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Does Trade Openness Always Cause Cleaner Production? Evidence from newly Industrialized Economies

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Evidence from newly Industrialized Economies

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Abstract:

This paper applies Pedroni's panel cointegration approach to explore the causal relationship between trade openness, CO_2 emission, energy consumption and economic growth (real GDP) for the panel of newly industrialized economies, over the period of 1970–2013. Our panel cointegration estimation results found majority of variables are cointegrated, and Granger causality test indicates bi-directional causality between CO_2 emission and energy consumption, unidirectional causality is running from trade openness to CO_2 emission and energy consumption, and economic growth to CO_2 emission. The Causality results suggest that in short-run, trade liberalization in newly industrialized economies induces higher energy consumption and CO_2 emission. Further, the causality results are checked using innovative accounting approach (variance decomposition test) and impulse response function. The long-run association of variables is tested by employing FMOLS (Fully Modified OLS) test, where trade openness and economic growth reduces the CO_2 emission in long-run. The results of FMOLS test sounds the existence of EKC (environmental Kuznets Curve) hypothesis. It means, trade liberalization induces CO2 emission with increased national output, but it offsets that impact in long-run with reduced level of CO2.emission.

Introduction

Over the last few decades, the global economy has observed spectacular growth trend. This growth trend is mainly associated with the liberalization of trade started with the establishment of GATT[1] and later WTO[2]. The reduced trade barriers and technological advancement not only contribute to growth in trade, but also increased overall world production simultaneously. Trade openness has helped both developing and developed economies to grow with faster pace. Many

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[1] General Agreement of Trade and Tariffs (GATT) came in to force on January 1, 1948.

[2] World Trade Organization (WTO) commenced on January 1, 1995 under Marrakesh Agreement and replaced GATT

of the developing economies opened their borders in order to attain economic development via trade openness. Some of these developing economies even grew exceptionally faster than many of the industrialized economies. In 2013, emerging economies account more than half of the world GDP (IMF, 2013). The group of these countries is referred as BRICS[3]. BRICS combines holds 40% of world population, accounts 20% of world gross domestic production (GDP) and overall represents 18% of the world economy. However, this rapid growth trend has come along with severe environmental consequences. The huge expansion in world merchandise trade (as mentioned in Figure-1) means more production, and the establishment of more industrial units. Thus far and wide expansion in world aggregates output demands for higher energy resources which are referred as the potential source of carbon dioxide (CO_2) emissions. Figure-2 shows an increase in world CO_2 emissions trend from 1948 to 2010. It is projected that by 2030, developing countries will share 72% of global emissions, mainly arising from industrial output (World Bank, 2008), and primary energy consumption is expected to grow by 72% in BRICS region alone (OECD, 2008). Moreover, the global efforts towards multilateral agreements on climate change and trade-environment policies are facing consecutive failure and major opposition is coming from these newly industrialized countries. This policy conflict can also be noticed among trade and environmental scientists. Trade block believes that trade openness leads to cleaner production with technological dissemination among advanced and developing economies with reduced cost and efficient resource allocation using comparative advantage.

However, environmentalists have been blaming trade openness as a key source of negative impacts of climate change and environmental degradation since the trade liberalization has got momentum. Whether trade induce cleaner production or not, the empirical evidences from literature are also contradictory. The results vary country to country, region to region and as per income levels. Therefore, the study of the links between trade openness, CO_2 emissions, energy consumption and economic growth have been of primary interests of development economists, environmental agencies, governments and production processes. Similarly, the main motivation to conduct this research is to investigate the relationship between trade openness and carbon emissions by incorporating energy consumption and economic growth as potential determinants playing key role in CO_2 emissions function for case of newly industrialized BRICS economies.

Figure-1: World Merchandise Exports (1948-2013)

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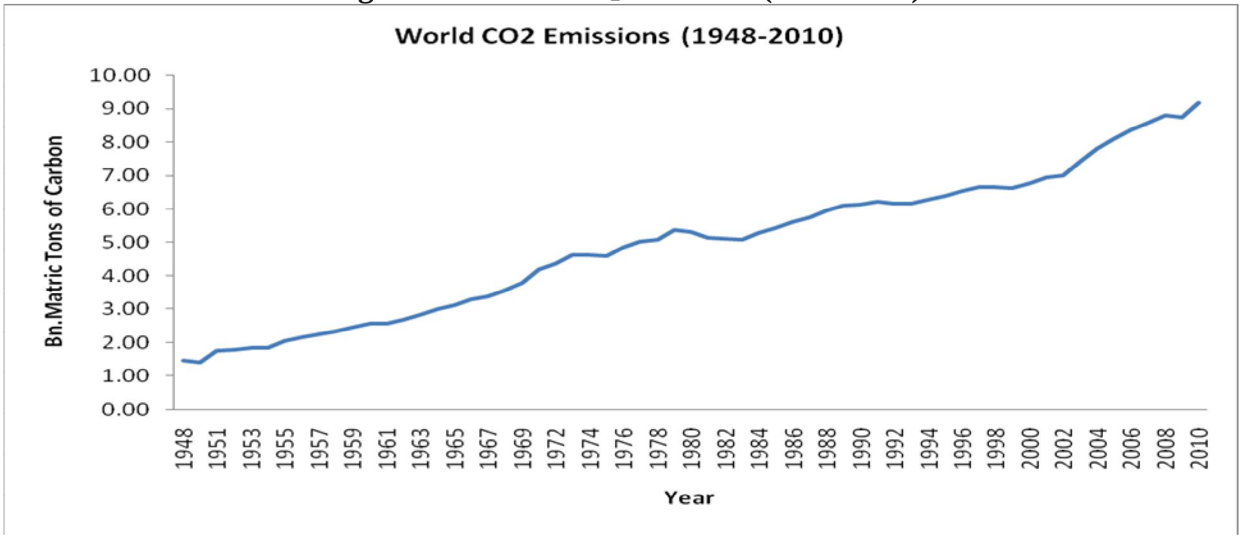
[3] BRICS (Brazil, Russia, India, China, South Africa)

Source: World Bank WDI-2013

Figure-2: World CO_2 Emission (1948-2010)



Source: Carbon Dioxide Information Analysis Center http://cdiac.ornl.gov (U.S-Department of Energy)

