP_CH, GDP_IN, GDP_RU, GDP_SO
Date: 10/08/13 Time: 17:07
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -4.60616 | 0.0000 | 5 | 225 |
| Breitung t-stat | -2.36526 | 0.0090 | 5 | 220 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | -4.57219 | 0.0000 | 5 | 225 |
| ADF - Fisher Chi-square | 44.6759 | 0.0000 | 5 | 225 |
| PP - Fisher Chi-square | 44.8625 | 0.0000 | 5 | 225 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

**Table 3a: Panel unit root tests for Trade Liberalization index (1960-2012)**

Group unit root test: Summary
Series: L_BR, L_CH, L_IN, L_RU, L_SO
Date: 10/08/13 Time: 13:50
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 2
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | 2.58749 | 0.9952 | 5 | 216 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 2.60270 | 0.9893 | 5 | 216 |
| PP - Fisher Chi-square | 2.65307 | 0.9885 | 5 | 219 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: L_BR, L_CH, L_IN, L_RU, L_SO
Date: 10/08/13 Time: 13:50
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 3
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -0.25834 | 0.3981 | 5 | 215 |
| Breitung t-stat | 1.11575 | 0.8677 | 5 | 210 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | -1.33169 | 0.0915 | 5 | 215 |
| ADF - Fisher Chi-square | 18.5528 | 0.0463 | 5 | 215 |
| PP - Fisher Chi-square | 22.5769 | 0.0124 | 5 | 219 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

**Table 3b: Panel unit root tests for 1st difference Trade Liberalization index (1960-2012)**

Group unit root test: Summary
Series: L_BR, L_CH, L_IN, L_RU, L_SO
Date: 10/08/13 Time: 13:50
Sample: 1960 2012
Exogenous variables: None
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 4
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -12.6177 | 0.0000 | 5 | 209 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| ADF - Fisher Chi-square | 220.000 | 0.0000 | 5 | 209 |
| PP - Fisher Chi-square | 308.118 | 0.0000 | 5 | 214 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Group unit root test: Summary
Series: L_BR, L_CH, L_IN, L_RU, L_SO
Date: 10/08/13 Time: 13:51
Sample: 1960 2012
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 4
Newey-West bandwidth selection using Bartlett kernel

| Method | Statistic | Prob.** | Cross-sections | Obs |
|---|---|---|---|---|
| Null: Unit root (assumes common unit root process) | | | | |
| Levin, Lin & Chu t* | -10.8264 | 0.0000 | 5 | 210 |
| Breitung t-stat | -9.59865 | 0.0000 | 5 | 205 |
| | | | | |
| Null: Unit root (assumes individual unit root process) | | | | |
| Im, Pesaran and Shin W-stat | -12.1247 | 0.0000 | 5 | 210 |
| ADF - Fisher Chi-square | 123.107 | 0.0000 | 5 | 210 |
| PP - Fisher Chi-square | 377.518 | 0.0000 | 5 | 214 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

**Table 4: Hausman Test results**

Correlated Random Effects - Hausman Test
Pool: POOL01
Test cross-section random effects

| Test Summary | Chi-Sq. Statistic | Chi-Sq. d.f. | Prob. |
|---|---|---|---|
| Cross-section random | 62.362845 | 3 | 0.0000 |

Cross-section random effects test comparisons:

| Variable | Fixed | Random | Var(Diff.) | Prob. |
|---|---|---|---|---|
| (GDP?) | 0.001763 | 0.001642 | 0.000000 | 0.2357 |
| (GDP?^2) | -0.000000 | -0.000000 | 0.000000 | 0.0758 |
| (L?) | 0.010832 | 0.018427 | 0.000004 | 0.0001 |

Cross-section random effects test equation:
Dependent Variable: CO?
Method: Panel Least Squares
Date: 10/08/13 Time: 17:28
Sample (adjusted): 1960 2009
Included observations: 50 after adjustments
Cross-sections included: 5
Total pool (unbalanced) observations: 208

