ARTICLE IN PRESS

Atmospheric Pollution Research xxx (2016) 1–10

Contents lists available at ScienceDirect

Atmospheric Pollution Research

journal homepage: http://www.journals.elsevier.com/locate/apr

Original article

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

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ARTICLE INFO

Article history:
Received 10 April 2016
Received in revised form
8 June 2016
Accepted 10 June 2016
Available online xxx

Keywords:
Economic growth
CO_2
Trade
Human development indicator
BRIC
GMM

ABSTRACT

This paper looks into the causal association between economic growth, CO_2 emission, trade volume, and human development indicator for Brazil, Russia, India, and China (BRIC countries) during 1980–2013. Following a generalized method of moments (GMM) technique, we have found out that bidirectional causality exists between CO_2 emissions and economic growth. Feedback hypothesis is supported between CO_2 emissions and human development, trade volume and human development, economic growth, and human development, and CO_2 emissions and trade volume. Apart from finding out the unidirectional association from trade volume to economic growth, this study also validated the existence of Environmental Kuznets curve. Empirical findings of the study substantiate that the policymakers of the BRIC nations must focus on the green energy initiatives, either by in-house development or by technology transfer. This movement will allow them to control the ambient air pollution prevalent in these nations.

1. Introduction

Global warming and climate change is one of the major concerns worldwide. The Kyoto Protocol was signed with the objective to minimize the damage of global warming and climate change by taking steps to reduce greenhouse gases (GHG) emissions. Although the BRIC countries signed the Kyoto Protocol, environmental concerns still remain due to their growth potential (Pao and Tsai, 2010). The World Bank data on CO_2 emission shows that BRIC countries emissions increased for these economies for the period from 2011 to 2015, with Brazil growing at 1.15%, Russia 12.6%, India 1.7% and China 6.7% (World Bank, 2015). These four countries, with a combined population of 3 billion people and a GDP of \$16tn, will have a huge direct impact on global emissions.

The last few decades has seen several empirical studies connecting trade openness, environmental conditions and human development (Ehrlich and Lui, 1991; Ekins, 1997; Pao and Tsai, 2010, 2011a, 2011b). However, very few studies were done in the context of BRIC economies (Belloumi, 2009; Zhang and Cheng, 2009). Considering the causal associations, Zhang and Cheng (2009) designed one of the earliest multivariate models, and the latest work is carried out by Omri et al. (2015). These studies focused on establishing possible causal associations between energy consumption, economic growth, and carbon emission by using multivariate models, and these models assume the economic structure to be four-sector (Mahalanobis, 1955), where the social determinants of economic growth and environmental degradation have been ignored. Moreover, all of the studies show that the relationship between the proxy measures of these concepts cannot be generalized as they vary significantly across countries. Several studies reveal that the relationship varies even among transient economies that are expected to face similar growth challenges (Ozturk and Acaravci, 2010; Palamalai et al., 2014; Sinha, 2014; Sinha and Bhattacharya, 2014; Sinha and Mehta, 2014; Omri et al., 2015; Sinha, 2015).

In the light of the above discussion, this paper studies the causal association between economic growth, trade openness, environmental condition and human development in BRIC countries. We employ the extended Cobb-Douglas production function approach

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Peer review under responsibility of Turkish National Committee for Air Pollution Research and Control.
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http://dx.doi.org/10.1016/j.apr.2016.06.003
1309-1042/

by Omri et al. (2015), where economic growth depends on human development indicator, trade openness, gross capital formation, and energy consumption. This particular model permits us to discover the causal association among the variables: economic growth, emission level, human development indicator, and trade openness. These variables are selected for capturing the attributes of BRIC countries. This study accordingly contributes to the literature on energy economics by demonstrating an integrated approach to scrutinize the four-way associations between economic growth, CO_2 emissions, human development indicator, and trade openness in the BRIC countries by using the simultaneous-equation models with panel econometric techniques over the period 1980–2013. Consequently, the results of this study can prove to be beneficial for the policymakers to come out with an effective policy-level decision for endorsing long-term economic growth for BRIC nations. By far, the studies carried out for BRIC nations have largely ignored the aspects of human development and majorly focused on the aspects of economic growth (Tamazian et al., 2009; Pao and Tsai, 2010, 2011a; Cowan et al., 2014; Sebri and Ben-Salha, 2014). According to the latest study by Azahaf and Schraad-Tischler (2012), the sustainable development framework in the BRIC nations needs reconsideration, as economists are posing doubts regarding the convergence of income in these nations (Mpoyi, 2012). During the course of economic growth, economists are of the opinion that the sustainable development targets are largely being compromised (Rowlands, 2012). Chakravarty and Mandal (2016) talked about this issue in their recent study, and they have indicated the importance of considering developmental aspects while analyzing the economic growth scenario in BRIC countries. In this kind of a situation, considering the human development aspect within the framework of economic growth and environmental emission may result in significant policy implications. As BRIC nations are also in the process of building several trade linkages with less developed nations for improving the scenario of development in those nations (De Castro, 2012; Çakır and Kabundi, 2013), it may be required to revisit their own sustainable development framework at the very beginning. When these characteristics of the BRIC nations are considered, they adequately comply with the model specification.

