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1 **Atmospheric consequences of trade and human development: A case of BRIC countries**

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10 **Abstract:**

11 This paper looks into the causal association between economic growth, CO<sub>2</sub> emission, trade  
12 volume, and human development indicator for Brazil, Russia, India, and China (BRIC countries)  
13 during 1980-2013. Following a generalized method of moments (GMM) technique, we have  
14 found out that bidirectional causality exists between CO<sub>2</sub> emissions and economic growth.  
15 Feedback hypothesis is supported between CO<sub>2</sub> emissions and human development, trade  
16 volume and human development, economic growth, and human development, and CO<sub>2</sub> emissions  
17 and trade volume. Apart from finding out the unidirectional association from trade volume to  
18 economic growth, this study also validated the existence of Environmental Kuznets curve.  
19 Empirical findings of the study substantiate that the policymakers of the BRIC nations must  
20 focus on the green energy initiatives, either by in-house development or by technology transfer.  
21 This movement will allow them to control the ambient air pollutions prevalent in these nations.

22 *Keywords:* economic growth; CO<sub>2</sub>; trade; human development indicator; BRIC; GMM

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## 1 **1. Introduction**

2           Global warming and climate change is one of the major concerns worldwide. The Kyoto  
3 Protocol was signed with the objective to minimize the damage of global warming and climate  
4 change by taking steps to reduce greenhouse gases (GHG) emissions. Although the BRIC  
5 countries signed the Kyoto Protocol, environmental concerns still remain due to their growth  
6 potential (Pao and Tsai, 2010). The World Bank data on CO<sub>2</sub> emission shows that BRIC  
7 countries emissions increased for these economies for the period from 2011-2015, with Brazil  
8 growing at 1.15%, Russia 12.6%, India 1.7% and China 6.7% (World Bank, 2015). These four  
9 countries, with a combined population of 3 billion people and a GDP of \$16tn, will have a huge  
10 direct impact on global emissions.

11           The last few decades has seen several empirical studies connecting trade openness,  
12 environmental conditions and human development (Ehrlich and Lui, 1991; Ekins, 1997; Pao and  
13 Tsai, 2010; Pao and Tsai, 2011). However, very few studies were done in the context of BRIC  
14 economies (Belloumi, 2009; Zhang and Cheng, 2009). Considering the causal associations,  
15 Zhang and Cheng (2009) designed one of the earliest multivariate models, and the latest work is  
16 carried out by Omri et al. (2015). These studies focused on establishing possible causal  
17 associations between energy consumption, economic growth, and carbon emission by using  
18 multivariate models, and these models assume the economic structure to be four-sector  
19 (Mahalanobis, 1955), where the social determinants of economic growth and environmental  
20 degradation have been ignored. Moreover, all of the studies show that the relationship between  
21 the proxy measures of these concepts cannot be generalized as they vary significantly across  
22 countries. Several studies reveal that the relationship varies even among transient economies that  
23 are expected to face similar growth challenges (Ozturk and Acaravci, 2010; Palamalai et al.,

1 2014; Sinha, 2014; Sinha and Bhattacharya, 2014; Sinha and Mehta, 2014; Omri et al., 2015;  
2 Sinha, 2015).

3         In the light of the above discussion, this paper studies the causal association between  
4 economic growth, trade openness, environmental condition and human development in BRIC  
5 countries. We employ the extended Cobb-Douglas production function approach by Omri et al.  
6 (2015), where economic growth depends on human development indicator, trade openness, gross  
7 capital formation, and energy consumption. This particular model permits us to discover the  
8 causal association among the variables: economic growth, emission level, human development  
9 indicator, and trade openness. These variables are selected for capturing the attributes of BRIC  
10 countries. This study accordingly contributes to the literature on energy economics by  
11 demonstrating an integrated approach to scrutinize the four-way associations between economic  
12 growth, CO<sub>2</sub> emissions, human development indicator, and trade openness in the BRIC countries  
13 by using the simultaneous-equation models with panel econometric techniques over the period  
14 1980–2013. Consequently, the results of this study can prove to be beneficial for the  
15 policymakers to come out with an effective policy-level decision for endorsing long-term  
16 economic growth for BRIC nations. By far, the studies carried out for BRIC nations have largely  
17 ignored the aspects of human development and majorly focused on the aspects of economic  
18 growth (Tamazian et al., 2009; Pao and Tsai, 2010, 2011a; Cowan et al., 2014; Sebri and Ben-  
19 Salha, 2014). According to the latest study by Azahaf and Schraad-Tischler (2012), the  
20 sustainable development framework in the BRIC nations needs reconsideration, as economists  
21 are posing doubts regarding the convergence of income in these nations (Mpoyi, 2012). During  
22 the course of economic growth, economists are of the opinion that the sustainable development  
23 targets are largely being compromised (Rowlands, 2012). Chakravarty and Mandal (2016) talked

1 about this issue in their recent study, and they have indicated the importance of considering  
2 developmental aspects while analyzing the economic growth scenario in BRIC countries. In this  
3 kind of a situation, considering the human development aspect within the framework of  
4 economic growth and environmental emission may result in significant policy implications. As  
5 BRIC nations are also in the process of building several trade linkages with less developed  
6 nations for improving the scenario of development in those nations (De Castro, 2012; Çakır and  
7 Kabundi, 2013), it may be required to revisit their own sustainable development framework at  
8 the very beginning. When these characteristics of the BRIC nations are considered, they  
9 adequately comply with the model specification.

