Impact of Corruption in Public Sector on Environmental Quality: Implications for Sustainability in BRICS and Next 11 Countries

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Abstract: This study investigates the impact of corruption in public sector on carbon emissions in presence of energy use segregation, following the Environmental Kuznets Curve (EKC) framework. The study has been carried out for Brazil-Russia-India-China-South Africa (BRICS) and Next 11 countries over the period of 1990-2017. Along with the finding of inverted N-shaped EKC for both the cases, we find that incidents of corruption enhance environmental degradation by reducing the positive impact of renewable energy consumption on environmental quality, and increasing the negative impact of fossil fuel consumption. This study has also divulged that the corruptive practices are more prone in case of the countries, where the development is mature and institutionalization is more stringent. Based on these findings, we suggest that environmental policies should take account of the corruption, and thereby, making the policies more robust and effective.

Keywords: Environmental Kuznets Curve; CO_2 Emissions; Corruption; Next 11; BRICS

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1. Introduction

Paris climate meet in 2015 and recent UN meeting in Bonn show how the developing countries have become active in their Carbon Dioxide (CO_2) emissions reduction target via Intended Nationally Determined Contribution (INDC). Intergovernmental Panel on Climate Change (2014) report shows that per capita CO_2 emissions and per capita energy consumption in developing countries is far less than in developed countries. The report also states that the issues of increasing emissions and climate change can harm the economic growth pattern in emerging economies. So, it becomes imperative to recognise the relationship between income and environmental quality, which is well-explained by the Environmental Kuznets Curve (EKC) hypothesis. The Kuznets Curve, initially developed by Simon Kuznets in 1955, shows an inverted-U shaped association between income and inequality. Later, the same trend was found between economic growth and environmental degradation, and this association started to be known as EKC. Grossman and Krueger (1991) presented a seminal work while describing the environmental impact of the North American Free Trade Agreement (NAFTA). In the study, they found an inverted-U shaped relationship between income growth and pollution.

Given the growth prospect, the income-emission association might become noteworthy for the emerging economies across the globe. Goldman Sachs, a leading global investment company, introduced both terms BRICS and N11 for different groups of emerging industrialised economies.[2] Owing to the trend of their energy-led economic growth, it is imperative to explore the income-carbon emissions association in these countries. As on 2017, BRICS and N11 comprise almost 64% of the world population and 30% of the world's GDP (World Bank, 2017). International

[2] BRICS: Brazil, Russia, India, China and South Africa.
N11 / Next 11: Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, South Korea, Turkey, and Vietnam.

Energy Outlook 2017 (EIA, 2017) shows that non-OECD Asian countries account for more than 60% of worldwide energy consumption, and this share is increasing rapidly. The rapid economic growth of these countries contributes to two-thirds of global economic growth. However, BRICS and N11 countries together produce 4.4 million kt CO_2 emissions, which are around 51.4% of the world's total CO_2 emissions (World Bank, 2017), which is ecologically alarming. For encountering these issues, many of these countries have started working on clean energy initiatives. Climatescope report 2016 (Bloomberg, 2016) shows that investment in renewable energy sources (e.g., tidal and photovoltaic) has started booting up in non-OECD countries, especially Mexico ($4.2 billion, increased by 114%), South Africa ($4.5 billion, increased by 329%) and Turkey which are the part of N11. Renewable 2016 Global Status Report (Zervos and Lins, 2016) shows that from 785 gigawatts world's renewable capacities, around 33% (262 gigawatts), is exploited by BRICS countries in 2015. This also shows the growth potential and market for renewable energy in these countries.

However, despite having growth potential, these nations have not been able to exploit the advantage of these initiatives to the fullest, and one of the major reasons behind this is the presence of corruptive practices in the public sector these nations. In presence of corruption in the public sector, the renewable energy initiatives may not be effective in reducing the CO_2 emissions and might not produce the best-expected results. Literature has very limited evidences in terms of analyzing the impact of corruption in public sector on environmental quality for the developing nations. Moreover, we have not come across any study, which depicts a comparative scenario, in which the impact corruption changes with level of economic maturity, in case of emerging economies. Hence, the aim of the present article is to analyze the impact of corruption in the public sector on carbon emissions in N11 and BRICS countries, following a corruption-augmented EKC framework, over the period of 1990-2017. Further, to bring forth additional insights, the study also incorporates segregation of energy consumption into renewable and non-renewable energy consumption. The Corruption Perceptions Index is used to encounter the effect of corruption in the public sector on the EKC relationship, and hereafter in the study, we will refer to "corruption in the public sector" as "corruption". Corruption affects the functioning of public institution and leads to misallocation of government funds. Lacklustre environmental norms and regulation, cases of bribery, illegal and extreme exploitation of natural resources demotivate the adoption of environment-friendly technology. It also distorts the market for green energy investments. Since these countries are rapidly growing and bureaucratic structure is an inherent feature of these countries, corruption may have an important role in hampering the environmental policy effectiveness by demotivating the efforts to use green technology. Hence, the study investigates the role of corruption in environmental degradation, in presence of energy use segregation, which has not been carried out in the literature so far. Further, it will help to test the applicability of EKC in these emerging economies, as it might have implications in terms of analyzing the pattern of energy consumption through economic growth and suggest ways to combat increase in emissions.

For the emerging economies, prospect of renewable energy solutions and incidents of corruption are coexistent, and the impact of corruption on the environmental quality varies from one country to another. The present study contributes to the extant literature in several ways: (a) we put forth a comparative scenario between BRICS and N11 countries concerning the impact of corruption on environmental quality, (b) the study also tries to show how the energy use segregation affects the environmental degradation in BRICS and N11 countries differently, (c) the findings suggest the existence of inverted N-shaped EKCs for the emerging economies, and (d) in methodological terms, this study used the second generation panel methods for the estimation of the EKCs for both BRICS and N11 countries.