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

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

2. Literature review

The extant literature working on the nexus between economic growth, emission level, human development indicator and trade-openness have been carried out in silos, and nearly all of the econometric models have ignored the social parameters to a great extent. Moreover, the causality among these variables also continues to be ambiguous due to varied results of cross-sectional and time series studies that took place in different countries. BRIC, being a significant emerging economy cluster (46% of the world population resides in these countries), has not been studied extensively for these dimensions, especially for human resource development. Consequently, the literature review has been divided into six subsections a) Carbon emission and economic growth; b) Carbon emission and human development; c) Human Development and Trade; d) Economic Growth and Trade; e) Human Development and Economic Growth; and f) Carbon Emission and Trade. We will discuss them in the next subsections.

2.1. Carbon emission and economic growth

The relationship between carbon emission and economics growth has been widely studied for more than two decades. However, the empirical results vary widely mainly due to different sets of underlying variables. In the context of the association between environmental degradation and economic growth, Environmental Kuznets Curve (EKC) hypothesis is one of the extensively researched hypotheses. According to this hypothesis, environmental degradation starts at the earliest stage of economic growth, grows with the rise in income, and once the income reaches a certain point, i.e. the turnaround point, the environmental degradation starts to decline. Therefore, the generally accepted form of EKC is inverted U-shaped. Galeotti et al. (2006) studied the link between carbon emission and economic growth for the OECD and non-OECD countries. They find evidence for the EKC only for the OECD countries. Azomahou et al. (2006) examine the EKC hypothesis for CO_2 emission using a non-parametric approach. They use data for 100 countries over the period 1960–1996 and found some evidence of the EKC hypothesis. The studies considered only bivariate relationship and obtained results that support EKC (Pao and Tsai, 2010). For the advocates of economic growth, EKC hypothesis became an empirical tool to favor economic growth at the cost of CO_2 emission. However, studies by Ekins (1997), Stern (2000), Ozturk and Acaravci (2010), Sinha (2014), Sinha and Bhattacharya (2014), Sinha and Mehta (2014), Sinha (2015) and others obtained different relationship between CO_2 emission and economic growth thus weakening the equivocal hold of EKC. However, empirical study by Tamazian et al. (2009) supported the EKC hypothesis for BRIC nations and argues that economic development has reduced environment degradation in these countries. Since such bivariate studies are likely to suffer from endogeneity issue, the present study has been chipped with suitable instrumental variable.

2.2. Carbon emission and human development

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

2.3. Carbon emission and trade

Studies incorporating trade as a variable in testing the EKC hypothesis include Grossman and Krueger (1991), Lucas et al. (1993), Wyckoff and Roop (1994), Suri and Chapman (1998), and Nahman and Antrobus (2005). Most of these studies intuitively show that increase in trade should result in higher pollution. While this

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intuition has been invalidated empirically for local pollutants (like SO_2 and NO_2) but for global pollutant i.e., CO_2, the relationship is positive Frankel and Rose (2005). In the Indian context, Palamalai et al. (2014) identified a bidirectional relationship between trade and carbon emission. The causality cannot be generalized considering varied results obtained by Jalil and Feridun (2011), where they obtained a negative relation between CO_2 emission and trade development in China. Therefore, it is interesting to decipher who can and who cannot gain from trade at the cost of environment.

2.4. Human development and trade

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

2.5. Economic growth and trade

According to Stiglitz (1998, p. 36), "most specifications of empirical growth regressions find that some indicator of external openness-whether trade ratios or indices or price distortions or average tariff level is strongly associated with per-capita income growth." The literature on trade openness and economic growth have tried to check this association by: (1) constructing alternative indicators of openness (Dollar, 1992; Sachs et al., 1995); (2) testing robustness by using a wide range of measures of openness, including subjective indicators (Edwards, 1992, 1998); and (3) comparing convergence experience among groups of liberalizing and non-liberalizing countries (Ben-David, 1993). This convergence literature is generally credited with finding significant relationship between trade and economic growth than the other two strands, but most of the literature available till date equivocally supports the bidirectional relation between economic growth and Trade and none has used the BRIC countries. Recent studies by Yucel (2009) and Shahbaz et al. (2013) investigated the causality between economic growth, financial development and trade openness in Turkey and China respectively. In the context of BRIC, Mercan et al. (2013) presented panel data analysis in support of unidirectional relationship between trade openness and economic growth.