10 This study also contributes to the literature by addressing the inherent endogeneity  
11 problem which researchers argue about when using simultaneous equation modeling. From the  
12 methodological point of view, this study employs the generalized method of moments (GMM)  
13 technique, which allows us to get over the endogeneity issue.

14 The structure of the article is as follows: Section 2 deals with the review of relevant  
15 literature, Section 3 delineates the econometric techniques and data, Section 4 illustrates the  
16 empirical findings, and Section 5 summarizes the article with concluding remarks.

## 17 **2. Literature review**

18 The extant literature working on the nexus between economic growth, emission level,  
19 human development indicator and trade-openness have been carried out in silos, and nearly all of  
20 the econometric models have ignored the social parameters to a great extent. Moreover, the  
21 causality among these variables also continues to be ambiguous due to varied results of cross-  
22 sectional and time series studies that took place in different countries. BRIC, being a significant  
23 emerging economy cluster (46% of the world population resides in these countries), has not been

1 studied extensively for these dimensions, especially for human resource development.  
2 Consequently, the literature review has been divided into six subsections a) Carbon emission and  
3 economic growth; b) Carbon emission and human development; c) Human Development and  
4 Trade; d) Economic Growth and Trade; e) Human Development and Economic Growth; and f)  
5 Carbon Emission and Trade. We will discuss them in the next subsections.

## 6 **2.1. Carbon emission and economic growth**

7 The relationship between carbon emission and economics growth has been widely  
8 studied for more than two decades. However, the empirical results vary widely mainly due to  
9 different sets of underlying variables. In the context of the association between environmental  
10 degradation and economic growth, Environmental Kuznets Curve (EKC) hypothesis is one of the  
11 extensively researched hypotheses. According to this hypothesis, environmental degradation  
12 starts at the earliest stage of economic growth, grows with the rise in income, and once the  
13 income reaches a certain point, i.e. the turnaround point, the environmental degradation starts to  
14 decline. Therefore, the generally accepted form of EKC is inverted U-shaped. Galeotti et al.  
15 (2006) studied the link between carbon emission and economic growth for the OECD and non-  
16 OECD countries. They find evidence for the EKC only for the OECD countries. Azomahou et al.  
17 (2006) examine the EKC hypothesis for CO<sub>2</sub> emission using a non-parametric approach. They  
18 use data for 100 countries over the period 1960–1996 and found some evidence of the EKC  
19 hypothesis. The studies considered only bivariate relationship and obtained results that support  
20 EKC (Pao and Tsai, 2010). For the advocates of economic growth, EKC hypothesis became an  
21 empirical tool to favor economic growth at the cost of CO<sub>2</sub> emission. However, studies by Ekins  
22 (1997), Stern (2000), Ozturk and Acaravci (2010), Sinha (2014), Sinha and Bhattacharya (2014),  
23 Sinha and Mehta (2014), Sinha (2015) and others obtained different relationship between CO<sub>2</sub>

1 emission and economic growth thus weakening the equivocal hold of EKC. However, empirical  
2 study by Tamazian et al. (2009) supported the EKC hypothesis for BRIC nations and argues that  
3 economic development has reduced environment degradation in these countries. Since such  
4 bivariate studies are likely to suffer from endogeneity issue, the present study has been chipped  
5 with suitable instrumental variable.

## 6 **2.2. Carbon emission and human development**

7 Carbon emission gave rise to global health concern which is a vital indicator of human  
8 development. Desai (1995) developed an ‘index of intensity of environmental exploitation’ (p.  
9 23). Neumayer (2001) connected the Human Development Index with carbon emission in such a  
10 way to check whether a country is ‘mortgaging the choices of future generations.’ Most of these  
11 studies have focused on integrating an emission factor in calculating the Human Development  
12 Index. Few studies by Hill et al. (2009), Woodcock et al. (2009), Smith et al. (2010) and others  
13 have quantified the human development cost and its causal association with climate change and  
14 paved way for policy change in respective countries. As human resource is an important asset,  
15 aspiration of BRIC countries to leap forward in economic ranking entails it important to  
16 understand the association between the two, but the association is partial. This paper tries to  
17 visualize these variables in an entire framework.

## 18 **2.3. Carbon emission and trade**

19 Studies incorporating trade as a variable in testing the EKC hypothesis include Grossman  
20 and Krueger (1991), Lucas et al. (1992), Wyckoff and Roop (1994), Suri and Chapman (1998),  
21 and Nohman and Antrobus (2005). Most of these studies intuitively show that increase in trade  
22 should result in higher pollution. While this intuition has been invalidated empirically for local  
23 pollutants (like SO<sub>2</sub> and NO<sub>2</sub>) but for global pollutant i.e., CO<sub>2</sub>, the relationship is positive

1 Frankel and Rose (2005). In the Indian context, Palamalai et al. (2014) identified a bidirectional  
2 relationship between trade and carbon emission. The causality cannot be generalized considering  
3 varied results obtained by Jalil and Feridun (2011), where they obtained a negative relation  
4 between CO<sub>2</sub> emission and trade development in China. Therefore, it is interesting to decipher  
5 who can and who cannot gain from trade at the cost of environment.

#### 6 **2.4. Human development and trade**

7 Bhagwati and Daly (1993) and Lash (1997) in their studies showed that pro-free-trade is  
8 either a zero-sum game where “the rich grow richer and the poor become poorer,” or trade at  
9 best “lifts all boats,” but it promotes inequality. They also emphasized that trade is a major  
10 source of environmental degradation. Seminal research by Grossman (2003) debunked this  
11 environmental degradation story. Grossman (2003) showed strong empirical evidence that trade-  
12 inspired growth increases the per-capita income of developing countries. Although these studies  
13 mentioned about the role of trade in human development, they never explicitly tested for it.  
14 Davies and Quinlivan (2006) provided evidence for positive relationship between trade and  
15 human development mediated by per capita income. In contrast, recent WTO 2014 report  
16 dismisses any relationship of trade with health, human development, inequality or environmental  
17 performance. For BRIC nations there is a dearth of literature that talks about these two  
18 parameters along with others which make it essential to study them in a holistic framework.