The remainder of the paper is as follows: section 2 presents the review of relevant literature, section 3 shows the theoretical schema, section 4 discusses the model, results and discussion are presented in sections 5, policy discussions are carried out in section 6, and finally, the last section concludes the study with limitations and future research.

2. Literature review

In the literature of energy and environmental economics, a plethora of studies have discussed EKC for diverse contexts (e.g., Arrow et al., 1995; Grossman and Krueger, 1995; Stern, 2004; Saboori et al., 2014; Shahbaz and Sinha, 2019).[3] Our study intends to investigate the impact of corruption on environmental quality for N11 and BRICS countries, following the EKC framework. Since the scope of the study is N11 and BRICS countries, the following subsections will talk about the previous studies which focus on the (a) impact of corruption on environmental quality, and (b) EKC relationship between economic growth and environmental degradation especially CO_2 emissions in these countries.

2.1. Impact of corruption on environmental quality

In case of emerging economies, policies for environmental protection are always given second preference in the wake of industrialization, and this is sometimes caused by the corruptive practices in the system. In literature, corruption is defined as the "abuse of public power for private benefit" (Rodriguez et al., 2005, p. 383). These corruptive practices can take several forms, such as lack of stringency in environmental protection policies, providing undue advantage to preferred companies, and rent-seeking behaviour of the public officials. The literature of energy and

[3] A detailed account has been given in Appendix 1.

environmental economics has documented evidence of various incidences, where the impact of corruptive practices on environmental quality has been seen. The reduction in the rigour of environmental laws might be associated with environmental degradation, and various researchers have identified this issue (Lucas et al., 1992; Gray and Shadbegian, 2003; Reijnders, 2003; Ren et al., 2018; Yang et al., 2018). Many-a-times, incidents of environmental degradation might also be associated with the poor administration of these environmental laws, and this also comes under the purview of corruptive practices (Aşıcı and Acar, 2018; Yuan and Xiang, 2018; Jiang et al., 2019; Wang et al., 2019; Yuan et al., 2019). Researchers have also identified that the corruptive practices might affect the economic dynamics of a nation, and thereby, can affect environmental degradation. An example of this situation can be given in terms of the presence of corruptive practices in emissions trading (Pearse, 2016; Qi and Cheng, 2018).

Now, when we talk about the sustainable development of any nation, presence of corruptive practices plays a major role in terms of the roadblock on the way of implementation. Though this study is conducted from the environmental perspective, corruption affects the triple bottom line of sustainability (i.e. economic, social, and environmental), by affecting the supply chain mechanism (Silvestre et al., 2018). At the same time, the rent-seeking behaviour of the public officials might create a roadblock in the implementation of renewable energy solutions and cleaner production processes (Burritt et al., 2009; Geng et al., 2010; Gupta, 2016). While considering the sustainable development of any nations, these issues might have far-reaching consequences in the policymaking front.

While considering the impact of corruption on environmental degradation, the energy-pollution nexus is also needed to be analysed, and that is where the role of the present study comes to pass. From the perspective of sustainable development, energy sources play a major role, and in case of emerging nations, this is one area, where a great deal of corruption takes place (Lin et al., 2017). The corruption in this domain takes place in terms of the less rigorous energy policies, and sometimes even the energy prices (Du and Li, 2019). The existence of corruptive practices impedes the growth of renewable energy implementation in these nations, and thereby, contributing to the environmental degradation. Going by this logic, it can be inferred that corruption has differential impacts on fossil fuel and renewable energy solutions. From the perspective of sustainable development, segregation of energy sources is important (Sinha et al., 2018), and that too in presence of corruption. Studies have indicated this aspect several times. However, this impact has not been tested empirically. To the best of our knowledge, this study is the first one to analyse the impact of corruption on environmental degradation, by segregating the energy sources into fossil fuel and renewable energy sources, and thereafter, coming up with possible policy implications. In this way results will have an important contribution in the literature of energy and environmental economics.

2.2. EKC analysis in N11 countries

In case of N11 countries, the findings are diverse in defining EKC relationship between economic growth and environmental degradation. Sharker et al. (2010) examine the EKC hypothesis in case of Bangladesh, and they found a linear relationship between CO_2 emissions and GDP growth, whereas Rabbi et al. (2015) and Faridul and Muhammad (2012) note the existence of an inverted U-shaped EKC for Bangladesh. In case of Egypt, Abdou and Atya (2013) find the evidence of N-shaped EKC. In Indonesia, Sugiawan and Managi (2016) analyze the ecological importance of renewable energy consumption and found the EKC holds in the long run, whereas Saboori and Soleymani (2011) does not support EKC. Lotfalipour et al. (2010) and Zamani (2007) find a significant positive relationship between GDP, energy consumption and CO_2 emissions in

Iran. Gallagher (2004) infers that due to lack of economic initiatives environmental problems take place in the presence of economic integration and therefore, the study does not find any EKC relationship in the Mexican economy. Omisakin and Olusegun (2009) find a U-shaped EKC, whereas Chuku (2011) and Akpan and Chuku (2011) find N-shaped EKCs in Nigeria. In case of Pakistan, Ahmed and Long (2012) found inverted-U shaped EKC for both long-run and short-run, and it falls in the similar lines with Nasir and Ur Rehman (2011) and Shahbaz et al. (2012). Seriño (2014) finds EKC association between income and carbon emissions in the Philippines with the help of input-output analysis. Many studies (Halicioglu, 2009; Ozturk and Acaravci, 2013; Shahbaz et al., 2013; Yavuz, 2014) confirms the presence of EKC in Turkey. Tutulmaz (2015) tests EKC through different models and compare the results. Akbostancı et al. (2009) investigate the income and environmental quality at two levels – time series analysis at country level and panel data analyses for 58 provinces of Turkey. Their results defer at both levels; time series analysis shows the monotonically increasing relationship between CO_2 and income whereas N-shaped relationship is extracted from panel data analysis. Lise and Van Montfort (2007) analyze the co-integrated relationship between energy consumption and GDP over the period of 1970 to 2003. They find that these two variables are co-integrated; however, rejected the existence of EKC in Turkey. Baek and Kim (2013) found empirical evidence of EKC in South Korea, whereas Park and Lee (2011) study a regional model for testing of EKC in the Republic of Korea and found no unique shape of EKC in these regions. Al-Mulali et al. (2015) found that EKC hypothesis does not exist in Vietnam over the twenty years rather the study shows a positive relationship between GDP and pollution both in a long run and short run. However, the study conducted by Tang and Tan (2015) find evidence of EKC in Vietnam.