2.6. Human development and economic growth

Human development is long understood to be an important input for economic growth. Preliminary empirical evidence of the interaction between the two came from Ehrlich and Lui (1991) and Barro (1996). They took life expectancy as a health indicator and established a conceptual framework by instilling health in growth theory. Ranis et al. (2000) showed the connections between economic growth (EG) and human development (HD) form two chains, the EG to HD chain and the HD to EG chain. They used a cross-country regression to show a significant relationship in both directions. Their study establishes a two-way causality which gives rise to "virtuous or vicious cycles", with high or low levels on HD and EG reinforcing each other. On the other hand, studies by Mayer (2001), Bloom et al. (2004) and Weil (2005) showed evidences for unidirectional causality between health as a proxy for human development and economic growth. Thus the link between two indicators is inarguably valid for developing as well as developed countries (Bhargava et al., 2001). However, we have not come across any study, which talks about human development along with trade, carbon emission in economic growth studies. This paper is an attempt to explore the role of human development among other parameters of growth.

3. Econometric techniques

3.1. Model specification

For analyzing the causal association between economic growth, CO_2 emission, trade volume, and human development indicator for BRIC countries, we used an extended Cobb-Douglas production function as per Omri et al. (2015):

$$Y = AK^{\alpha}E^{\lambda}L^{\beta}e^{\mu} \tag{1}$$

where, Y is the GDP of the countries, A is the technological advancement, K is capital formation, E is energy consumption, L is number of labors, and e is error term. α, β, and λ are the respective elasticities of capital, labor, and energy consumption, and we relax the assumption of constant return to scale, as it is not mandatory for this model. In a constant technological regime, scale of industrial emission is directly proportionate to energy consumption (Taft, 1952), such as $E = xC$, C is the CO_2 emissions, and x is time-invariant constant. On the other hand, for the BRIC countries, the technological innovation is largely dependent on the technology transfers via foreign direct investment (FDI) route (Ranjan and Agrawal, 2011). Consequently, we can write

$$A(t) = \varphi \cdot T(t) \tag{2}$$

where φ is time-invariant constant and T is volume of trade.

In the similar way, the amount of people in working condition can be derived based on the total population and the human development index (HDI) of any country in a linear fashion (Ranis et al., 2006), such as $L(t) = cP(t) \cdot H(t)$, P is the population, H is the HDI of the country, and c is time-invariant constant.

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

$$Y = x\varphi c \cdot T(t) \cdot H(t)^{\theta 1} C(t)^{\theta 2} K(t)^{\alpha} P(t)^{\beta} e^{\mu} \tag{3}$$

Firstly, Eq. (3) has been transformed into per capita terms by dividing both sides by P. Now, the linearized Cobb-Douglas function for panel data analysis becomes:

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

where, $i = 1, \ldots, n$ denotes BRIC countries, and $t = 1, \ldots, T$ denotes duration of the study, i.e. 1980–2013.

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

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

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

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

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

In the above equations, the subscript $i = 1 \ldots$ N denotes the country and $t = 1 \ldots$ T denotes the time period. Eq. (6) states that economic growth (Y), human development indicator (H), volume of trade (T), gross capital formation (K), and energy consumption (E) are the driving forces of CO_2 emissions (C) (e.g. Smith, 1993; Harbaugh et al., 2002; Munksgaard et al., 2005). Eq. (7) states that human development (H) depends on economic growth (Y), CO_2 emissions (C), volume of trade (T), and out-of-pocket health expenditure (HEX) (e.g. Messier et al., 2004; Davies and Quinlivan, 2006). Eq. (8) states that volume of trade (T) depends on economic growth (Y), CO_2 emissions (C), human development indicator (H), exchange rate (EX), and foreign direct investment (FDI) (e.g. Aizenman and Noy, 2006; Bogin et al., 2007).

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

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

3.2. Unit root tests

With the recent developments in the literature of econometric techniques, panel unit root tests have undergone a transformation in terms of first generation (Levin et al., 2002; Im et al., 2003) and second generation (Pesaran, 2007). This differentiation lies in view of the cross-sectional dependence in the panel data. First generation panel unit root tests assume that the cross-sections in the panel data are independent, whereas second generation panel unit root tests relax this assumption. If there is cross-sectional dependence present in the data, then application of first generation panel unit root test may produce fallacious results owing to size distortions. On the other hand, if there is no cross-sectional dependence present in the data, then application of second generation panel unit root test may produce loss of power. In this study, the latter one is the case here, and therefore, we employ the first generation panel unit root tests.