#### 19 **2.5. Economic growth and trade**

20 According to Stiglitz (1998, p. 36), “most specifications of empirical growth regressions  
21 find that some indicator of external openness-whether trade ratios or indices or price distortions  
22 or average tariff level is strongly associated with per-capita income growth.” The literature on  
23 trade openness and economic growth have tried to check this association by: (1) constructing



1 alternative indicators of openness (Dollar, 1992; Sachs and Warner, 1995); (2) testing robustness  
2 by using a wide range of measures of openness, including subjective indicators (Edwards, 1992,  
3 1998); and (3) comparing convergence experience among groups of liberalizing and non-  
4 liberalizing countries (Ben-David, 1993). This convergence literature is generally credited with  
5 finding significant relationship between trade and economic growth than the other two strands,  
6 but most of the literature available till date equivocally supports the bidirectional relation  
7 between economic growth and Trade and none has used the BRIC countries. Recent studies by  
8 Yucel (2009) and Shahbaz et al. (2013) investigated the causality between economic growth,  
9 financial development and trade openness in Turkey and China respectively. In the context of  
10 BRIC, Mercan et al. (2013) presented panel data analysis in support of unidirectional  
11 relationship between trade openness and economic growth.

## 12 **2.6. Human development and economic growth**

13 Human development is long understood to be an important input for economic growth.  
14 Preliminary empirical evidence of the interaction between the two came from Ehrlich and Lui  
15 (1991) and Barro (1996). They took life expectancy as a health indicator and established a  
16 conceptual framework by instilling health in growth theory. Ranis et al. (2000) showed the  
17 connections between economic growth (EG) and human development (HD) form two chains, the  
18 EG to HD chain and the HD to EG chain. They used a cross-country regression to show a  
19 significant relationship in both directions. Their study establishes a two-way causality which  
20 gives rise to “virtuous or vicious cycles”, with high or low levels on HD and EG reinforcing each  
21 other. On the other hand, studies by Mayer (2001), Bloom et al. (2004) and Weil (2005) showed  
22 evidences for unidirectional causality between health as a proxy for human development and  
23 economic growth. Thus the link between two indicators is inarguably valid for developing as

1 well as developed countries (Bhargava et al., 2001). However, we have not come across any  
2 study, which talks about human development along with trade, carbon emission in economic  
3 growth studies. This paper is an attempt to explore the role of human development among other  
4 parameters of growth.

### 5 **3. Econometric techniques**

#### 6 **3.1. Model specification**

7 For analyzing the causal association between economic growth, CO<sub>2</sub> emission, trade  
8 volume, and human development indicator for BRIC countries, we used an extended Cobb-  
9 Douglas production function as per Omri et al. (2015):

$$10 \quad Y = AK^\alpha E^\lambda L^\beta e^\mu \quad (1)$$

11 Where,  $Y$  is the GDP of the countries,  $A$  is the technological advancement,  $K$  is capital formation,  
12  $E$  is energy consumption,  $L$  is number of labors, and  $e$  is error term.  $\alpha$ ,  $\beta$ , and  $\lambda$  are the respective  
13 elasticities of capital, labor, and energy consumption, and we relax the assumption of constant  
14 return to scale, as it is not mandatory for this model. In a constant technological regime, scale of  
15 industrial emission is directly proportionate to energy consumption (Taft, 1952), such as  
16  $E = xC$ ,  $C$  is the CO<sub>2</sub> emissions, and  $x$  is time-invariant constant. On the other hand, for the  
17 BRIC countries, the technological innovation is largely dependent on the technology transfers  
18 via foreign direct investment (FDI) route (Ranjan and Agrawal, 2011). Consequently, we can  
19 write

$$20 \quad A(t) = \varphi \cdot T(t) \quad (2)$$

21 Where  $\varphi$  is time-invariant constant and  $T$  is volume of trade.

22 In the similar way, the amount of people in working condition can be derived based on the total  
23 population and the human development index (HDI) of any country in a linear fashion (Ranis et

1 al., 2006), such as  $L(t) = cP(t).H(t)$ ,  $P$  is the population,  $H$  is the HDI of the country, and  $c$  is  
 2 time-invariant constant.

3 Now substituting the values in Eq. (1) reveals:

$$4 \quad Y = x\varphi c.T(t).H(t)^{\theta_1}C(t)^{\theta_2}K(t)^\alpha P(t)^\beta e^\mu \quad (3)$$

5 Firstly, Eq. (3) has been transformed into per capita terms by dividing both sides by  $P$ .

6 Now, the linearized Cobb-Douglas function for panel data analysis becomes:

$$7 \quad \ln Y_{it} = \sigma_1 + \sigma_2 \ln C_{it} + \sigma_3 \ln H_{it} + \sigma_4 \ln T_{it} + \sigma_5 \ln K_{it} + \varepsilon_t \quad (4)$$

8 Where,  $i = 1, \dots, n$  denotes BRIC countries, and  $t = 1, \dots, T$  denotes duration of the study, i.e.  
 9 1980-2013.