It is mutually agreed point between development and environmental researchers that growing environmental degradation due to increased emissions are the main cause of harming earth's health. This continued trend will have unrecoverable implications for ecology and biodiversity as whole. Therefore, the economy's goal now is just not to attain higher production, but also to achieve the sustainable development (cleaner production). Sustainable development is directly associated with the use of sustainable and renewable energy resources based on newer technology. The free movement of such technological resources needs sufficient trade openness between economies. This thread is actually a conceptual development that literature up to date has suggested. The literary debate on the relationship between trade openness and environmental degradation is a decade long. This debate is spread over the arguments based on both theoretical and empirical studies, but found contradictory results in equal proportion (Cole and Elliott, 2003). There are a number of empirical studies on the relationship of trade-environment-growth nexus i.e. (Cole and Elliott, 2003; Frankel and Rose, 2005; Managi et al. 2008) but very few are based on theoretical framework i.e. (Antweiler et al. 2001; Copeland and Taylor, 2004). The trade and environmental economist are still at the crossroads of deciding what cause what in an economy because of the bias results (Shahbaz et al. 2014). The recent literature mainly suggests that either single economy analysis or economies belonging to similar income level are most suitable to analyze trade-environmental-growth nexus. Hence, the results of such studies are more reliable for policy use. The argument that trade liberalization support efficient use of resources while contributing sustainable growth could make an essential contribution towards improved environmental conditions. But the question whether the structural transition in BRICS allows trade openness to counter negative environmental implications over the time, formulates a real research question and to be addressed in this study.

The BRICS countries are the current manufacturing engine of world economy. Their contribution towards global production is increasing sizably. The future projections regarding their energy consumption and emissions trend have global environmental impacts. Moreover, in the absence of significant multilateral agreement on environment necessitate further digging of literary work and conducting empirical investigation in order to assess the impact of trade openness on future economic growth. This study uses trade openness, energy consumption and economic growth as independent variables and carbon dioxide emissions as an endogenous variable used as a proxy variable for cleaner production. This study aims to use Pedroni panel cointegration approach to cointegration on time series data (1970-2012). This econometric approach tells us the individual relationship of all cointegrating vectors and also the relationship of the endogenous variable with underlying control variables. The long-run association among variables is also checked using FMOLS model. The sensitivity of the model is also checked using diagnostic test to see the stability and fitness of the model.

The endogenous variable tells us possible how GHG emissions and why we choose several empirical studies have been conducted on the relationship between trade openness and environmental degradation. However, there are very few empirical studies on environmental degradation based on theoretical framework. The trade economists and environmentalists argue that liberalization of trade through the efficient use of resources and sustaining growth could make an essential contribution towards creating the conditions necessary for environmental improvements. They also argue that trade liberalization and environmental policies will generate benefits through improving allocative efficiency, correcting market failures, and strengthening the potential of internalization of environmental instruments. In fact, the wealth created by trade liberalization will also improve the quality of life and eliminate poverty, which has been considered as an underlying cause of environmental degradation in many developing countries. The evidences of trade openness on environmental degradation from individual countries vary according to their income levels and this may happen due to difference in policy, economic structure, level of economic openness and country specific variations (Baek et al. 2009; Naranpanawa, 2011; Wiebe et al. 2012; Forslid et al. 2014).

The most worrying thing on this stage is the conflict oriented situation between trade and climate economists. The policy deadlock between high and low income countries is widening as table talks suffer more failures. It is projected that the advance countries will limit the trade of lower income countries to control carbon leakages. As discussed by Messerlin, (2010); Ahmed and

Long, (2013b) trade and climate change policies are interdependent and due to the global externality effect, the trade-climate policies will either suffer from mutual destruction or mutual construction. Consequently, the unilateral measures towards trade restriction from advanced economies to emerging economies would result in division of global economies in clean and dirty production heavens. The neoclassical model theoretically defines that how trade liberalization expands cleaner and dirty production due to income differences. It implies that the environmental impacts of trade opening are opposite on high and low income countries (for more details see Copeland and Tylor, 1995). There is series of literature available on the single country analysis of trade-and CO_2 emissions nexus, but to assist global surge towards multilateral agreement on climate change policy using the world trading system requires meta-analysis. During the upcoming trade-climate negotiations, the regional and income leveled group of countries will have more importance. Similarly, the adoption of the trade-environment policy will also be based on group of countries not unilateral. Therefore, this notion suggests that there is need of panel data analysis on the relationship of trade openness and CO_2 emissions. In order to fill such literary gap, this study utilizes panels of high, middle and low income countries to empirically examine the causal behavior of trade openness and CO_2 emissions. The most appropriate technique for panel cointegration proposed by Pedroni, (1999) is incorporated with Granger causality approach of Engle and Granger, (1987) to find out causal relationships between trade openness and CO_2 emissions for underlined panels.

The remaining paper is divided as; section (II) presents in brief literature review, section (III) is methodological framework, section (IV) discusses the results, and section (V) presents the conclusion and policy recommendations. The findings of this paper are highly significant and possess deep policy implications for countries included in the panels, international trade and environmental agencies, regional economic blocks and researchers. This study opens future directions as well.

II. Review of Relevant Literature

The trade-environment-growth nexus is emerged with the concept of environmental Kuznets's curve (EKC) hypothesis in early 1990's. The concept of EKC is derived from the work of Simon Kuznets, 1955 who explored that there is inverted-U shaped relationship between income and inequality. He proposed with initial economic growth, inequality rises, but after certain threshold point inequality diminishes. The same is replicated for the environment and growth nexus. The seminal study of Grossman and Krueger, (1991) first examined the environmental consequence of NAFTA[4] using the EKC hypothesis and opened the new research direction in the relationship of economic growth and environment. However, the EKC hypothesis are widely accepted and used in many scholarly literature soon after the Earth summit[5] held in Rio-de-Janeiro (Brazil) and subsequent contribution of Shafik and Bandyopadhyay, (1992) in the background study for the World Development Report (1992) granted more recognition to EKC. The report concluded that the environmental quality is an essential indicator of sustainable development. Later, the concept of the EKC is widely accepted and further indicators of growth and environment are investigated (David Stern, 2004). The literature on trade, environment and growth are further advanced with the use of pollution haven hypothesis (Eskeland Harrison, 2003; Kearsley and

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[4] North American Free Trade Agreement (NAFTA)

[5] Also known as Rio-Summit organized by United Nations at Rio-de-Janeiro (Brazil) from 3~14 June, 1992