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

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

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 number of lags. The error term ($\varepsilon_{i,t}$) are assumed to be IID (0, σ^2) and to be independent of units of the sample. The null hypothesis for indicating non-stationarity in this case can be stated as:

H_0: $\alpha_i = 0$, for all I; H_1: $\alpha_i = \alpha < 0$, for all i.

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

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

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 number of lags. The error term ($\varepsilon_{i,t}$) are assumed to be IID (0, σ^2) and to be independent of the units of the sample. Both α and Ø are permitted to differ in accordance with the cross sections. The null hypothesis for indicating non-stationarity in this case can be stated as:

H_0: $\alpha_i = 0$, for all I; H_1: $\alpha_i = \alpha < 0$, for all i.

4. Data and results

4.1. Data and descriptive statistics

The data used in this study are for BRIC countries covering the period of 1980–2013. We have collected annual data for CO_2 emission, income, trade, capital formation, exchange rate, energy consumption, and out-of-pocket health expenditure from the World Bank indicators, and HDI data from UNDP. Descriptive statistics of the variables for BRIC countries are provided in Table 1.

4.2. Results of panel unit root and cointegration tests

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

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Table 1
Descriptive statistics.

Area	Variable	Units	Obs.	Mean	Std. Dev.	CV.
Brazil	C	in kt	34	284574.10	86929.70	0.31
	H	index	34	0.65	0.06	0.09
	Y	in current US$	34	809801209917.36	659783903735.94	0.81
	T	percentage	34	20.86	4.59	0.22
	K	constant 2005 US$	34	138184857476.07	47181997594.19	0.34
	E	in kt	34	179883.91	52050.02	0.29
	FDI	constant 2005 US$	34	19580496107.76	23440725822.20	0.84
	HEX	percentage	34	39.06	5.64	0.14
	EX	LCU per US$	34	1.11	1.07	0.96
Russia	C	in kt	34	2074331.68	615746.25	0.30
	H	index	34	0.73	0.03	0.04
	Y	in current US$	34	714252036788.48	536583235197.20	0.75
	T	percentage	34	55.83	12.70	0.23
	K	constant 2005 US$	34	385688105004.49	348046987632.91	0.90
	E	in kt	34	752044.58	131502.93	0.17
	FDI	constant 2005 US$	34	14898188803.32	22706734660.34	0.65
	HEX	percentage	34	23.58	11.99	0.51
	EX	LCU per US$	34	14.10	13.50	0.96
India	C	in kt	34	1097148.30	586577.54	0.53
	H	index	34	0.47	0.07	0.15
	Y	in current US$	34	638560600248.32	534010159893.25	0.84
	T	percentage	34	27.29	14.60	0.53
	K	constant 2005 US$	34	188078139967.17	158689991099.79	0.84
	E	in kt	34	430979.18	169010.59	0.39
	FDI	constant 2005 US$	34	8483605634.06	12801029471.68	0.66
	HEX	percentage	34	67.87	3.92	0.06
	EX	LCU per US$	34	32.11	15.82	0.49
China	C	in kt	34	4115730.22	2466890.37	0.60
	H	index	34	0.57	0.09	0.16
	Y	in current US$	34	1930795896088.15	2479741237056.22	1.28
	T	percentage	34	38.82	17.60	0.45
	K	constant 2005 US$	34	665182162786.37	665649533445.06	1.00
	E	in kt	34	1294166.54	656078.08	0.51
	FDI	constant 2005 US$	34	75240042455.15	102180648161.82	0.74
	HEX	percentage	34	54.71	10.47	0.19
	EX	LCU per US$	34	5.98	2.41	0.40

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

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

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

Table 2
Results of cross-section dependence test.

Variables	p-values with lags
C	0.753 (1)
H	0.956 (1)
Y	0.964 (1)
T	0.465 (2)
K	0.948 (2)
E	0.998 (1)
FDI	0.648 (5)
HEX	0.995 (1)
EX	0.980 (1)

Note: Lag lengths are shown in parentheses after the p-value.

Table 3a
Results of panel unit root tests.

Variables	LLC test		IPS test	
	Level	First difference	Level	First difference
C	8.3459	−5.6587[a]	1.1623	−6.9971[a]
H	6.5749	−4.0412[a]	0.0530	−2.1781[b]
Y	0.5257	−4.8135[a]	5.6333	−6.0516[a]
T	−0.6142	−2.9753[a]	−1.1672	−6.2841[a]
K	4.0159	−6.6882[a]	1.8813	−8.3292[a]
E	0.6942	−6.4490[b]	0.3969	−5.2767[a]
FDI	−1.3660	−9.2700[a]	−0.6093	−5.4377[a]
HEX	2.0465	−7.8437[a]	3.8814	−8.9034[a]
EX	−0.2210	−3.3724[a]	2.4247	−4.8528[a]

[a] Significant at 1% level.
[b] Significant at 5% level.