There is a dearth of literature which has specifically analyzed the EKC hypothesis in case of N11 countries altogether. Esfahani and Rasoulinezhad (2016) explore the relationship between GDP, oil consumption and CO_2 emissions in case of N11 countries and find the inverted U-shaped pattern between GDP and CO_2 emissions which verifies the EKC hypothesis in these countries. Further, they find the long run relationship between crude oil, income and carbon emissions. Contrary to these studies, Sinha et al. (2017) find an N-shaped EKC in N11 countries. With the help of the generalized method of moments, they analyze this relationship by segregating the different forms of energy like renewable and non-renewable energy consumption and biomass energy consumption. Chen and Huang (2013) also analyze the relationship between CO_2 emissions and economic growth in N11 countries. Their study confirms the short-term unidirectional relationship from CO_2 emissions to GDP, energy use to GDP and urbanization to electrical power consumption due to rapid economic growth in these countries. Yıldırım et al. (2014) use bootstrapped autoregressive metric method to analyze the relationship between energy consumption and economic growth. This study suggests that energy conservation-oriented policies should be implemented to match the economic growth with sustainable development in these countries. Paramati et al. (2017) show the enhancement of renewable energy sources can lead to long-term sustainable growth and reduction in CO_2 emissions in N11 nations.

2.3. EKC analysis in BRICS countries

Chousa et al. (2008) analyze the EKC in case of BRIC countries and find that increased energy consumption due to economic growth leads to increased CO_2 emissions. It is because of higher domestic demand due to a rapid growth trajectory, which ultimately results in an imbalance in the environment; though the study does not support EKC. Pao and Tsai (2010) found an inverted U-shaped pattern between energy consumption and CO_2 emissions. While comparing the environment quality with respect to income in US and BRIC countries, Rashid (2009) shows that environmental improvement as a function of income effect occurs at an early stage for BRIC countries, and EKC exists for BRIC.

Tamazian et al. (2009) study the income-pollution relationship, with the inclusion of financial development, as well. After controlling the country-specific observed heterogeneity, economic and financial development both are found to be the essential determinants of environmental quality in these countries. The analysis suggests that financial liberation and openness are the essential factors for CO_2 reduction. They also find that these results are robust when tested with the US and Japanese economies. Pao and Tsai (2010), like Tamazian et al. (2009) address the role of financial development and economic growth on environmental degradation over the period of 1980-2007 in BRIC countries. The results of this study support EKC. Further, they found the evidence of pollution heaven in these countries as in the long run CO_2 emissions are found to be FDI inelastic and energy consumption elastic.

While the above studies only talk about BRIC countries, recent studies also include South Africa in the BRICS analyses. Mehrara and Rezaei (2013) investigate the relationship between economic growth, CO_2 emissions and trade liberalization during the span of 1960 to 1996 for BRICS. With the help of unit root tests and Kao panel co-integration test, they found the proof of EKC with the inflexion point, occurs at $5269.4 level of per-capita income. They suggest that BRICS countries have to sacrifices their high growth in order to reduce emissions. Bakirtas et al. (2014) analyze EKC through short and long-run income elasticity and found a statistically significant relationship between CO_2 emissions and income in the long run for BRICS.

Chang (2015) examines the scope of low carbon economies in G7 and BRICS countries. He estimates three EKC by taking energy intensity, emissions intensity and carbonization value with respect to GDP per capita, and found U-shaped EKCs in all three cases. Chakravarty and Mandal (2016) attempt to estimate EKC in BRICS during 1997-2011, and found monotonically increasing EKC relationship. Ahmed et al. (2016) analyze the relationship between energy consumption, growth, CO_2 emissions and trade for BICS as Russia was not part of the study over the period of 1970 to 2013. As compared to previous studies they show that in the long run, trade liberalization helps to reduce CO_2 emissions. The fully modified OLS results exhibit the EKC relationship for these countries. Sinha and Sen (2016) try to examine the validity of EKC in case of BRICS countries from 1980 to 2013. They evidently found the EKC pattern between economic growth and air pollution in Brazil and India, but it was not found in case of Russia and China. Tedino (2017) found that EKC exists for China, India and South Africa, but did not find the existence of EKC in Brazil and Russia. Nassani et al. (2017) analyze EKC using finance, transport, energy and economic growth for 1990-2015, and they found inverted-U shaped EKC.

As per our acquaintance with relevant literature, very few previous studies (such as Liao et al., 2017) have empirically tested and talked about the role of corruption in analyzing the EKC relationship. Further, a fistful of studies has segregated the impacts of fossil fuel and renewable energy resources in these countries. Since these countries are among the fastest growing economies in the world, the findings of this study would be useful in analyzing and understanding the dynamics of corruption in shaping the income-carbon emissions relationship. In our knowledge, this is the by far the first study in the literature of energy and environmental economics, which analyzes the impact of corruption on environmental quality in presence of energy use segregation and puts forth the analysis in a comparative form between two groups of emerging economies. It will help to explore the avenues for clean energy sources and sustainable development. Hence, the study will contribute in terms of analyzing the effects of the use of renewable energy sources, corruption, trade openness and urbanization in EKC relationship among these important group of countries which has a major role at the global front.