Riddel, 2010). However, the results of both the studies on the EKC hypothesis and pollution hypothesis remained inconclusive whether trade contribute to lower environmental quality (for EKC hypothesis see, Grossman and Krueger, 1991; Shafik, 1994; Soytas et al. 2007; Ang, 2007 and pollution heaven hypothesis see, Copeland and Taylor, 2004; Kearsley and Riddel, 2010). On the other hand, Frankle and Rose, (2005) found positive and statistically significant correlation between trade openness and measures of environmental quality (NO_2 and SO_2) but using the same technique Kellenberg, (2008) found mixed evidence on the relationship between trade openness and four pollutants (NO_2, SO_2, CO_2 and VOCs). But the connection between trade openness and environmental degradation seems to be mostly influenced by economic structure, level of income and quantitative technique adopted in the studies. First, on the basis of economic structure the study of Antweiler et al. (2001) explored trade-environment nexus in terms of three broad categories[6] involved in production processes; scale, technique and composition effects. Keeping in view of the environmental repercussions of trade openness, composition effect dominates scale effect and technique effect dominates both scale and composition effect. It means the economy in which scale effect is dominating has the largest tendency of emissions intensive growth. Composition effect lies in middle and technique effect is the least emissions intensive hence, contribute to cleanest production (for more details on scale, composition and technique effect refer; Grossman and Krueger, 1993; Lopez, 1994). The further evidence from Kahuthu, (2006) based on the methodological framework of Shafik and Bandyopadhyay, (1992); Selden and Song, (1994) found that composition effect of trade openness could have positive or negative environmental consequences depending on the relative size of capital-labor effect and existing environmental regulations in the economy.

Secondly, the study of Frankel, (2008) analyzes the same income level sample test on SO_2 emissions, trade openness and economic growth and found results quite similar to Grossman and Krueger, (1993); Selden and Song, (1993); Suri and Chapman, (1998). Similarly, as noted from the Kahuthu, (2006) change in terms of trade alters the composition of trade. Therefore, if the trading partners belong to different income levels, effect travels in the opposite direction. For example: if trade flows from developing country to a developed country, it increases emissions intensity in developing country but reduces in developed country. The study of Cole, (2004) examines the trade-environment impact of OECD and non-OECD countries and validates this notion with 'pollution haven hypotheses'. Managi et al. (2009) re-visited the trade-environment nexus for OECD and non-OECD countries using different estimation technique on two pollutants (SO_2 and CO_2) and found identical results to Cole, (2004). The further contribution to trade environment literature considering change in the EKC's of countries with changing trade patterns is recently studied by Managi and Jena, (2008); Ahmed and Long, (2013a). Thirdly, the quantitative techniques and methodology utilized for the analysis of trade and its environmental repercussions has a sufficient role in contradictory results. Therefore, while comparing the empirical results and cross-policy analysis of environmental consequence of trade openness, the methodological framework possesses important consideration [Suri and Chapman, (1998); Copeland and Taylor, (2003); Duro and Padilla, (2006); Pan et al. (2008); Hossain, (2011); Qazi et al. (2012); Shahbaz et al. (2013); Ahmed and Qazi, (2014)]. For example: the study of Grossman and Krueger, (1991) used a random effects model to estimate the three pollutants and

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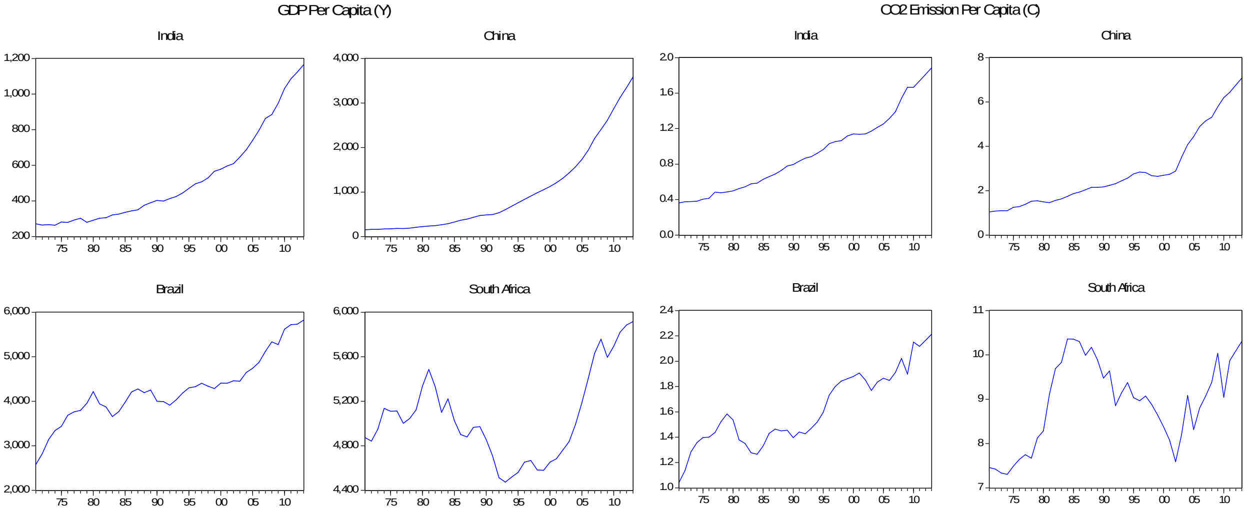
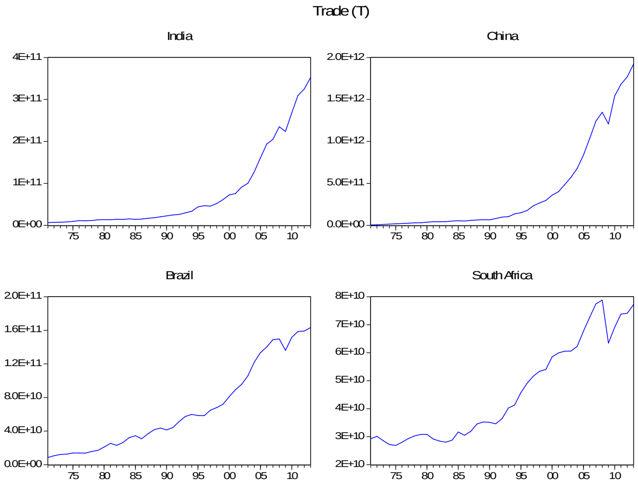
[6] These three categories were identified by Grossman and Krueger, (1993) and explained by Lopez, (1994) that growth in the economy can be observed due to the prevalence of these effects.