Table 3b
Results of cointegration tests.

	Panel	p-value
Model represented by Eq. (5)	1.6256	0.9480
Model represented by Eq. (6)	0.4248	0.6645
Model represented by Eq. (7)	−0.0925	0.4631
Model represented by Eq. (8)	0.0469	0.5187

Note: Group ADF-Statistic for between-dimension are reported.

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

4.3. Results of regression tests and discussion

While estimating four way linkages between CO_2 emission, economic growth, trade, and health, instrumental variables are *K*, Y^2, *E*, *FDI*, *HEX*, and *EX*.

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

Estimation results of Eq. (5) for four countries are recorded in Table 4a. The results show that CO_2 emission has a negative impact on economic growth, and it is evident for Brazil, India, and China. This implies that the economic growth is elastic to CO_2 emissions, and 1% increase in CO_2 emissions causes decrease in economic growth by 1.7334% (Brazil), 0.7553% (India), and 0.7473% (China). No significant result was found for Russia. For the panel result, CO_2 emissions have a negative and significant impact on economic growth at 5% level, and 1% increase in CO_2 emissions causes decrease in economic growth by 0.2088%. These results show that the environmental degradation is causing harm to the pattern of economic growth, and thereby, addressing the feedback hypothesis of EKC. These results also show that the economic growth pattern in BRIC nations is unsustainable in nature, and the developmental goals in these nations must consider the environmental sustainability aspects more seriously. The results obtained by us are in the similar lines with the findings of Zhang and Cheng (2009), Pao and Tsai (2011a, 2011b), and Sinha (2015).

Table 4a
Results of simultaneous GMM estimation for Eq. (5).

Countries	Dependent variable: Economic growth (Y)				
	Constant	C	H	T	K
Brazil	−15.5927[a]	−1.7334[a]	5.2094[a]	0.6131[a]	2.6771[a]
	(0.001)	(0.005)	(0.000)	(0.000)	(0.000)
Russia	20.7279[a]	0.4354	19.1633[a]	0.7181[a]	0.3439[a]
	(0.000)	(0.256)	(0.000)	(0.000)	(0.001)
India	11.2626	−0.7553[b]	2.5419	0.3789[a]	1.1362[a]
	(0.174)	(0.040)	(0.172)	(0.003)	(0.000)
China	27.0866[a]	−0.7473[a]	7.9154[a]	0.7789[a]	−0.1269
	(0.000)	(0.000)	(0.000)	(0.000)	(0.476)
Panel	2.0923[c]	−0.2088[b]	1.4525[a]	0.4366[b]	1.1709[a]
	(0.059)	(0.019)	(0.000)	(0.024)	(0.000)
Hansen's J statistics	0.0008 (0.977)				
DWH Test statistics	135.9302[a] (0.000)				

p-values are within the parentheses.
[a] Significant at 1% level.
[b] Significant at 5% level.
[c] Significant at 10% level.

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

The coefficients of trade are positive and significant for all the countries. This implies that the economic growth is elastic to trade volume, and 1% increase in trade causes increase in economic growth by 0.6131% (Brazil), 0.7181% (Russia), 0.3789% (India), and 0.7789% (China). For the panel result, trade have a positive and significant impact on economic growth at 5% level, and 1% increase in trade causes increase in economic growth by 0.4366%. The trade linkages formed by the BRIC nations with Africa and other nations are gradually proving out to be fruitful, and this is reflected in these results. Lucas et al. (1993), Schneider (2005) and others have confirmed this in diverse contexts.

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

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

The coefficients of energy consumption are positive and significant for Russia, India, and China. These results imply that CO_2 emission is elastic to energy consumption, and 1% rise in the level of energy consumption causes increase in emission by 2.1021% (India) and 0.9341% (China). No significant result was found for Brazil and Russia. For the panel result, energy consumption have a positive and significant impact on CO_2 emission at 1% level, and 1% increase in energy consumption causes increase in CO_2 emission by 1.2947%. Considering the economic growth pattern of the BRIC nations, it can be seen that the economic growth achieved by these nations is majorly catalyzed by fossil fuel consumption. Therefore, in BRIC nations, the level of ambient air pollution in terms of CO_2 emission

Table 4b
Results of simultaneous GMM estimation for Eq. (6).