10 This production function in Eq. (4) is used to develop empirical models to simultaneously  
 11 estimate the interactions between per capita income, per capita emission, and inequality in  
 12 energy intensity. These models are designed based on the existing literature, which we have  
 13 already discussed. While estimating quadrilateral linkage between economic growth, emissions,  
 14 trade, and health, square of per capita income ( $Y^2$ ), capital ( $K$ ), health expenditure ( $HEX$ ), energy  
 15 consumption ( $E$ ), foreign direct investment ( $FDI$ ), and exchange rate ( $EX$ ) have been used as  
 16 instrumental variables. The four models for assessing this linkage are:

$$17 \quad \ln Y_{it} = \sigma_1 + \sigma_2 \ln C_{it} + \sigma_3 \ln H_{it} + \sigma_4 \ln T_{it} + \sigma_5 \ln K_{it} + \varepsilon_t \quad (5)$$

$$18 \quad \ln C_{it} = \sigma_1 + \sigma_2 \ln Y_{it} + \sigma_3 \ln Y_{it}^2 + \sigma_4 \ln H_{it} + \sigma_5 \ln T_{it} + \sigma_6 \ln K_{it} + \sigma_7 \ln E_{it} + \varepsilon_t \quad (6)$$

$$19 \quad \ln H_{it} = \sigma_1 + \sigma_2 \ln Y_{it} + \sigma_3 \ln C_{it} + \sigma_4 \ln T_{it} + \sigma_5 \ln HEX_{it} + \varepsilon_t \quad (7)$$

$$20 \quad \ln T_{it} = \sigma_1 + \sigma_2 \ln Y_{it} + \sigma_3 \ln C_{it} + \sigma_4 \ln H_{it} + \sigma_5 \ln EX_{it} + \sigma_6 \ln FDI_{it} + \varepsilon_t \quad (8)$$

21 In the above equations, the subscript  $i = 1 \dots N$  denotes the country and  $t = 1 \dots T$  denotes  
 22 the time period. Eq. (6) states that economic growth ( $Y$ ), human development indicator ( $H$ ),  
 23 volume of trade ( $T$ ), gross capital formation ( $K$ ), and energy consumption ( $E$ ) are the driving

1 forces of CO<sub>2</sub> emissions (*C*) (e.g. Smith, 1993; Harbaugh et al., 2002; Munksgaard et al., 2005).  
2 Eq. (7) states that human development (*H*) depends on economic growth (*Y*), CO<sub>2</sub> emissions (*C*),  
3 volume of trade (*T*), and out-of-pocket health expenditure (*HEX*) (e.g. Messier et al., 2004;  
4 Davies and Quinlivan, 2006). Eq. (8) states that volume of trade (*T*) depends on economic  
5 growth (*Y*), CO<sub>2</sub> emissions (*C*), human development indicator (*H*), exchange rate (*EX*), and  
6 foreign direct investment (*FDI*) (e.g. Aizenman and Noy, 2006; Bogin et al., 2007).

7         The models represented by Eq. (5) to (8) are simultaneously estimated by generalized  
8 method of moments (GMM) technique. Apart from efficiency of this technique for estimation of  
9 multiple linkages in a panel dataset, it also allows us to make use of instrumental variables, in  
10 order to get rid of endogeneity problems.

11         Though GMM always provides us with the opportunity to carry out an empirical analysis  
12 even in the presence of random heteroscedasticity, diagnostic tests have been used in this study  
13 for reconfirmation of the validity of instruments being used and endogeneity. For checking the  
14 validity of instruments, Hansen's test of overidentification has been used, and the null hypothesis  
15 of this test is that the instruments in the model are appropriate. For checking the endogeneity,  
16 Durbin-Wu-Hausman test has been used, and the null hypothesis of this test is that the  
17 instruments are endogenous in nature, resulting in misappropriation of the model.

### 18 **3.2. Unit root tests**

19         With the recent developments in the literature of econometric techniques, panel unit root  
20 tests have undergone a transformation in terms of first generation (Levin et al., 2002; Im et al.,  
21 2003) and second generation (Pesaran, 2007). This differentiation lies in view of the cross-  
22 sectional dependence in the panel data. First generation panel unit root tests assume that the  
23 cross-sections in the panel data are independent, whereas second generation panel unit root tests

1 relax this assumption. If there is cross-sectional dependence present in the data, then application  
 2 of first generation panel unit root test may produce fallacious results owing to size distortions.  
 3 On the other hand, if there is no cross-sectional dependence present in the data, then application  
 4 of second generation panel unit root test may produce loss of power. In this study, the latter one  
 5 is the case here, and therefore, we employ the first generation panel unit root tests.

6 By and large, Augmented Dickey Fuller (ADF) (Dickey et al., 1991) unit root test is used  
 7 to identify the order of integration of time series variables. But it has the inherent difficulty of  
 8 low power in discarding the null hypothesis of stationarity, predominantly for relatively  
 9 undersized samples, and because of this, we have not employed this test in this study. In place of  
 10 ADF unit root test, Levin-Lin-Chu (LLC) (Levin et al., 2002) and Im-Pesaran-Shin (IPS) (Im et  
 11 al., 2003) panel unit root tests are employed, as both of the tests are superior in terms of  
 12 explanatory power for relatively higher sample size. LLC presumes homogeneity in the  
 13 autoregressive coefficients for all data points, while IPS presumes heterogeneity in those  
 14 coefficients. LLC offers a panel-base ADF test and restricts  $\alpha$  (coefficient of lagged dependent  
 15 variable) to maintain it alike throughout cross sections. The test imposes homogeneity on  
 16 autoregressive coefficient that points toward the existence/nonexistence of a unit root, whereas  
 17 intercept and trend may vary across individual series. The model permits heterogeneity only in  
 18 the intercept and is given by

$$19 \Delta X_{i,t} = \partial_i + \alpha X_{i,t-i} + \sum_{j=1}^{p_i} \phi_j X_{i,t-j} + \varepsilon_{i,t} \quad (9)$$