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.932189 | 0.249634 | 3.734226 | 0.0002 |
| GDP? | 0.001763 | 0.000282 | 6.262917 | 0.0000 |
| GDP?^2 | -1.67E-07 | 3.74E-08 | -4.455666 | 0.0000 |
| L? | 0.010832 | 0.006495 | 1.667817 | 0.0969 |

Effects Specification

Cross-section fixed (dummy variables)

| | | | |
|---|---|---|---|
| R-squared | 0.967739 | Mean dependent var | 3.946206 |
| Adjusted R-squared | 0.966610 | S.D. dependent var | 3.845503 |
| S.E. of regression | 0.702684 | Akaike info criterion | 2.169883 |
| Sum squared resid | 98.75290 | Schwarz criterion | 2.298250 |
| Log likelihood | -217.6678 | Hannan-Quinn criter. | 2.221788 |
| F-statistic | 857.0716 | Durbin-Watson stat | 0.121604 |
| Prob(F-statistic) | 0.000000 | | |

**Table 5: Panel cointegration between carbon dioxide emissions , real GDP per capita and trade liberalization (1960-2012)**

Kao Residual Cointegration Test
Series: CO? GDP? L?
Date: 10/08/13 Time: 17:25
Sample: 1960 2012
Included observations: 53
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Lag selection: fixed at 1
Newey-West bandwidth selection using Bartlett kernel

| | t-Statistic | Prob. |
|---|---|---|
| ADF | -1.592244 | 0.0557 |
| Residual variance | 0.055827 | |
| HAC variance | 0.077805 | |

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID?)
Method: Panel Least Squares
Date: 10/08/13 Time: 17:25
Sample (adjusted): 1962 2009
Included observations: 48 after adjustments
Cross-sections included: 5
Total pool (unbalanced) observations: 198

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RESID?(-1) | -0.074699 | 0.024917 | -2.997935 | 0.0031 |
| D(RESID?(-1)) | 0.142380 | 0.077153 | 1.845427 | 0.0665 |

| | | | |
|---|---|---|---|
| R-squared | 0.054618 | Mean dependent var | 0.009878 |
| Adjusted R-squared | 0.049795 | S.D. dependent var | 0.248602 |
| S.E. of regression | 0.242333 | Akaike info criterion | 0.013042 |
| Sum squared resid | 11.51016 | Schwarz criterion | 0.046257 |
| Log likelihood | 0.708807 | Hannan-Quinn criter. | 0.026487 |
| Durbin-Watson stat | 1.718207 | | |

### Table 6: Panel estimation results

Dependent Variable: CO?
Method: Pooled Least Squares
Date: 10/13/13 Time: 18:23
Sample (adjusted): 1960 2009
Included observations: 50 after adjustments
Cross-sections included: 5
Total pool (unbalanced) observations: 208

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.932189 | 0.249634 | 3.734226 | 0.0002 |
| GDP? | 0.001763 | 0.000282 | 6.262917 | 0.0000 |
| GDP?^2 | -1.67E-07 | 3.74E-08 | -4.455666 | 0.0000 |
| L? | 0.010832 | 0.006495 | 1.667817 | 0.0969 |
| Fixed Effects (Cross) | | | | |
| _BR--C | -3.773822 | | | |
| _RU--C | 5.435004 | | | |
| _IN--C | -1.102123 | | | |
| _CH--C | 0.002672 | | | |
| _SO--C | 2.917207 | | | |

Effects Specification

Cross-section fixed (dummy variables)

| | | | |
|---|---|---|---|
| R-squared | 0.967739 | Mean dependent var | 3.946206 |
| Adjusted R-squared | 0.966610 | S.D. dependent var | 3.845503 |
| S.E. of regression | 0.702684 | Akaike info criterion | 2.169883 |
| Sum squared resid | 98.75290 | Schwarz criterion | 2.298250 |
| Log likelihood | -217.6678 | Hannan-Quinn criter. | 2.221788 |
| F-statistic | 857.0716 | Durbin-Watson stat | 0.121604 |
| Prob(F-statistic) | 0.000000 | | |