Countries	Dependent variable: CO_2 emission (C)						
	Constant	H	Y	T	Y^2	K	E
Brazil	−28.8687	0.8197	2.0963[b]	0.2210[a]	−0.0388	0.3118[a]	0.4020
	(0.372)	(0.430)	(0.039)	(0.000)	(0.322)	(0.005)	(0.222)
Russia	14.2315	−3.6688[a]	−0.9268	0.0819[a]	0.0189	0.1337	0.4776
	(0.662)	(0.002)	(0.684)	(0.001)	(0.644)	(0.121)	(0.120)
India	−17.5668	−0.5642	0.7153[c]	−0.0590[a]	−0.0120	−0.2086[a]	2.0121[a]
	(0.251)	(0.157)	(0.114)	(0.000)	(0.537)	(0.000)	(0.000)
China	51.4235[c]	0.2444	−3.8259[b]	0.1928[b]	0.0650[c]	0.2234[a]	0.9341[a]
	(0.094)	(0.764)	(0.046)	(0.019)	(0.054)	(0.000)	(0.001)
Panel	−30.4186[a]	−0.3712[a]	1.9215[a]	0.0980[a]	−0.0358[a]	0.0445[a]	1.2947[a]
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)
Hansen's J statistics	0.0008 (0.9772)						
DWH Test statistics	85.1781[a] (0.0000)						

p-values are within parentheses.
[a] Significant at 1% level.
[b] Significant at 5% level.
[c] Significant at 10% level.

is on the rise. The result is consistent with the findings of Pao and Tsai (2011a, 2011b).

The coefficients of trade volume are significant in all the cases, and positive for Brazil, Russia, and China, and negative for India. These results imply that CO_2 emission is elastic to trade volume, and 1% rise in the level of trade volume causes increase in emission by 0.2210% (Brazil), 0.0819% (Russia), and 0.1928% (China), and decrease in emission by 0.0590% (India). For the panel result, trade volume have a positive and significant impact on CO_2 emission at 1% level, and 1% increase in trade volume causes increase in CO_2 emission by 0.0980%. At the earliest stages of economic growth, the BRIC nations provided less importance to the developmental aspects in order to attract more foreign investors. In this context, when they started achieving growth in international trade, they also started deteriorating the environmental quality, which is evident in the rising level of CO_2 emission in these nations. The result is consistent with the findings of Sebri and Ben-Salha (2014).

Finally, the coefficients of gross capital formation are significant for Brazil, India, and China. These results imply that CO_2 emission is elastic to gross capital formation, and 1% rise in the level of gross capital formation causes increase in emission by 0.3118% (Brazil), and 0.2234% (China), and decrease in emission by 0.2086% (India). For the panel result, gross capital formation have a positive and significant impact on CO_2 emission at 1% level, and 1% increase in gross capital formation causes increase in CO_2 emission by 0.0445%. The output generated in these nations are just the result of continuous consumption of fossil fuel, and following this cue, it can be said that the rising level of CO_2 emission in these nations is just a negative byproduct of the production process. The environmentally unsustainable manufacturing practices added to the environmental degradation by means of rising CO_2 emission. The result is an extension of the findings by Mehrara et al. (2011).

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

The coefficients of economic growth are significant and positive for Russia, India, and China. This implies that human development is elastic to economic growth, and 1% increase in economic growth causes human development indicator to increase by 0.0448% (Russia), 0.0571% (India), and 0.1019% (China). No significant result was found for Brazil. For the panel result, economic growth has a positive and significant impact on human development at 1% level, and 1% increase in health expenditure causes increase in human development indicator by 0.0724%. Though rise in income is a debatable indicator of development, but it may be hard to deny the fact that with rise in economic growth, a nation can implement more number of developmental initiatives. For BRIC nations, rise in economic growth not only opened up several vocational opportunities before the citizens, the betterment and widening of trade linkages helped several export-oriented sectors to grow. This in turn resulted in better lifestyle for the citizens, and this uplifting in

Table 4c
Results of simultaneous GMM estimation for Eq. (7).

Countries	Dependent variable: Human development indicator (H)				
	Constant	C	Y	T	HEX
Brazil	−2.1922[a]	0.1747[a]	−0.0035	−0.0066	0.0079[a]
	(0.000)	(0.000)	(0.685)	(0.705)	(0.001)
Russia	-.3579[a]	−0.0826[a]	0.0448[a]	0.0068	−0.0001
	(0.000)	(0.000)	(0.000)	(0.528)	(0.836)
India	−5.1246[a]	0.1874[a]	0.0571[a]	0.0110[b]	0.0031[a]
	(0.000)	(0.000)	(0.000)	(0.046)	(0.000)
China	−3.9503[a]	0.0100	0.1019[a]	0.0954[a]	0.0011[b]
	(0.000)	(0.766)	(0.000)	(0.000)	(0.033)
Panel	−1.7418[a]	−0.0651[a]	0.0724[a]	0.1380[a]	0.0067[a]
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen's J statistics	2.8463 (0.4159)				
DWH Test statistics	110.0520 (0.0000)				

p-values are within parentheses.
[a] Significant at 1% level.
[b] Significant at 5% level.

the living standard has been reflected in the HDI level of the BRIC nations. The result is consistent with the findings of Ardichvili et al. (2012).