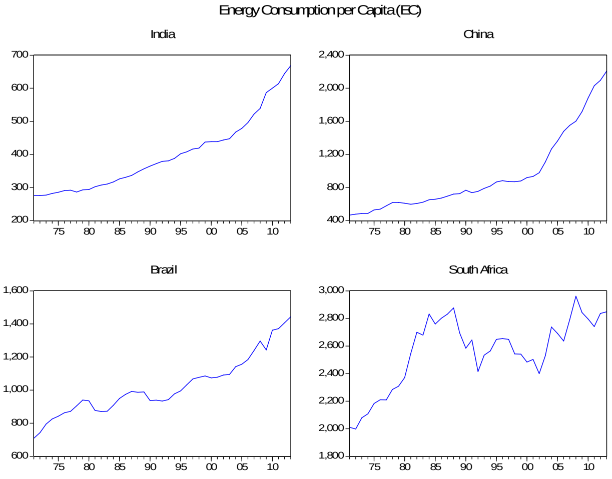
found SO_2 statistically significant. However, Seldon and Song, (1994) conducted a similar study on four pollutants using cross-national panel data and found all four pollutant exhibits inverted-U shaped relationship. The later study of Suri and Chapman, (1998) incorporates the actual movement of goods between industrializing and industrialized countries. Their study uses pooled cross-section time series data and reveals that manufacturing goods are imported from industrializing countries the curve moves downward and shows improving environmental conditions. Nevertheless, Birdsall and Wheeler, (1994) using case study method on Latin America concluded that the protected economies favor emissions intensive industries. On pollution havens, Mani and Wheeler, (1998) opine that the pollution havens are as transient as low wage havens, because the counter-vailing effects contribute to cleaner production through technical efficiency and tougher environmental regulations. Meanwhile, criticism on both growth-environment relationship and methodology continued simultaneously. A survey study of Dinda, (2004) explains the progress of economic development in three stages. It starts with agrarian economy and attains pollution intensive industrial economy and then turns to clean service economy. Multivariate economic analyses of Cole et al. (2005) validate the analysis of Dinda, (2004) and found developing countries as consistent pollution havens and hence contribute to dirty production. It is mainly because of FDI inflow from developed countries. Nevertheless, recent literature shows consistent results due to improved methodology and empirical techniques for single country analysis [Wacziarg and Welch, (2008); Jalil and Mahmud, (2009); Fodha and Zaghdoud, (2010); Peters et al. (2011); Sadorsky, (2012); Shahbaz et al. (2013) and Kawahara, (2014)] but cross-country and panel data estimation requires further investigation.

Keeping in view of the past literature, this study is uniquely designed while selecting the data set and methodological framework. The BRICS countries are opted on the basis of income level, their profile in terms of trade volume, production and future emissions, and having similarity in economic structure. The literary debate on the relationship of trade openness and CO_2 emissions started with the advent of industrialization. The last three decades have witnessed the most proliferating period of trade openness. The world economy has grown at its fastest rate in human history. The fruits of globalization disseminated far and wide and many of developing economies transformed into developed phase, and many are in the process. The future projections are quite healthy and global surge to eradicate poverty and boosting world economy uniformly provide confidence to such projections. However, this industrialization and globalization has come with certain cost and that cost is environmental health. Undoubtedly, the globalization has expanded the world trade in manifolds and contributed consecutive growth trend with smooth technology transfer, financial development, fast communication and ease of mobility of goods and services with geographical and comparative advantage amongst the economies. The world production has increased by 500% during last thirty years. This production process becomes possible with the combustion of land and energy resources. Simultaneously the emissions of CO_2 in earth's atmosphere is concentrated to such extend that its negative impacts are highly damaging and deteriorating to eco-system. The frequent occurrence of natural disasters, disease breakout, and extinction of hundreds of living species has raises questions for researchers. However, the scholarly community of divided in to two main school of though. Some support trade liberalization as the key source during last decades that helped million of people to come out of poverty and disseminate the growth fruits and equally distribution of resources. On the other hand, the environmentalists argue that globalization has took us at that stage where we need to care global environment which is a global externality and re-shape the policies of trade with the compatibility of environmental friendly. This division is not just on the basis of theoretical background but the research conducted on the relationship of trade openness and emissions trend has shown different and biased results. There are some studies which show that trade openness contribute to emissions and some does not. Some argue that the structure of economy is much more important for the cause and effect of technical development and has been the central due to opening of trade relationship (Topalova and Khandelwal, 2011; Copeland and Taylor, 2013; Shahbaz et al. 2013). Some argued that the methodology used to conduct such study also released biased results (Managi, 2009; Hossain, 2011; Ahmed and Long, 2013; Shahbaz et al. 2014; Ahmed et al. 2014. The single and multi-country analysis and regional studies have also shown different outcomes (Mazzanti et al. 2008; Lee et al. 2009; Hossain, 2011; Jalil and Faridun, 2011; Shahbaz et al. 2012).

Nevertheless, there is still wide gap persist in literature on trade-environment nexus discussed by Dinda, 2004 and later proceeded by Managi and Jena, 2008. The empirical investigations on trade-environment nexus are not sufficient is ample literature available on growth and environment (e.g. Grossman and Krueger, 1991) debate during the since trade liberalization and contributes. Till today, trade liberalization has widely contributed in the mid of twentieth century. With the opening of economies, it is commonly believed that trade benefited both for developed and developing countries and as a result, more countries are now moving towards liberal trade regimes to enhance their economic growth.







III. Model Construction and Data Collection

Economic growth, trade openness and energy consumption are widely used determinants of environmental quality. Environmental quality is a set of characteristics of air, noise and water pollution. Four types of indicators are commonly used to measure different pollutants: (i) emissions per capita, (ii) emissions per gross domestic product (pollution intensity), (iii) ambient levels of pollution (concentrations; impacts on a certain area) and (iv) total emissions. In panel data studies, the most frequently used indicator for pollution is CO_2 emissions per capita (see Arouri et al. 2012; Han and Lee, 2013; Omri, 2013). The present study uses CO_2 emissions per capita (C_{it}) to measure environmental pollution. Real GDP per capita (Y_{it}) is used to measure economic growth (US$). The indicator of trade openness (TR_{it}) is defined as export plus import divided by population i.e. total volume of trade per capita (US$). Energy consumption in kg of oil equivalent per capita is used to measure energy consumption (E_{it}). All variables are in natural logarithm. The review of literature leads us to formulate following empirical model:

$$C_{it} = \alpha_1 + \alpha_2 Y_{it} + \alpha_3 FD_{it} + \alpha_4 TR_{it} + \alpha_5 E_{it} + \mu_i \qquad (1)$$

The BRICS countries are selected for the estimation of causality between CO_2 emissions and trade openness on the basis of data availability over the period of 1970-2013. All necessary data for the sample period are obtained from World development Indicators (CD- ROM, 2013).