3. Theoretical framework

Over the period of time, the EKC relationship between economic growth and environmental degradation has been evolved. There is no unique consensus regarding the pattern/shape of the relationship of CO_2 emissions vis-a-vis economic growth which is defined as EKC. Different shapes of EKC are found for different pollutants in various countries. These shapes are defined due to the role of scale, composition and technique effects on this relationship.

In current EKC framework, we are analyzing the EKC hypothesis, concerning renewable energy consumption, corruption index, trade openness, and urbanization. The inverted N-shaped relationship shows that pollution decreases with increase in growth for some time and rest of the part is related to inverted-U-shaped EKC, i.e. with an increase in income, pollution increases and after a threshold, it starts decreasing. Many studies have found the inverted N-shaped EKC, which shows the nonlinear cubic polynomial relationship (Balsalobre et al., 2015; Allard et al., 2018). It implies that CO_2 emissions tend to decrease with an increase in economic growth. With an increase in income, environmental quality gradually improves at the initial stage. The initial and later part of the inverted N-shaped curve can also relate to the process of delinking of economic growth and environmental pollution.

For developing or emerging economies, incidences of poor electrification and energy poverty coexist with good environmental quality. It is noted that around 1.6 billion people live without electricity and N11 and BRICS has huge share in this group (World Bank, 2017). Due to lack of access, increase in energy consumption is low as compared to income increase. Initially, increase in income is faster than the increase in energy consumption, and therefore, for a particular income range, environmental quality improves, and growth benefits the environment. Gradually income increases, and it impacts environment positively, which is depicted by a downward part of the inverted N-shaped curve. As economic growth takes place, these countries focus on necessities and due to energy poverty and fewer energy sources, with economic development pollution starts decreasing. Later on, it starts increasing as energy consumption increases with increasing per capita income. It follows a different trajectory as compare to traditional EKC and shows dynamic EKC relationships for these groups of countries. With increased growth, these countries are consistently working to improve energy intensity. It implies that the government can directly adopt a pricing policy on pollutants in future.

These countries face two challenges, i.e. to provide access to energy sources to poor, and gradually shift to clean energy sources. As these countries have started exploiting energy consumption from renewable energy sources, favourable geographical conditions might help them to have a positive relationship between income and ecological quality, explicated by composition effect. Since most of these economies were/are the primarily agrarian economy and suffered from energy poverty, initial economic growth does not have much negative effect on environmental quality, which explains the decreasing part of inverted N-shaped EKC. Here comes the first turning point, after which economy starts picking up the growth and due to a huge population and consumer demand, production increases at the cost of environmental quality. Later, with high-income growth and transition of economy from manufacturing to service sectors, environmental quality gradually improves. Technique effect also helps to improve environmental quality at the later stages of development (e.g., Balsalobre-Lorente et al., 2017). Investment in R&D and innovations for fuel-efficient technology helps to reduce emissions. Government start motivating and promoting the use of clean technology which focuses on energy efficiency and energy saving.

Strict government policies and regulation help in this delinking. As mentioned earlier many of these countries, such as Brazil's PróÁlcool and India's initiatives toward green energy such as the promotion of CNG and electric vehicles, aimed at the cleaner environment and renewable sources of energy because of huge energy demand.

While discussing the EKC model followed in this study, it is also imperative to incorporate the aspect of corruption in the theoretical framework, as this is the central focus of our study. We have used a corruption-augmented EKC framework in this study, so that the impact of corruption on environmental degradation can be captured. In the presence of corruption, it might be hypothesized that the environmental degradation in the form of carbon emissions might rise. The reasons for the same can be attributed to lack of rigour in the environmental laws, energy regulation, definitions of property rights, and rent-seeking behaviour of public officials. In such a situation, corruption is expected to have a positive impact on carbon emissions. Following He et al. (2017), Pata (2018), and Ulucak and Bilgili (2018), we have also included urbanization and trade openness in the empirical model, in order to have additional insights. With the rise in industrialization, it is expected that these nations will experience a rural-urban migration, and that might exert pressure on the existing urban infrastructure. Due to the lack of basic amnesties of life, the shadow cities formed around the cities will add to the emissions problem (Sinha and Bhattacharya, 2016, 2017), and therefore, urbanization is expected to have a positive impact on the carbon emissions. On the other hand, trade openness symbolizes the technological advancement in a nation, as emerging economies are characterized by technology transfer from developed nations. From that perspective, trade openness is expected to have negative impact on carbon emissions. The entire theoretical schema of our empirical model is shown in Figure 1.

<Insert Figure 1 here>

4. Empirical modelling and data

In order to find, an N-shaped or inverted N-shaped EKC for N11 and BRICS countries, first we need to establish a long run association between CO_2 emissions, GDP, renewable and fossil fuel energy consumption, trade openness, urbanization, population, and corruption index. Let us start with a standard EKC model with cubic specification, as per the following:

$$C = \gamma_0 + \gamma_1 Y + \gamma_2 Y^2 + \gamma_3 Y^3 + \gamma_Z Z + \epsilon \qquad \ldots (1)$$

Where C is per capita carbon emissions, Y is per capita income, Z is the other explanatory variables, and ϵ is the error term.