20 where,  $X_{i,t}$  is the series for panel members  $i$  (1, 2, ..., N) over period  $t$  (1, 2, ..., T), and  $p_i$  is the  
 21 number of lags. The error term ( $\varepsilon_{i,t}$ ) are assumed to be IID (0,  $\sigma^2$ ) and to be independent of units  
 22 of the sample. The null hypothesis for indicating non-stationarity in this case can be stated as:

$$23 H_0: \alpha_i = 0, \text{ for all } i; \quad H_1: \alpha_i = \alpha < 0, \text{ for all } i$$

1 The IPS test initiates by denoting different ADF regressions for each cross sections:

$$2 \Delta X_{i,t} = \partial_i + \alpha_i X_{i,t-i} + \sum_{j=1}^{p_i} \phi_{i,j} X_{i,t-j} + \varepsilon_{i,t} \quad (10)$$

3 where,  $X_{i,t}$  is the series for panel members  $i$  (1, 2, ..., N) over period  $t$  (1, 2, ..., T), and  $p_i$  is the  
4 number of lags. The error term ( $\varepsilon_{i,t}$ ) are assumed to be IID (0,  $\sigma^2$ ) and to be independent of the  
5 units of the sample. Both  $\alpha$  and  $\phi$  are permitted to differ in accordance with the cross sections.

6 The null hypothesis for indicating non-stationarity in this case can be stated as:

$$7 H_0: \alpha_i = 0, \text{ for all } i; \quad H_1: \alpha_i = \alpha < 0, \text{ for all } i$$

## 8 **4. Data and results**

### 9 **4.1. Data and descriptive statistics**

10 The data used in this study are for BRIC countries covering the period of 1980-2013. We  
11 have collected annual data for CO<sub>2</sub> emission, income, trade, capital formation, exchange rate,  
12 energy consumption, and out-of-pocket health expenditure from the World Bank indicators, and  
13 HDI data from UNDP. Descriptive statistics of the variables for BRIC countries are provided in  
14 Table 1.

15

### 16 **4.2. Results of panel unit root and cointegration tests**

17 As we have discussed earlier, we employ two first generation panel unit root tests on the  
18 data. However, prior to conducting the same, we conducted Pesaran (2007) test to check the  
19 cross-section dependence in the data. Null hypothesis of this test is that the cross sections are  
20 independent, and it is computed based on average of pair-wise correlation coefficients of the  
21 ADF regression residuals for each individual unit. The test statistics are recorded in Table 2, and  
22 they show that the null hypothesis cannot be rejected. It signifies that the cross sections of all the

1 panels are independent, and therefore, first generation panel unit root tests can be applied for this  
2 study.

3 Heterogeneity of various sections is taken care of by LLC test, and the possibility of low  
4 power can be overruled because of the data volume. IPS test also takes care of the same, and it  
5 has the ability to eradicate the plausible serial correlation in the data. Null hypotheses of both the  
6 tests are that the variables are non-stationary and they have unit root(s).

7 *<Insert Table 1 here>*

8 *<Insert Table 2 here>*

9 Results of both of these tests are recorded in Table 3a. It can be seen that the variables are  
10 insignificant at level and significant at first difference for both of the tests, thereby indicating  
11 their order of integration as one, i.e. the variables are I(1) in nature.

12 *<Insert Table 3a here>*

13 As the variables are I(1) in nature, we can now proceed for cointegration test. To carry  
14 out the same, we employ panel cointegration technique of Pedroni (2004). This test provides us  
15 with seven statistics (parametric and non-parametric) with an assumption of cross-sectional  
16 independence, which has already been verified. As our study is parametric in nature, we are  
17 interested in three parametric test statistics, ADF test statistics to be particular. Going by the  
18 pooling of tests, we are interested in between-dimension test statistics.

19 Table 3b provides us with the results of cointegration tests being carried out based on the  
20 variables specified in Eq. (5) to (8). P-values of the results evidently suggest that the null  
21 hypothesis of no cointegration between the variables cannot be rejected. The results state that the  
22 variables included in the specified models are not cointegrated.

23 *<Insert Table 3b here>*

### 1 **4.3. Results of regression tests and discussion**

2 While estimating four way linkages between CO<sub>2</sub> emission, economic growth, trade, and  
3 health, instrumental variables are  $K$ ,  $Y^2$ ,  $E$ ,  $FDI$ ,  $HEX$ , and  $EX$ .

4 However, before carrying out the regression analysis, two specific tests are needed to be  
5 conducted. As indicated by Omri et al. (2015), two tests are important before proceeding with  
6 any simultaneous equation regression model, and those tests are test of endogeneity and test of  
7 overidentification. First, to test for endogeneity Durbin-Wu-Hausman (DWH) test has been used  
8 and null hypothesis of this test is that endogeneity among variables will have significant impact  
9 on ordinary least squares (OLS) estimates. Rejection of this hypothesis signifies that the models  
10 require instrumental variable technique. Second, the overidentifying restrictions are tested for  
11 verifying the validity of the selected instruments. Hansen test is used for this purpose, and null  
12 hypothesis of overidentifying restrictions cannot be rejected, thereby signifying the precision of  
13 the instruments being used in the model.