III.I Cross Sectional Dependence Tests

Trade liberalization insinuates interdependence of countries via import and export phenomena. Because the goods and services produced and traded in a well defined and systematic process, technically statistical analysis foresee the possibility unobserved common shocks in cross-sections of our panel. Later, these unobserved shocks become the integrated part of residual and give inconsistent standard error [De Hoyos and Sarafidis, (2006); Driscoll and Kraay, (1998)]. The cross-sectional dependence is tested by applying two different but appropriate parametric tests proposed by Friedman, (1937) and Pesaran, (2007). The tests' specification is as follow:

Freidman's statistics compute:

$$R = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{r}_{ij} \qquad (2)$$

Where $\hat{r}$ is the spearman's rank correlation coefficient

$$r_{ij} = r_{ji} = \frac{\sum_{t=1}^{T} \left(r_{it} - (T+1/2)\right)\left(r_{jt} - (T+1/2)\right)}{\sum_{t=1}^{T} \left(r_{it} - (T+1/2)\right)^2}$$ of the residuals.

Pesaran's statistics compute:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right) \qquad (2)$$

Where $\hat{\rho}_{ij}$ is the estimate of;

$$\rho_{ij} = \rho_{ji} = \frac{\sum_{t=1}^{T} \varepsilon_{it} \varepsilon_{jt}}{\left(\sum_{t=1}^{T} \varepsilon_{it}^2 \right)^{1/2} \left(\sum_{t=1}^{T} \varepsilon_{jt}^2 \right)^{1/2}} \qquad (3)$$

The null hypothesis to be tested as: $\rho_{ij} = \rho_{ji} = corr(\varepsilon_{it}, \varepsilon_{jt}) = 0$ for i ≠ j and the alternative hypothesis to be tested is $\rho_{ij} = \rho_{ji} \neq 0$ for some i ≠ j.

III.II Panel unit root tests

This study applies cointegration test to see the long-run association among all underlying vectors (i.e. CO_2 emissions, trade openness, energy consumption and economic growth) on time series data. Time series data require unit root tests of all the variables to ensure that the variables are non-stationary. Therefore, it is now a standard approach in time series analysis to apply unit root test prior to cointegration test. There are number of unit root tests proposed by Levin and Lin (1993); Hansen, (1995); Im, Pesaran and Shin, (1997); Madala and Wu, (1999); and Levin et al. (2002). We utilize panel covariate-augmented Dickey Fuller (*p* CADF) test for unit root originally developed in Hansen, (1995) and not to be confused with Pesaran, (2007). The Pesaran's test explicitly addresses the problem of cross-sectional dependence. The *p-CADF* is further generalizing for individual unit root testing and applicable even in the presence of cross-section dependence (Hartung, 1999) due to asymptotic used and does not require N→∞ (Choi, 2001). Hence, this approach is easily computable, allows power gain, possesses better size properties than other unit root tests and suits macroeconomic data (Costantini and Lupi, 2013).

III.III Panel Cointegration Tests

Once the panel unit root tests confirm that the time series data is non-stationary, we now proceed to panel cointegration test. There are two types of approaches used for cointegration, one tests the underlying vectors on the basis of the null hypothesis of "cointegration" (McCoskey and Kao, 1998; Westerlund, 2007) and other takes null hypothesis of "no-cointegration" (Pedroni, 1999; Kao, 1999; Larsson et al. 2001; Groen and Kleibergen, 2003). We utilize Pedroni panel cointegration test proposed by Pedroni (1999, 2004). Pedroni's test proposes seven different statistics to test for cointegration relationship in heterogeneous panel. These tests are corrected for bias introduced by potentially endogenous repressors. The seven test statistics of Pedroni are classified into within dimension and between dimensions statistics. Within dimension statistics are referred to as panel cointegration statistics, while between dimension statistics are called group mean panel cointegration statistics. These cointegration test statistics are based on the extension of two step residual based strategy of Engle and Granger, (1987). The procedure involves the estimation of seven test statistics require in the first step to estimate the following panel cointegration regression and store the residuals:

$$x_{i,t} = \alpha_{0i} + \rho_i t + \beta_{1i} Z_{1i,t} + ... + \beta_{mi} Z_{mi,t} + \mu_{it} \qquad (4)$$

In the second step, take the first difference of original data series of each country and compute the residual of differenced regression:

$$\Delta x_{i,t} = \theta_{1i} \Delta Z_{1i,t} + ... + \theta_{mi} \Delta Z_{mi,t} + \eta_{it} \qquad (5)$$

In the third step, estimate the long-run variance ($\hat{\kappa}^2_{11,i}$) from the residuals ($\hat{\eta}_{it}$) of the differenced regression. In the fourth step, using the residual ($\hat{\mu}_{it}$) of the original co integrating equation, estimate the appropriate autoregressive model. Following these steps, the seven panel statistics are then computed with appropriate mean and variance adjustment terms as described by Pedroni, (1999).

Panel v-Statistic:

$$Z_v \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1} \qquad (6)$$

Panel ρ -statistic:

$$Z_p \equiv T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \left(\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i \right) \qquad (7)$$

Panel t-statistic (non-parametric):

$$Z_t \equiv \left(\tilde{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \left(\hat{\mu}_{it-1} \Delta \hat{\mu}_{it} - \hat{\lambda}_i \right) \qquad (8)$$

Panel t-statistic (parametric):

$$Z^*{}_t \equiv \left(\tilde{s}^{*2}_{N,T} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^2_{it-1} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\kappa}^{-2}_{11,i} \hat{\mu}^*_{it-1} \Delta \hat{\mu}^*_{it} \qquad (9)$$

Group ρ-statistic:

$$\tilde{Z}_p \equiv TN^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right) \qquad (10)$$

Group t-statistic (non-parametric):

$$\tilde{Z}_t \equiv N^{-1/2}\sum_{i=1}^{N}\left(\hat{\sigma}_i^2\sum_{t=1}^{T}\hat{\mu}_{it-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{\mu}_{it-1}\Delta\hat{\mu}_{it}-\hat{\lambda}_i\right) \qquad (11)$$

Group t-statistic (parametric):

$$\tilde{Z}_t^{*} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}\tilde{s}^{*2}\,\hat{\mu}_{it-1}^{2*}\right)^{-1/2}\sum_{t=1}^{N}\hat{\mu}_{it-1}^{*}\Delta\hat{\mu}_{it}^{\;*} \qquad (12)$$

Where $\hat{\lambda}_i = \frac{1}{2}(\hat{\sigma}_i^2 - \hat{s}_i^2)$ and $\tilde{s}_{N,T}^{*2} = \frac{1}{N}\sum_{i=1}^{N}\hat{s}^{*2}$ (13)

After the calculation of the panel cointegration test statistics the appropriate mean and variance adjustment terms are applied, so that the test statistics are asymptotically standard normally distributed.

$$\frac{X_{N,T}-\mu\sqrt{N}}{\sqrt{V}} \Rightarrow N(0,1) \qquad (14)$$

Where $X_{N,T}$ is the standardized form of test statistics with respect N and T. u and v are the functions of moment of the underlying Brownian motion functional. All statistics test the null hypothesis of no cointegration as:

$$H_0:\rho_i = 1 \quad for\ all\ i = 1,2,........,N \qquad (15)$$

Alternative hypothesis for between dimension and within dimension for panel co integration is different. The alternative hypothesis for between dimension statistics is as following:

$$H_0:\rho_i < 1 \quad for\ all\ i = 1,2,........,N \qquad (16)$$

Where a common value for $\rho_i = \rho$ is not required. The alternative hypothesis for within dimension based statistics is given below:

$$H_0:\rho_i = \rho < 1 \quad for\ all\ i = 1,2,........,N \qquad (17)$$

Assume a common value for $\rho_i = \rho$. Under the alternative hypothesis, all the panel test statistics diverge to negative infinity. Thus, the left tail of the standard normal distribution is required to reject the null hypothesis.