From Eq. 1, we obtain the subsequent conditions, which represent definite functional forms:

(i) $\gamma_1 = \gamma_2 = \gamma_3 = 0$; No EKC

(ii) $\gamma_1 > 0$, $\gamma_2 = \gamma_3 = 0$; EKC monotonically rising

(iii) $\gamma_1 < 0$, $\gamma_2 = \gamma_3 = 0$; EKC monotonically falling

(iv) $\gamma_1 > 0$, $\gamma_2 < 0$, $\gamma_3 = 0$; EKC inverted U-shaped

(v) $\gamma_1 < 0$, $\gamma_2 > 0$, $\gamma_3 = 0$; EKC U-shaped / monotonically rising

(vi) $\gamma_1 > 0$, $\gamma_2 < 0$, $\gamma_3 > 0$; EKC N-shaped

(vii) $\gamma_1 < 0$, $\gamma_2 > 0$, $\gamma_3 < 0$; EKC inverted N-shaped

The necessary condition for the EKC to be N-shaped is that γ_1, $\gamma_3 > 0$ and $\gamma_2 < 0$. Similarly, for the EKC to be inverted N-shaped, the necessary condition is γ_1, $\gamma_3 < 0$ and $\gamma_2 > 0$. However, this condition is not sufficient for commenting on the nature of the EKC, as this condition does not reflect anything about the validity of the model. To check the validity of the model, the model should be differentiated to the first order. The first order differential of Eq. 1 is given by

$$\frac{dC}{dY} = \gamma_1 + 2\gamma_2 Y + 3\gamma_3 Y^2 = 0 \qquad \ldots (2)$$

For the EKC to be N-shaped or inverted N-shaped, Eq. 1 must have local maxima and minima at two distinct values of *Y*.[4] The condition for Eq. 1 having local maxima and minima is given by Eq. 3:

$$\gamma_2{}^2 - 3\gamma_1\gamma_3 > 0 \qquad \ldots (3)$$

To find the values of the maxima and minima, arriving at the second order condition is required. The second order condition, derived from Eq. 2, takes the following form:

$$\frac{d^2C}{dY^2} = 2\gamma_2 + 6\gamma_3 Y = \pm\sqrt{4\gamma_2^2 - 12\gamma_1\gamma_3} \qquad \ldots (4)$$

The validity of the second order condition is also given by Eq. 3. Therefore, it can be stated that Eq. 3 is the sufficient condition for cubic specification of EKC to be valid.[5]

For estimation purpose, we will be using the following system of equations:

$$\Delta\log C_{it} = \gamma_0 + \gamma_1 \log Y_{it} + \gamma_2(\log Y_{it})^2 + \gamma_3(\log Y_{it})^3 + \gamma_4 \log R_{it} + \gamma_5 \log F_{it} + \gamma_6 \log T_{it} + \gamma_7 \log U_{it} + \epsilon_{it} \qquad \ldots (5)$$

$$\Delta\log C_{it} = \gamma_0 + \gamma_1 \log Y_{it} + \gamma_2(\log Y_{it})^2 + \gamma_3(\log Y_{it})^3 + \gamma_4 \log R_{it} + \gamma_5 \log F_{it} + \gamma_6 \log T_{it} + \gamma_7 \log U_{it} + \gamma_8 \log CORR_{it} + \gamma_9 \log CORR_{it} * \log Y_{it} + \gamma_{10} \log CORR_{it} * \log F_{it} + \gamma_{11} \log CORR_{it} * \log R_{it} + \epsilon_{it} \qquad \ldots (6)$$

Where, C_{it} denotes per capita CO_2 emissions, Y_{it} is real GDP per capita, R_{it} is per capita renewable energy consumption, F_{it} is per capita fossil fuel energy consumption, T_{it} is trade openness, U_{it} is urbanization, $CORR_{it}$ is corruption index, ϵ_{it} is error term, *t* is the time period (*t* = 1, 2, …, T), and *i* is the cross section (*i* = 1, 2, …, N). The variables included in the model are chosen in keeping with the literature of energy and environmental economics. When the economic growth sets pace,

[4] The local maxima and minima can be found at $Y = \left(-2\gamma_2 \pm \sqrt{4\gamma_2^2 - 12\gamma_1\gamma_3}\right)/6\gamma_3$, or, $Y = \left(-\gamma_2 \pm \sqrt{\gamma_2^2 - 3\gamma_1\gamma_3}\right)/3\gamma_3$. These are derived by solving the first order condition given in Eq. 2.

[5] $Y_{maxima} > Y_{minima}$: EKC is N-shaped.
$Y_{maxima} < Y_{minima}$: EKC is inverted N-shaped.

industrialization sets in, and fossil fuel consumption rises. During the course of industrialization, job creation rises around the urban areas, which results in a rural-urban migration. Both the fossil fuel consumption and urbanization not only create problem of energy efficiency, but also increases the environmental pressure through rise in ambient emissions. In such a situation, renewable energy solutions are introduced in the economic systems with the objective of reducing the fossil fuel consumption. Along with this, the government also initiates the technology transfer through the trade channel for bringing cleaner technologies. Therefore, renewable energy consumption and trade openness are expected to have negative impact on the emissions created by fossil fuel consumption and urbanization. Lastly, presence of corruption in the economic system can have an impact on institutional quality, which might reduce the impact of renewable energy consumption by impeding its implementation process. Owing to these reasons, the above-mentioned variables are included in the current empirical model.

Now, let us look at the expected sign of the coefficients of other explanatory variables. As renewable energy consumption will exert no negative ecological pressure, sign of γ_4 is expected to be negative. On the contrary, fossil fuel consumption can have a probable adverse effect on environmental quality, and so, the sign of γ_5 is likely to be positive. For the emerging economies, trade openness is largely associated with technological trade, which might have an optimistic environmental effect. Therefore, the sign of γ_6 is expected to be negative. The rate of urbanization might exert a pressure of urban infrastructure, and this pressure is in turn reflected in the ecological pressure, denoted by rapid deforestation. Owing to this reason, the sign of γ_7 is expected to be positive.