14 Estimation results of Eq. (5) for four countries are recorded in Table 4a. The results show  
15 that CO<sub>2</sub> emission has a negative impact on economic growth, and it is evident for Brazil, India,  
16 and China. This implies that the economic growth is elastic to CO<sub>2</sub> emissions, and 1% increase in  
17 CO<sub>2</sub> emissions causes decrease in economic growth by 1.7334% (Brazil), 0.7553% (India), and  
18 0.7473% (China). No significant result was found for Russia. For the panel result, CO<sub>2</sub> emissions  
19 have a negative and significant impact on economic growth at 5% level, and 1% increase in CO<sub>2</sub>  
20 emissions causes decrease in economic growth by 0.2088%. These results show that the  
21 environmental degradation is causing harm to the pattern of economic growth, and thereby,  
22 addressing the feedback hypothesis of EKC. These results also show that the economic growth  
23 pattern in BRIC nations is unsustainable in nature, and the developmental goals in these nations  
24 must consider the environmental sustainability aspects more seriously. The results obtained by us



1 are in the similar lines with the findings of Zhang and Cheng (2009), Pao and Tsai (2011), and  
2 Sinha (2015).

3 *<Insert Table 4a here>*

4 The coefficients of human development are positive and significant for Brazil, Russia,  
5 and China. This implies that the economic growth is elastic to human development, and 1%  
6 increase in human development indicator causes increase in economic growth by 5.2094%  
7 (Brazil), 19.1633% (Russia), and 7.9154% (China). No significant result was found for India.  
8 For the panel result, human development have a positive and significant impact on economic  
9 growth at 1% level, and 1% increase in human development indicator causes increase in  
10 economic growth by 1.4525%. These results demonstrate the significance of the quality of life of  
11 the labor force in the process of achieving economic growth, as the labor force is the major  
12 building block of economic growth in any nation. Srinivasan (1994), Ranis et al. (2000),  
13 Chontanawat et al. (2008) and others have confirmed this in diverse contexts.

14 The coefficients of trade are positive and significant for all the countries. This implies  
15 that the economic growth is elastic to trade volume, and 1% increase in trade causes increase in  
16 economic growth by 0.6131% (Brazil), 0.7181% (Russia), 0.3789% (India), and 0.7789%  
17 (China). For the panel result, trade have a positive and significant impact on economic growth at  
18 5% level, and 1% increase in trade causes increase in economic growth by 0.4366%. The trade  
19 linkages formed by the BRIC nations with Africa and other nations are gradually proving out to  
20 be fruitful, and this is reflected in these results. Lucas (1988), Schneider (2005) and others have  
21 confirmed this in diverse contexts.

22 Finally, the coefficients of capital are positive and significant at 1% level for Brazil,  
23 Russia, and India. These results imply that economic growth is elastic to capital formations, and

1 1% rise in the level of capital formation causes increase in economic growth by 2.6771%  
2 (Brazil), 0.3439% (Russia), and 1.1362% (India). No significant result was found for China. For  
3 the panel result, capital formation have a positive and significant impact on economic growth at  
4 1% level, and 1% increase in capital formation causes increase in economic growth by 1.1709%.  
5 The growth in output in BRIC nations is adding to their economic growth, and this growth in  
6 output has been possible by the continuous flow of FDI from other nations (Chakravarty and  
7 Mandal, 2016). The result is consistent with the findings of Omri et al. (2015).

8 Estimation results of Eq. (6) for four countries are recorded in Table 4b. The results show  
9 that impact of economic growth on air pollution follows an EKC framework, and it is evident for  
10 Brazil and India. Coefficients of economic growth are positive and that of squared economic  
11 growth are negative for these two countries only. This implies that for Brazil and India, the  
12 environmental degradation is elastic to economic growth, and the change in the slope of EKC is  
13 negative, thereby indicating presence of inverted U-shaped EKC. For Russia and China, the  
14 evidences for EKC are not found. For the panel result, impact of economic growth on air  
15 pollution follows an EKC framework. This result is the extension of the findings by Galeotti and  
16 Lanza (1999) and Jayanthakumaran et al. (2012). However, for Russia and China, the results  
17 contradict the findings by Caviglia-Harris et al. (2009) and Diao et al. (2009), respectively.

18 *<Insert Table 4b here>*

19 The coefficients of energy consumption are positive and significant for Russia, India, and  
20 China. These results imply that CO<sub>2</sub> emission is elastic to energy consumption, and 1% rise in  
21 the level of energy consumption causes increase in emission by 2.1021% (India) and 0.9341%  
22 (China). No significant result was found for Brazil and Russia. For the panel result, energy  
23 consumption have a positive and significant impact on CO<sub>2</sub> emission at 1% level, and 1%

1 increase in energy consumption causes increase in CO<sub>2</sub> emission by 1.2947%. Considering the  
2 economic growth pattern of the BRIC nations, it can be seen that the economic growth achieved  
3 by these nations is majorly catalyzed by fossil fuel consumption. Therefore, in BRIC nations, the  
4 level of ambient air pollution in terms of CO<sub>2</sub> emission is on the rise. The result is consistent  
5 with the findings of Pao and Tsai (2011).

6 The coefficients of trade volume are significant in all the cases, and positive for Brazil,  
7 Russia, and China, and negative for India. These results imply that CO<sub>2</sub> emission is elastic to  
8 trade volume, and 1% rise in the level of trade volume causes increase in emission by 0.2210%  
9 (Brazil), 0.0819% (Russia), and 0.1928% (China), and decrease in emission by 0.0590% (India).  
10 For the panel result, trade volume have a positive and significant impact on CO<sub>2</sub> emission at 1%  
11 level, and 1% increase in trade volume causes increase in CO<sub>2</sub> emission by 0.0980%. At the  
12 earliest stages of economic growth, the BRIC nations provided less importance to the  
13 developmental aspects in order to attract more foreign investors. In this context, when they  
14 started achieving growth in international trade, they also started deteriorating the environmental  
15 quality, which is evident in the rising level of CO<sub>2</sub> emission in these nations. The result is  
16 consistent with the findings of Sebri and Ben-Salha (2014).