IV. Panel Cointegration Estimates

When all the variables are cointegrated, the next step is to estimate the associated long-run cointegration parameters. Fixed effect, random effect and GMM method could lead to inconsistent and misleading coefficients when applied to cointegrated panel data. For this reason, we estimate the long-run models using the FMOLS (fully modified OLS) methods. Following Pedroni (2001), FMOLS technique generates consistent estimates in small samples and does not suffer from large size distortions in the presence of endogeneity and heterogeneous dynamics. The panel FMOLS estimator for the coefficient β is defined as:

$$\hat{\beta} = N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(y_{it}-\bar{y})^{2}\right)^{-1}\left(\sum_{t=1}^{T}(y_{it}-\bar{y})\right)z_{it}^{*}-T\hat{\eta}_{i} \qquad (18)$$

Where $z_{it}^{*} = (z_{it}-\bar{z}) - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}\Delta y_{it}$, $\hat{\eta}_{i} \equiv \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \frac{\hat{L}_{21i}}{\hat{L}_{22i}}(\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{0})$ and $\hat{L}_{i}$ is a lower triangular decomposition of $\hat{\Omega}_{i}$. The associated t-statistics gives:

$$t_{\hat{\beta}^{*}} = N^{-1/2}\sum_{i=1}^{N} t_{\hat{\beta}^{*},i} \quad \text{Where} \quad t_{\hat{\beta}^{*},i} = \left(\hat{\beta}_{i}^{*}-\beta_{0}\right)\left[\hat{\Omega}_{11i}^{-1}\sum_{t=1}^{T}(y_{it}-\bar{y})^{2}\right]^{1/2} \qquad (25)$$

III.V Panel Causality Test

The work of Granger, (1969) developed an econometric model that investigates the causal relationship among the variables, based on cross-spectral method. Following the similar method, we analyse the causal relationship between trade openness, CO_2 emissions, economic growth and energy consumption. We opt bilateral (pairwise) Granger causality teats for heterogeneous panels instead of the VECM Granger causality approach developed in Engle and Granger (1987), because the vectors are already passed through unit-root and cointegration tests that ensure the time series is non-stationary and cointegration. Eq. 26-27 tests the bilateral causal relationship between trade openness and CO_2 emission, and similar expression can be rewritten for each pair of variables as mentioned in Table-5:

$$C_{it} = \alpha_{i} + \sum_{j=1}^{K}\alpha_{11ij}^{(j)}C_{i,t-j} + \sum_{j=1}^{K}\alpha_{12ij}^{(j)}T_{i,t-j} + \varepsilon_{it} \qquad (26)$$

$$T_{it} = \alpha_{i} + \sum_{j=1}^{K}\alpha_{11ij}^{(j)}T_{i,t-j} + \sum_{j=1}^{K}\alpha_{12ij}^{(j)}C_{i,t-j} + \varepsilon_{it} \qquad (27)$$

Where α_i are constant throughout the time dimension, K denotes uniform lag orders for all cross-sections of the panel. We allow $\alpha_{11ij}^{(j)}$ as an autoregressive parameter and $\alpha_{12ij}^{(j)}$ is coefficient of slope to vary across the groups. The model is fixed coefficient model and uses fixed individual effect as in Dumitrescu and Hurlin, (2012). The bilateral Granger causality with lag lenth (SIC=2) is applied to test the direction of causality between the variables. We test the heterogeneous no-causality hypothesis (under the null hypotheses ($H_0 : \alpha_{12ij} = 0$ $\forall_{12ij}$ = 1, ..N). The value of F-statistics and p-value signify whether to reject or not to reject the null hypothesis, reports the existence or no causality, respectively.

VI. Results and Discussion

This section interprets the results of empirical analysis. Table-1 demonstrates the results of cross-sectional independence tests of Friedman and Pesaran for all variables. The null of cross-sectional independence is rejected and it ensures the variables are not dependent in each cross-section. Afterward, the variables are tested for panel unit root analysis to see whether any of the series is stationary. Table-2 reports the result of both, LLC panel unit root and CADF unit root tests. In LLC unit root test, economic growth is stationary at its level with intercept and trend, however all other variables are non-stationary at their 1st difference with both intercept and intercept and trend. During the CADF unit root test all variables are non-stationary at 1st difference with intercept and intercept and trend. It is now confirmed that whole time series is non-stationary and ready for cointegration analysis.

Table-1: Cross-sectional Independence Tests

Test Statistics	Friedman	Pesaran	ABS*
$\ln C_{it}$	0.19 (0.842)	28.21(0.000)	0.615
$\ln Y_{it}$	0.21 (0.680)	5.00 (0.000)	0.386
$\ln T_{it}$	13.65 (0.000)	-1.28 (0.202)	0.805
$\ln EC_{it}$	0.19 (0.842)	28.21(0.000)	0.671
Note: P-values are in parentheses. (*)ABS is the average absolute value of the off-diagonal elements of the residuals.			

Table-2: Panel Unit Root Analysis

Variables	**At level**				**At 1st Difference**			
	Constant	P-value	Constant and Trend	P-value	Constant	P-value	Constant and Trend	P-value
LLC Unit Root Test on Demeaned Series								
$\ln C_{it}$	3.8546	0.1916	0.7189	0.9181	-5.0100*	0.0000	-6.3768*	0.0000
$\ln Y_{it}$	4.0052	1.0000	0.0115	0.5046	-5.1540*	0.0000	-5.1302*	0.0000
$\ln T_{it}$	2.8043	0.9975	-1.1562	0.1238	-6.7009*	0.0000	-6.9385*	0.0000

$\ln EC_{it}$	3.6933	0.9030	1.2898	0.9030	-4.3763*	0.0000	-4.2742*	0.0000
CADF Unit Root Test								
$\ln C_{it}$	4.8729	1.2356	-3.4567	0.3750	-3.6541*	0.0045	-3.8237*	0.0038
$\ln Y_{it}$	3.3248	0.8272	-3.0601	0.0904	-3.0609*	0.0098	-4.1723*	0.0023
$\ln T_{it}$	3.7484	1.2638	-3.5262	0.2941	-3.5262*	0.0011	-3.8270*	0.0023
$\ln EC_{it}$	3.5678	0.2237	-3.0609	0.8873	-3.0607*	0.0275	-3.8734*	0.0763
Note: * shows significant at 1% level.								