Following the work of Desai (1998), the environmental economics literature has started to identify corruption as one of the important factors behind environmental degradation, with a special focus on developing economies. The impact of corruption can be seen in the development and enforcement of environmental regulations, failing of which consequently deteriorates environmental quality. Researchers have already identified the impact of corruption on CO_2 emissions in case of developing nations (Fujii and Managi, 2016; Ibrahim and Law, 2016). Recently, Liao et al. (2017) have analyzed the impact of corruption on SO_2 emissions in China, following an EKC framework, the authors have found that anti-corruption cases lead to a decline in the level of emission. In light of this evidence, the signs of γ_8, γ_9, γ_{10} and γ_{11} are expected to be positive.

In this study, we have used the data of N11 and BRICS member countries over the period of 1990-2017. Annual data for per capita CO_2 emissions (in kt), per capita GDP (constant 2010 US$), per capita renewable energy consumption (in kt), per capita fossil fuel energy consumption (in kt), trade openness (as a % of GDP), population, and urbanization are gathered from World Bank Indicators, and data for corruption perceptions index from Transparency International.

5. Results and discussion

5.1. Cross-sectional dependence testing

We will begin the analysis with scrutinizing cross-sectional dependence, and Pesaran (2004) and Chudik and Pesaran (2015) tests are utilized for this purpose. The null hypothesis of Pesaran (2004) assumes cross-sectional independence, whereas the null hypothesis of Chudik and Pesaran (2015) assumes the cross-sectional dependence to be insignificant. The results are reported in Table 1, and it can be seen that the cross-sections are significantly dependent on each other, and thereby, fulfilling the applicability of second-generation unit root tests.

<Insert Table 1 here>

5.2. Unit root testing

Following the applicability of second-generation unit root tests, CIPS and CADF tests are used (Pesaran, 2007). These tests assume the cross-sectional dependence in the data. The null hypothesis of second-generation unit root test is that the data are non-stationary in nature, against the alternate hypothesis of at least one cross-section of the data is stationary.

Results of these tests are recorded in Table 2, and it can be seen that the variables do not suffer from unit roots after first differentiation. Therefore, we might say that the variables are stationary after first difference, i.e. the variables are I(1) in nature. With this result, we can proceed for the cointegration tests.

<*Insert Table 2 here*>

5.3. Cointegration testing

For checking the cointegrating association among the variables, we have employed Westerlund and Edgerton (2008) test and continuously updated FMOLS test (Bai et al., 2009). These cointegration tests assume cross-sectional dependence. The results of Westerlund and Edgerton (2008) test are reported in Table 3, and they show the significant cointegrating association among the variables. However, the unobserved non-linearity is not considered in this test, which is covered by a continuously updated FMOLS approach. Results of this test are reported in Table 4. LSDV (Least Square Dummy Variable) and Bai and Ng (2006) estimator tests are conducted to demonstrate the empirical vigour. The results show that the long-run cointegrating association among the variables is significant for the period of 1990-2017 in the N11 and BRICS countries.

<*Insert Table 3 here*>

<*Insert Table 4 here*>

While finding the cointegrating association among the variables, we found structural breaks in the dataset (see Appendix 2). Owing to the destruction of World Trade Centre and creation of single European market in 1993, a significant change in the business scenario was seen, and these events had a significant impact on the emerging economies (O'Neil, 2003). Owing to the speed of economic growth, the economic meltdown in 2001-02 had a bigger impact on Next 11 economies compared to BRICS nations. On the other hand, the first BRICS foreign ministers' meeting in 2006 had a significant impact on their trade relations, and this had very minimal impact on the Next 11 countries.

5.4. GMM model testing

5.4.1. Estimation of the model without corruption

The estimated coefficients of Eq. (5) are recorded in Table 5. The coefficients of income (Y), squared income (Y^2), and cubic income (Y^3) are negative, positive and negative for both N11 and BRICS country panels. This piece of evidence demonstrates the presence of inverted N-shaped EKC for both of these panels, and the validity conditions stated in Eq. (3) and (4) are fulfilled. This segment of our results contradicts the findings of Chen and Huang (2013), Esfahani and Rasoulinezhad (2016), Shahbaz et al. (2016), Sinha and Sen (2016), Dong et al. (2017), Sinha et al. (2017), Tedino (2017), Haseeb et al. (2018). For both of the cases, the first turnaround points are within the sample range, which signifies that both the groups have achieved EKC at a very early stage of economic growth, and then they departed from that state owing to the nature of economic growth. However, N11 countries have achieved the second turnaround point much earlier than BRICS countries, as it denotes the level of pollution abatement policies in N11 nations. The evidence of strong pollution abatement policies has already been identified by Shahbaz et al. (2016) and Sinha et al. (2017), and on the other hand, the pollution abatement policies of BRICS countries have been criticized by Chakravarty and Mandal (2016) and Sinha and Sen (2016). Our results support these evidences, along with the new finding regarding the presence of inverted N-shaped EKC in both of these groups of countries. The presence of inverted-N shaped EKC for BRICS countries might be a matter of concern for the policymakers, as the second turnaround point is very high.

<*Insert Table 5 here*>

The rise in CO_2 emissions in BRICS countries is majorly caused by the nature of economic growth in these nations. This can be majorly attributed to the use of fossil fuel-based energy for catalyzing economic growth. Now, if we look at both BRICS and N11 groups, then we can see that the negative impact of fossil fuel consumption is more in case of BRICS countries, as it is evident from the coefficients of fossil fuel consumption. Now, let us look at the impact of renewable energy consumption. Looking at both BRICS and N11 groups, it can be observed that the positive impact of renewable energy consumption is more in case of N11 countries, as it is evident from the coefficients. It can be best explained by the nature of industrialization in these two groups. The pace of economic growth in BRICS countries is higher compared to those of N11 countries, as the industrialization in the latter group of nations set in at an earlier stage. Following the financial crisis in 2008, the BRICS nations have focused more on economic growth, rather than environmental protection, and that might be the reason behind their failure to meet the Kyoto protocol standards (see Zakarya et al., 2015). In view of this evidence, it might be said that the pattern of economic growth in BRICS countries has been responsible for this rise in CO_2 emissions.