17 Finally, the coefficients of gross capital formation are significant for Brazil, India, and  
18 China. These results imply that CO<sub>2</sub> emission is elastic to gross capital formation, and 1% rise in  
19 the level of gross capital formation causes increase in emission by 0.3118% (Brazil), and  
20 0.2234% (China), and decrease in emission by 0.2086% (India). For the panel result, gross  
21 capital formation have a positive and significant impact on CO<sub>2</sub> emission at 1% level, and 1%  
22 increase in gross capital formation causes increase in CO<sub>2</sub> emission by 0.0445%. The output  
23 generated in these nations are just the result of continuous consumption of fossil fuel, and

1 following this cue, it can be said that the rising level of CO<sub>2</sub> emission in these nations is just a  
2 negative byproduct of the production process. The environmentally unsustainable manufacturing  
3 practices added to the environmental degradation by means of rising CO<sub>2</sub> emission. The result is  
4 an extension of the findings by Mehrara et al. (2011).

5 *<Insert Table 4c here>*

6 Estimation results of Eq. (7) for four countries are recorded in Table 4c. The results show  
7 that positive impact of out-of-pocket health expenditure on human development indicator is  
8 evident for Brazil, India, and China. This implies that human development is elastic to health  
9 expenditure, and 1% increase in health expenditure causes human development indicator to  
10 increase by 0.0079% (Brazil), 0.0031% (India), and 0.0011% (China). No significant result was  
11 found for Russia. For the panel result, health expenditure has a positive and significant impact on  
12 human development at 1% level, and 1% increase in health expenditure causes increase in  
13 human development indicator by 0.0067%. With the graduation of time, the policymakers in the  
14 BRIC nations started to realize the negative consequences of environmental degradation on the  
15 labor force, and the rising health expenditure in these nations reflect this policy decision. With  
16 more amount of health expenditure, the healthcare facility gradually turned out to be more  
17 affordable to the citizens. At the same time, the rise in economic growth resulted in the rise of  
18 disposable income, which was translated into the rise in out-of-pocket health expenditure.  
19 Therefore, people started to avail the healthcare facilities more than before, and the rising level  
20 of HDI reflected this. The result is consistent with the findings of Schrooten (2011).

21 The coefficients of economic growth are significant and positive for Russia, India, and  
22 China. This implies that human development is elastic to economic growth, and 1% increase in  
23 economic growth causes human development indicator to increase by 0.0448% (Russia),

1 0.0571% (India), and 0.1019% (China). No significant result was found for Brazil. For the panel  
2 result, economic growth has a positive and significant impact on human development at 1%  
3 level, and 1% increase in health expenditure causes increase in human development indicator by  
4 0.0724%. Though rise in income is a debatable indicator of development, but it may be hard to  
5 deny the fact that with rise in economic growth, a nation can implement more number of  
6 developmental initiatives. For BRIC nations, rise in economic growth not only opened up several  
7 vocational opportunities before the citizens, the betterment and widening of trade linkages  
8 helped several export-oriented sectors to grow. This in turn resulted in better lifestyle for the  
9 citizens, and this uplifting in the living standard has been reflected in the HDI level of the BRIC  
10 nations. The result is consistent with the findings of Ardichvili et al. (2012).

11 The coefficients of trade volume are significant and positive for India and China. This  
12 implies that human development is elastic to trade volume, and 1% increase in trade volume  
13 causes human development indicator to increase by 0.0110% (India) and 0.0954% (China). No  
14 significant result was found for Brazil and Russia. For the panel result, trade volume has a  
15 positive and significant impact on human development at 1% level, and 1% increase in trade  
16 volume causes increase in human development indicator by 0.1380%. Rise in the trade volume  
17 helped in opening up several vocational opportunities in the existing sectors, and also in starting  
18 several export-oriented units. This augmentation in the domestic income resulted in a gradual  
19 uplifting of the living standard of BRIC nations, and this uplifting has been reflected in the HDI  
20 values of these nations. The result is consistent with the findings of Waligóra (2015).

21 Finally, the coefficients of CO<sub>2</sub> emission are significant and negative for Russia, and  
22 positive for Brazil and India. This implies that human development is elastic to CO<sub>2</sub> emission,  
23 and 1% increase in CO<sub>2</sub> emission causes human development indicator to decrease by 0.0826%

1 (Russia), and to increase by 0.1747% (Brazil) and 0.1874% (India). The latter results can be  
2 defined by the green energy initiatives being taken up in these two nations, and this has been  
3 driven by the rising amount of CO<sub>2</sub> emissions in these two nations, which forced the  
4 policymakers to introduce clean energy initiatives, leading towards better HDI results. No  
5 significant result was found for China. For the panel result, CO<sub>2</sub> emission has a negative and  
6 significant impact on human development at 1% level, and 1% increase in CO<sub>2</sub> emission causes  
7 decrease in human development indicator by 0.0651%. These results partially answer to the  
8 questions being raised by Pacini and Silveira (2013).