Table-3 shows the results of panel cointegration test developed in Pedroni, (1999, 2004). The Pedroni approach to panel cointegration tests the residuals for a unit root in estimating equation. In total, seven test statistics provided in Pedroni panel cointegration test and these are further divided into two categories; four within dimension panel test statistics and three between dimension group statistics to check whether the variables in panel data are cointegrated. The within dimension tests are based on the estimators that pool the autoregressive coefficients across the countries (cross-sections) for the unit root test on the residual (Pedroni, 1999). The between dimension tests allow parametric heterogeneity across the countries (cross-sections). The results of within dimension and between dimension tests allow us to reject the null hypothesis of “no-cointegration” and confirm that CO_2 emissions, economic growth, energy consumption and trade openness are cointegrated in most of the cases.

Table-3: Pedroni Panel Cointegration Test Results

Alternative hypothesis: common AR coefs. (within-dimension)				
Tests	Statistics	P-value	Weighted Statistics	P-value
Panel υ-statistic	2.373081	0.0088	1.137388	0.1277
Panel σ-statistic	-2.872699	0.0020	-1.389854	0.0823
Panel ρρ-statistic	-3.045199	0.0012	-2.014688	0.0220
Panel adf-statistic	2.373081	0.0088	1.137388	0.0197
Alternative hypothesis: individual AR coefs. (between-dimension)				
Tests	Statistics	P-value		
Group σ-statistic	1.446330	0.1402		
Group ρρ-statistic	-0.831221	0.2824		
Group adf-statistic	-2.003168	0.0536		

Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 9
Newey-West automatic bandwidth selection and Bartlett kernel

Subsequent to Pedroni panel cointegration test, and confirming the cointegration among all underlying vectors, the long-run elasticity between CO_2 emissions and trade liberalization, economic growth and energy consumption is determined using panel-FMOLS test. This is a new method and has a property to estimate and test the hypothesis for cointegrating vectors in dynamic panels while being consistent with available degree of cross-sectional heterogeneity recently allowed in unit root and panel cointegration studies [Pedroni, (2001, 2007); Breitung, (2005); Liddle, (2012)]. The results of panel-FMOLS are reported in Table-4 and suggest that in long-run, a 1% increase in trade openness reduces CO_2 emissions by 0.5%. Similarly, economic growth also reduces CO_2 emissions in long-run however, energy consumption positively impacts emissions.

Table-4: FMOLS Panel Results

(lnC_{it}): Dependent Variable		
Variables	Coefficient	P-value
$\ln Y_{it}$	-0.398	0.0003
$\ln T_{it}$	-0.542	0.0264
$\ln EC_{it}$	0.365	0.0000

Table-5 shows the result of Granger causality test; we found the bi-directional causality running between energy consumption and CO_2 emissions. The unidirectional causality exists running from trade openness and economic growth to CO_2 emissions. Trade openness Granger causes energy consumption. The unidirectional causality is found running from trade openness to economic growth. The Granger causality test analyzes the causal relationship between the variables, but it does not tell us the ratio of contributions. However, variance decomposition approach and impulse response function calculate the link between variables in decomposed form. Hence, exact ratio of each variable over other is computed over the different time horizons during their own innovative shocks.

Table-5: Granger Causality Test Results

Granger Causality Test				
Null Hypothesis (H_0):	Results	Direction	F-Stat.	Prob.
EC does not Granger Cause C	Reject	EC→C	7.7840	0.0006
C does not Granger Cause EC	Reject	C→EC	3.8159	0.0241
T does not Granger Cause C	Reject	T→C	7.2610	0.0010
C does not Granger Cause T	Do not-Reject	-	2.0833	0.1279
Y does not Granger Cause C	Reject	Y→C	8.1950	0.0004
C does not Granger Cause Y	Do not-Reject	-	0.1075	0.8981
T does not Granger Cause EC	Reject	T→EC	10.411	6.E-05
EC does not Granger Cause T	Do not-Reject	-	1.9587	0.1444
Y does not Granger Cause EC	Do not-Reject	-	2.1802	0.1164
EC does not Granger Cause Y	Do not-Reject	-	0.0245	0.9758
Y does not Granger Cause T	Do not-Reject	-	1.7644	0.1746
T does not Granger Cause Y	Reject	T→Y	8.1159	0.0004

Note: (i) Arrow(→) shows the direction of causality.(ii) Lag-lenth (SIC=2). (iii)