Along with the rise in fossil fuel consumption, the economic growth in these emerging nations has been characteristically polarized, and this polarization has been seen in terms of disproportionate growth. Owing to the rural-urban divide, these nations have experienced rise in urbanization, which has been another reason behind the rise in CO_2 emissions in these nations. For both N11 and BRICS nations, urbanization has a direct impact on CO_2 emissions, and this finding falls in the similar lines with Wang et al. (2016) and Pata (2018), and contradicts the finding of Lin and Zhu (2018). However, owing to early industrialization and robust urban infrastructure, the negative impact of urbanization on ambient air quality has been found to be less in case of BRICS countries ($\gamma_7 = 0.0474$), compared to N11 countries ($\gamma_7 = 0.0768$). This is a new finding in the EKC literature. In spite of the robust urban infrastructure, the BRICS countries have not yet been able to reduce fossil fuel consumption, and the impact of the same can be seen in CO_2 emissions. On the other hand, the growing positive impact of renewable energy consumption can be associated with the technology trade, the effect of which is captured by trade openness. As expected, the higher positive impact of renewable energy consumption in N11 countries can be associated with trade openness ($\gamma_6 = -0.3145$), which is higher compared to that in case of BRICS countries ($\gamma_6 = -0.0811$). Though, Lv and Xu (2018), Ulucak and Bilgili (2018) have found trade openness to have negative environmental consequences, the results of our study contradict their finding.

5.4.2. Estimation of the model with corruption

By far, we have discussed the results of the model without the impact of corruption. Now, we will analyze Eq. (6), which allows the corruption index and its interactions with the other model variables. The results are reported in Table 5. We will analyze them now.

The coefficients of income (Y), squared income (Y^2), and cubic income (Y^3) are negative, positive and negative for both N11 and BRICS country panels. This piece of evidence demonstrates the presence of inverted N-shaped EKC for both of these panels, and the validity conditions stated in Eq. (3) and (4) are fulfilled. However, though the first turnaround points for both the cases are within the sample range, the second turnaround points are not only outside sample space, but also are much higher compared to the second turnaround points found for Eq. (5). For N11 countries, the second turnaround point found for Eq. (6) is nearly 4.31 times higher compared to the one found for Eq. (5), whereas the same for BRICS countries is nearly 11.20 times higher. On the other hand, when we look at the first turnaround points, then we can see that for N11 countries, there has been a reduction of nearly 3.89 times, whereas for BRICS countries, the same has shown an increase of 7.79 times. This shows the higher impact of corruption in case of BRICS countries, compared to N11 countries. This evidence is a contribution in the literature by putting forth a comparative scenario between emerging economies in terms of determining the impact of corruption of environmental quality, differed by the economic maturity of a nation.

The aforementioned scenario is depicted in Figure 2 and 3. For both the figures, TP(1) and TP(2) denote the first and second turnaround points for the EKC model without corruption, and $TP_C(1)$ and $TP_C(2)$ denote the first and second turnaround points for the EKC model with corruption. Let us start with the scenario of N11 countries. In this case, the EKCs are inverted N-shaped, and $TP(1) > TP_C(1)$, $TP(2) < TP_C(2)$. It shows that the existence of corruptive practices might make the environmental policies ineffective, and therefore, pollution abatement might be delayed. This delay in pollution abatement is reflected in the higher value of second turnaround point of the EKC with the impact of corruption, and this piece of finding is an empirical evidence of the arguments put forth by Cole (2007). For the N11 countries, it can be said that at the early stage of economic growth, corruptive practices decreased policy level inflexibilities, and it has been reflected in terms of higher first turnaround point for EKC without corruption (Damania et al., 2003). On the other hand, for the BRICS countries, the EKCs are inverted N-shaped, and $TP(1) < TP_C(1)$, $TP(2) < TP_C(2)$. Like N11 countries, delay in pollution abatement is reflected in the higher value of the second turnaround point of the second EKC. As BRICS nations are comparatively mature than N11 countries, corruptive practices increased the policy level inflexibilities at the earlier stage of economic growth. This segment of the results falls in the similar lines with the findings of Damania et al. (2003) and Butler et al. (2009), who found the rise in corruption coexisting with the maturity of economic growth. This segment of results also refutes the finding of Arminen and Menegaki (2019), who didn't find any impact of institutional quality in shaping the income-emissions association, as well as didn't find any evidence of EKCs. Following the context of their study and the theoretical foundation laid by Chen et al. (2018), it can be said that for the high-income countries, largely following the laissez-faire economy, private parties are not bound by the bureaucratic structure of the public institutions, and therefore, the incidents of corruption are less.

<*Insert Figure 2 here*>

<*Insert Figure 3 here*>

In order to explore more about the impact of corruption on CO_2 emissions, we have introduced the interactions between corruption and income, corruption and renewable energy consumption, and corruption and fossil fuel consumption. As anticipated, impacts of these three interaction variables on CO_2 emissions are positive, and it implies the negative impacts of corruptive practices on environmental policies. Moreover, the negative effects of corruption have increased through the interactions between fossil fuel consumption and renewable energy consumption. For both BRICS and N11 countries, corruption has increased the negative impact of fossil fuel consumption and enabled the negative impact of renewable energy consumption. This finding is new in the literature, as we have not across any study, which has analyzed the differential ecological impact of renewable and non-renewable energy consumption, in presence of corruption.

Lastly, in this case also, the coefficient of the interaction between income and corruption is also positive and significant. This segment of results shows that the corruptive practices imbibed in the policymaking framework not only makes the environmental policies ineffective but also make renewable energy policies turn against the betterment of environmental quality. This representation of a comparative scenario in terms of the impact of corruption on environmental quality between two groups of emerging economies, with different level of economic maturity, is a contribution in the literature.