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

Finally, the coefficients of CO_2 emission are significant and negative for Russia, and positive for Brazil and India. This implies that human development is elastic to CO_2 emission, and 1% increase in CO_2 emission causes human development indicator to decrease by 0.0826% (Russia), and to increase by 0.1747% (Brazil) and 0.1874% (India). The latter results can be defined by the green energy initiatives being taken up in these two nations, and this has been driven by the rising amount of CO_2 emissions in these two nations, which forced the policymakers to introduce clean energy initiatives, leading towards better HDI results. No significant result was found for China. For the panel result, CO_2 emission has a negative and significant impact on human development at 1% level, and 1% increase in CO_2 emission causes decrease in human development indicator by 0.0651%. These results partially answer to the questions being raised by Pacini and Silveira (2013).

Estimation results of Eq. (8) for four countries are recorded in Table 4d. The results show that impact of CO_2 emission on trade volume is evident for Brazil, India, and China. This implies that trade volume is elastic to CO_2 emission, and 1% increase in CO_2 emission causes trade volume to decrease by 2.1606% (Brazil), and 2.4687% (India), and increase by 1.8037% (China). No significant result was found for Russia. This increase and decrease in trade volume can be defined in terms of nature of trade being affected by CO_2 emission. When Brazil and India tried to develop in-house green technology for pollution abatement (Ivarsson and Alvstam, 2005), China was majorly look forward to technology transfer from abroad (Lema and Lema, 2012). For the panel result, CO_2 emission has a positive and significant impact on trade volume at 1% level, and 1% increase in CO_2 emission causes increase in trade volume by 0.3256%.

Table 4d
Results of simultaneous GMM estimation for Eq. (8).

Countries	Dependent variable: Trade volume (T)					
	Constant	C	H	Y	EX	FDI
Brazil	27.2639[a]	−2.1606[a]	2.1998	0.1151	0.3846[a]	0.0001[a]
	(0.003)	(0.000)	(0.368)	(0.581)	(0.000)	(0.002)
Russia	4.1437	−0.0306	−5.4208	−0.0602	0.0098[b]	0.0001
	(0.337)	(0.964)	(0.575)	(0.878)	(0.025)	(0.204)
India	39.8084[a]	−2.4687[a]	7.4437[a]	0.0586	0.0394[a]	0.0002[a]
	(0.001)	(0.000)	(0.003)	(0.723)	(0.000)	(0.000)
China	−37.9203[a]	1.8037[a]	−2.9160	0.4747[b]	0.0057	0.0005[a]
	(0.001)	(0.000)	(0.133)	(0.047)	(0.823)	(0.000)
Panel	3.1732	0.3256[a]	1.8837[a]	−0.1287	0.0137[a]	0.0001
	(0.188)	(0.000)	(0.000)	(0.124)	(0.000)	(0.942)
Hansen's J statistics	3.0147 (0.3894)					
DWH Test statistics	21.4819[a] (0.0001)					

p-values are within parentheses.
[a] Significant at 1% level.
[b] Significant at 5% level.

The coefficients of human development are significant and positive for India only. This implies that trade volume is elastic to human development, and 1% increase in human development indicator causes trade volume to increase by 7.4437% (India). No significant result was found for Brazil, Russia, and China. For the panel result, human development has a positive and significant impact on trade volume at 1% level, and 1% increase in human development indicator causes increase in trade volume by 1.8837%. Availability of healthy and comparatively cheap labor force may open up several opportunities before a nation in terms of foreign direct investment. In that way, the trade volume for that nation is bound to rise, and this is evident for the BRIC nations. The result is new considering the existing literature on human development and trade.

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

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

The coefficients of foreign direct investment are significant and positive for Brazil, India, and China. However, the effect size is nearly negligible and therefore, we will not consider the elasticity values in this case.

By and large, results obtained from this study can be summarized based on the individual associations. For the causal association between economic growth and trade volume, feedback hypothesis exists for China, and unidirectional causal association runs from trade volume to economic growth for Brazil, Russia, and India. Taking the causal association between economic growth and CO_2 emission, feedback hypothesis exists for Brazil, India, and China, and neutrality hypothesis exists for Russia. Next, taking the causal association between economic growth and human development, feedback hypothesis exists for Russia and China, unidirectional causal association runs from human development to economic growth for Brazil, and unidirectional causal association runs from economic growth to human development for India. For the causal association between human development and trade volume, feedback hypothesis exists for India, unidirectional causal association runs from trade volume to human development for China, and neutrality hypothesis exists for Brazil and Russia. Now, for the causal association between human development and CO_2 emission, feedback hypothesis exists for Russia, unidirectional causal association runs from CO_2 emission to human development for India and Brazil, and neutrality hypothesis exists for China.