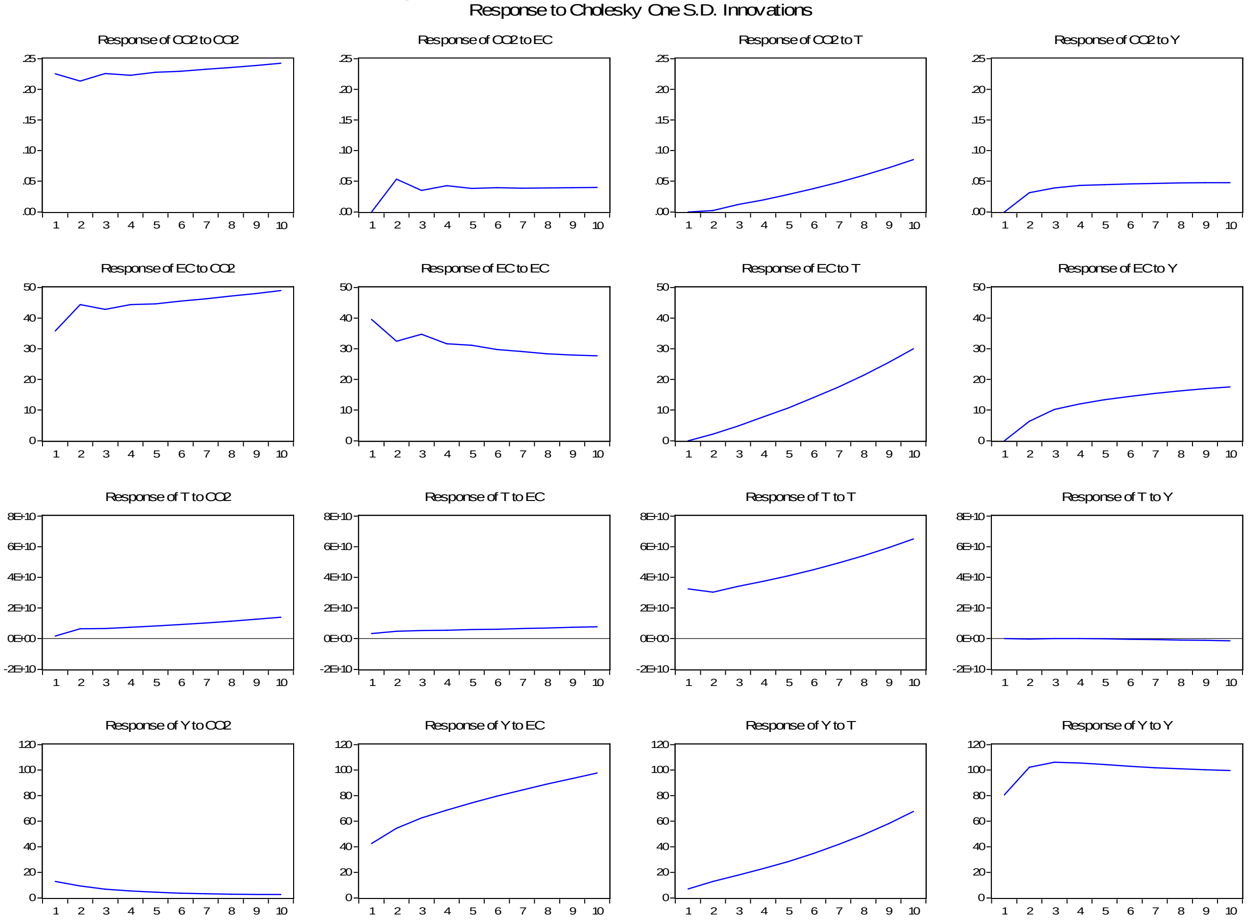
Table-6 shows the results of VDM analysis. The results suggest, during its own innovative shocks, energy consumption is 67.3% self contributed and 21.4% is contributed by trade openness. CO_2 emissions is 33.4% is self contributed and, 52.4% and 11.3% is contributed by energy consumption and trade openness, respectively. Trade openness is 94.2% self contributed and does not receive substantial impact from rest of the variables. However, economic growth is 44.0% self contributed and 21.0%, 20.8% and 14.0% contributed by trade openness, energy consumption and CO_2 emissions, respectively. Overall, we find that trade openness causes energy consumption and same is true from opposite side. Energy consumption leads to CO_2 emissions. The VDM test results are further checked for impulse response function (IRF) test and Figure-1 displays the pair-wise impact of variables during the period of shocks. The IRF is used as an alternate to VDM test but shows the graphical representation of reaction of variables throughout the period. We note that forecast error arsing in energy consumption, trade openness and economic growth has positive contribution to CO_2 emissions. Trade openness and economic growth contribute to energy consumption positively. Energy consumption responds positively due to forecast error occurs in CO_2 emissions. Trade openness and energy consumption stimulate economic growth by their forecast errors.

Table-6: Variance Decomposition Analysis

Variance Decomposition of EC:				
Period	EC	C	T	Y
1	100.0000	0.0000	0.0000	0.0000
3	95.9593	2.1407	0.3020	1.5978
5	92.5842	3.0956	1.3025	3.0176
7	88.7947	3.9723	3.1431	4.0897
9	84.4181	4.7259	5.9924	4.8634
11	79.3799	5.3046	9.9806	5.3347
13	73.6618	5.6785	15.1583	5.5011
15	67.3247	5.8389	21.4558	5.3804
Variance Decomposition of C				
Period	EC	C	T	Y
1	45.0508	54.9491	0.0000	0.0000
3	56.9775	41.3055	0.0973	1.6195
5	58.1682	38.9175	0.5067	2.4074
7	57.9781	37.9122	1.3303	2.7793
9	57.2477	37.1069	2.6909	2.9543
11	56.0984	36.1740	4.7272	3.0002
13	54.5091	34.9701	7.5772	2.9435
15	52.4278	33.4183	11.3547	2.7991
Variance Decomposition of T				
Period	EC	C	T	Y
1	1.1881	0.0942	98.7176	0.0000
3	4.3870	0.1602	95.4490	0.0036
5	4.9684	0.2071	94.8221	0.0022
7	5.1332	0.2754	94.5854	0.0058
9	5.1607	0.3573	94.4665	0.0153
11	5.1320	0.4476	94.3902	0.0299
13	5.0794	0.5426	94.3294	0.0484

15	5.0179	0.6392	94.2731	0.0695
Variance Decomposition of Y				
Period	EC	C	T	Y
1	18.8856	4.2825	0.5571	76.2747
3	16.8934	6.9356	1.3946	74.7763
5	17.8273	9.1920	2.6023	70.3782
7	19.0141	11.1011	4.4140	65.4707
9	20.0205	12.5998	7.0103	60.3691
11	20.7236	13.6179	10.551	55.1073
13	21.0698	14.1047	15.152	49.6732
15	21.0325	14.0400	20.849	44.0778

Figure-1: Impulse Response Function



VI. Conclusion and Policy Implications

This study is empirically examined the impact of trade openness on CO$_2$ emissions with energy consumption and economic growth for four newly industrializing economies i.e. China, India, Brail, and South Africa. We employed a cross-sectional independence test prior to panel unit root test. After confirming the variables are integrated at I (1) and cross-sectionally dependent, we applied dynamic panel cointegration test developed in Pedroni (2001, 2007). The results found that the majority of the variables are cointegrating and then variables are checked for long-run association using FMOLS analysis followed by Granger causality and VDM test.

The results of this study can be used for environmental policy analysis in China, India, Brazil and South Africa. Today, the share of these industrializing economies is one-fifth of the world GDP, 35% of global energy use, and 40% of global CO_2 emissions. Granger causality analysis suggests that there is the unidirectional causality running from trade openness to economic growth and carbon emissions. It means trade liberalization is good for economic growth, but also induces CO_2 emissions. However, there is also the feedback effect between energy consumption and CO_2 emissions. It further clarifies that trade openness enhances energy use in the economies due to the increased scale of production and deteriorates environmental quality. As a matter of fact, it is not feasible for economy to reduce its production in order to consume less energy and in return gets better environment and deteriorating economic growth. The absence of causality between energy consumption and economic growth suggests that energy conservation policies will not affect economic growth in these countries. This study also suggests that the newly industrializing economies should adopt renewable and alternate energy sources to reduce the emissions intensity of production units without compromising economic growth.

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