9 *<Insert Table 4d here>*

10 Estimation results of Eq. (8) for four countries are recorded in Table 4d. The results show  
11 that impact of CO<sub>2</sub> emission on trade volume is evident for Brazil, India, and China. This implies  
12 that trade volume is elastic to CO<sub>2</sub> emission, and 1% increase in CO<sub>2</sub> emission causes trade  
13 volume to decrease by 2.1606% (Brazil), and 2.4687% (India), and increase by 1.8037%  
14 (China). No significant result was found for Russia. This increase and decrease in trade volume  
15 can be defined in terms of nature of trade being affected by CO<sub>2</sub> emission. When Brazil and  
16 India tried to develop in-house green technology for pollution abatement (Ivarsson and Alvstam,  
17 2005), China was majorly look forward to technology transfer from abroad (Lema and Lema,  
18 2012). For the panel result, CO<sub>2</sub> emission has a positive and significant impact on trade volume  
19 at 1% level, and 1% increase in CO<sub>2</sub> emission causes increase in trade volume by 0.3256%.

20 The coefficients of human development are significant and positive for India only. This  
21 implies that trade volume is elastic to human development, and 1% increase in human  
22 development indicator causes trade volume to increase by 7.4437% (India). No significant result  
23 was found for Brazil, Russia, and China. For the panel result, human development has a positive

1 and significant impact on trade volume at 1% level, and 1% increase in human development  
2 indicator causes increase in trade volume by 1.8837%. Availability of healthy and comparatively  
3 cheap labor force may open up several opportunities before a nation in terms of foreign direct  
4 investment. In that way, the trade volume for that nation is bound to rise, and this is evident for  
5 the BRIC nations. The result is new considering the existing literature on human development  
6 and trade.

7         The coefficients of economic growth are significant and positive for China only. This  
8 implies that trade volume is elastic to economic growth, and 1% increase in economic growth  
9 causes trade volume to increase by 0.4747% (China). No significant result was found for Brazil,  
10 Russia, and India. For the panel result, economic growth has no significant impact on trade  
11 volume. For China, it may be the case that the domestic economic growth has been opening  
12 several opportunities to increase the trade volume intrinsically, which may not have been  
13 possible for the other three BRIC nations. Therefore, this phenomenon cannot be considered a  
14 general one for all the four BRIC nations. The result is in the similar lines with Lardy (1995).

15         The coefficients of exchange rate are significant and positive for all the four countries.  
16 This implies that trade volume is elastic to exchange rate, and 1% increase in exchange rate  
17 causes trade volume to increase by 0.3846% (Brazil), 0.0089% (Russia), 0.0394% (India), and  
18 0.0057% (China). These results indicate that lowering the level of protectionism boosts the  
19 volume of trade, and it is applicable for all the BRIC nations. For the panel result, exchange rate  
20 has a positive and significant impact on trade volume at 1% level, and 1% increase in exchange  
21 rate causes increase in trade volume by 0.0137%. The result is in the similar lines with De  
22 Grauwe (1988).





1 emissions and human development, (iii) bidirectional causality exists between CO<sub>2</sub> emission and  
2 trade volume, (iv) bidirectional causality exists between economic growth and human  
3 development, (v) bidirectional causality exists between trade volume and human development,  
4 and (vi) unidirectional causality exists from trade volume to economic growth. Figure 1  
5 summarizes the aforementioned results. These results confirm the four-way linkages between  
6 economic growth, CO<sub>2</sub> emission, human development, and trade volume in BRIC countries for  
7 the duration of 1980-2013.

## 8 **5. Conclusions and policy implications**

9 This study examined the causal associations between economic growth, CO<sub>2</sub> emissions,  
10 human development, and trade volume using simultaneous equation panel data model for BRIC  
11 countries for the duration of 1980-2013. Structural equations allowed us to examine the influence  
12 of (i) CO<sub>2</sub> emission, trade volume, human development, and other variables on economic  
13 growth, (ii) economic growth, trade volume, human development, and other variables on CO<sub>2</sub>  
14 emissions, (iii) economic growth, CO<sub>2</sub> emissions, human development, and other variables on  
15 trade volume, and (iv) economic growth, CO<sub>2</sub> emissions, trade volume, and other variables on  
16 human development.

17 Main findings of the study indicate that bidirectional causality exists between CO<sub>2</sub>  
18 emissions and economic growth. Feedback hypothesis is supported between CO<sub>2</sub> emissions and  
19 human development, trade volume and human development, economic growth and human  
20 development, and CO<sub>2</sub> emissions and trade volume. Apart from finding out the unidirectional  
21 association from trade volume to economic growth, this study also validated the existence of  
22 Environmental Kuznets curve.

1 Policy implications of the study can be put forth based on the directions of the causal  
2 associations being established in the study. Presence of feedback link between CO<sub>2</sub> emissions  
3 and economic growth indicates that environmental pressure in the form of ambient air pollution  
4 can affect the level of hygienic state of the labor force, and thereby, affecting the economic  
5 growth. In order to mitigate this effect, the policymakers should put forth more emphasis on  
6 green energy generation initiatives, which can either be developed in-house, or can be imported  
7 via technology transfer. Empirical evidence of the latter can be visualized by the feedback  
8 between CO<sub>2</sub> emissions and trade volume, and CO<sub>2</sub> emissions and human development,  
9 respectively. By importing green technologies, the state of hygiene of the labor force can be  
10 maintained, and this import need has been generated by the present state of human development  
11 in BRIC nations. This has been validated by the feedback between trade volume and human  
12 development. Finally, apart from technology transfer, the other forms of trade can boost up the  
13 economic growth, by catalyzing the FDI spillovers, which is indicated by the unidirectional  
14 causal association from trade volume to economic growth.

15

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