Please cite this article in press as: Sinha, A., Sen, S., Atmospheric consequences of trade and human development: A case of BRIC countries, Atmospheric Pollution Research (2016), http://dx.doi.org/10.1016/j.apr.2016.06.003

Finally, for the causal association between trade volume and CO_2 emission, feedback hypothesis exists for Brazil, India, and China, and unidirectional causal association runs from trade volume to CO_2 emission for Russia.

As a final point, conclusive results of this study are, (i) bidirectional causality exists between CO_2 emissions and economic growth, (ii) bidirectional causality exists between CO_2 emissions and human development, (iii) bidirectional causality exists between CO_2 emission and trade volume, (iv) bidirectional causality exists between economic growth and human development, (v) bidirectional causality exists between trade volume and human development, and (vi) unidirectional causality exists from trade volume to economic growth. Fig. 1 summarizes the aforementioned results. These results confirm the four-way linkages between economic growth, CO_2 emission, human development, and trade volume in BRIC countries for the duration of 1980–2013.

5. Conclusions and policy implications

This study examined the causal associations between economic growth, CO_2 emissions, human development, and trade volume using simultaneous equation panel data model for BRIC countries for the duration of 1980–2013. Structural equations allowed us to examine the influence of (i) CO_2 emission, trade volume, human development, and other variables on economic growth, (ii) economic growth, trade volume, human development, and other variables on CO_2 emissions, (iii) economic growth, CO_2 emissions, human development, and other variables on trade volume, and (iv) economic growth, CO_2 emissions, trade volume, and other variables on human development.

Main findings of the study indicate that bidirectional causality exists between CO_2 emissions and economic growth. Feedback hypothesis is supported between CO_2 emissions and human development, trade volume and human development, economic growth and human development, and CO_2 emissions and trade volume. Apart from finding out the unidirectional association from trade volume to economic growth, this study also validated the existence of Environmental Kuznets curve.

Policy implications of the study can be put forth based on the directions of the causal associations being established in the study. Presence of feedback link between CO_2 emissions and economic growth indicates that environmental pressure in the form of ambient air pollution can affect the level of hygienic state of the labor force, and thereby, affecting the economic growth. In order to mitigate this effect, the policymakers should put forth more emphasis on green energy generation initiatives, which can either be developed in-house, or can be imported via technology transfer. Empirical evidence of the latter can be visualized by the feedback between CO_2 emissions and trade volume, and CO_2 emissions and human development, respectively. By importing green technologies, the state of hygiene of the labor force can be maintained, and this import need has been generated by the present state of human development in BRIC nations. This has been validated by the feedback between trade volume and human development. Finally, apart from technology transfer, the other forms of trade can boost up the economic growth, by catalyzing the FDI spillovers, which is indicated by the unidirectional causal association from trade volume to economic growth.

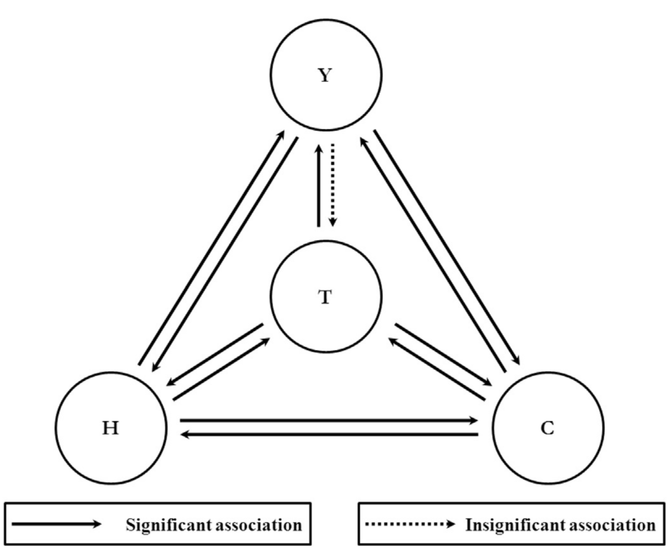

Fig. 1. Four-way linkages between economic growth-emission-trade-HDI.

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Please cite this article in press as: Sinha, A., Sen, S., Atmospheric consequences of trade and human development: A case of BRIC countries, Atmospheric Pollution Research (2016), http://dx.doi.org/10.1016/j.apr.2016.06.003

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Please cite this article in press as: Sinha, A., Sen, S., Atmospheric consequences of trade and human development: A case of BRIC countries, Atmospheric Pollution Research (2016), http://dx.doi.org/10.1016/j.apr.2016.06.003