Now, if we summarize the result of this section, then we can find that presence of corruption impedes the renewable energy implementation process, and in this regard, the institutional quality plays a major role. The rent-seeking behaviour of the public bodies create an obstacle in the renewable energy implementation process, and this is more predominant in BRICS nations, where the bureaucratic structure is more prevalent. Presence of corruptive practices dampens the institutional quality, and this has a direct impact on public property rights, energy prices, and licensing of the energy supply firms. By creating artificial demand for energy through power outages, they not only manipulate the energy price, but also seek economic rent through bribing mechanism from the distribution firms. The emergence of renewable energy solutions might be a permanent solution to the un-served energy demand, they create predicaments for the renewable energy firms in the form of licensing, higher cost of production, and several other institutional barriers, and thereby, disturbing the affordability of the clean energy. Moreover, the subsidies provided to the traditional fossil fuel-based solutions diminish the competitiveness of the renewable energy solutions. Following the findings of Gennaioli and Tavoni (2016), this segment of the results contributes to the literature in terms of divulging the impact of corruption on environmental quality by impeding renewable energy implementation in emerging economies.

In view of this discussion, it is also needed to be remembered that a mature bureaucratic structure is a seed of corruption, and that is the reason the incidence of corruption is found to be more prevalent in case of BRICS countries. If the economic structure of both N11 and BRICs countries are scrutinized, then it can be seen that the industrialization in N11 countries has not yet reached the maturity stage, and therefore, the institutional structure of these countries are still evolving, whereas BRICS nations are characterized with mature industrialization and institutions. Therefore, the impact of corruption in BRICS nations is more compared to that of in N11 countries due to the policy-level inflexibilities, which are arising out the corruptive practices imbibed in the institutional structure. This phenomenon can be attributed as a reason behind higher environmental degradation in BRICS nations compared to N11 nations.

5.4.3. Robustness check

In order to check the robustness of our empirical model, we have analyzed our model by using Common Correlated Effects (CCE), and using distinct model variables in the following manner:[6]

- First step: $C = f(Y, Y^2, Y^3)$
- Second step: $C = f(Y, Y^2, Y^3, R, F, T, U)$
- Third step: $C = f(Y, Y^2, Y^3, R, F, T, U, CORR)$
- Fourth step: $C = f(Y, Y^2, Y^3, R, F, T, U, CORR, CORR*Y, CORR*R, CORR*F)$

We have used these variable segregations for both N11 and BRICS countries, and the results are reported in Table 6. The results show that the signs of coefficients of the model variables are as per expectation, and they are significant. Consistency of the associations among the model variables demonstrates the robustness of the empirical model used in the study.

[6] This technique has been adapted from Barslund et al. (2007).

<Insert Table 6 here>

6. Implications for theory and practice

Till now, we have evaluated the impact of corruption on carbon emissions, in presence of energy use segregation following the EKC framework, and in doing so, this study has presented a comparative scenario between BRICS and N11 countries. From the perspective of sustainable development in emerging economies, these aspects become more important. The EKCs are found to be inverted N-shaped, signifying the inefficiency of the environmental regulations in these nations to reduce the level of pollution. Moreover, the policymakers should be aware that the existing form of growth in these nations is anti-environment, and therefore, the existing policies might be detrimental for the sustainable development in these nations. Researchers across the globe are trying to spotlight the advantages of renewable energy solutions and disadvantages of fossil fuel-based solutions under the purview of sustainable development, and given the background of N11 and BRICS nations, this aspect might prove to be crucial (Dovì et al., 2009; Abdulrahman and Huisingh, 2018; Lee et al., 2018; Baleta et al., 2019). As the impact of renewable energy consumption has been found to have a positive impact on environmental quality, the policymakers in these nations should strive to put more emphasis on the discovery of alternate energy sources. This initiative might help them in encountering the energy poverty issue prevailing in these nations.

Saying this, it should also be remembered that these nations are also facing the problem of corruption, which is impeding the developmental process in these nations. Ensuring sustainable development starts with the endogenous capacity building for discovery and implementation of renewable energy solutions, and incidents of corruption create roadblocks on these developmental paths. These incidences can be created in terms of rent-seeking behaviour, loosening environmental laws, and encouraging fossil fuel consumption. In case of developing nations, misutilization of subsidy funds for fossil fuel-based energy sources is one of the major areas of corruption, as indicated by several researchers (Ferraresi et al., 2018; Kyle, 2018). In such a situation, implementation of cleaner production processes in these nations can be initiated through technology transfer, as trade openness has a positive impact on the environmental quality even in presence of the corruptive practices. Further, the industrialization has already started in these nations, and the existing urban infrastructure is facing difficulties due to urbanization, implementation of cleaner production processes might be necessary to control the level of environmental degradation (Roy et al., 2018). In this pursuit, the policymakers should encourage people-public-private partnerships, and this is one of the ways to ensure implementation of renewable energy and cleaner production processes, by reducing the intervention of corruption (Chen, 2019). As per Shahbaz et al. (2019), if these partnerships can enhance the level of environmental awareness among the citizens, then the policymakers might be forced to strengthen the environmental regulations, and thereby, the incidences of corruption might be reduced.

While saying this, it should also be remembered that the economic systems in these nations are largely bureaucratic in nature, and the seed of corruptive practices start from there. In order to handle this issue, the policymakers should also think of market-driven mechanisms, rather than having the system pegged at the institutional level. The institutions should facilitate the process, not create barriers in the way of implementation. Once these things are in place, there will be more job creations along with the renewable energy implementation in these nations, which might also help in further bringing down corruption in the economic system and boost the growth. The increase in environmental awareness might be complemented by the increase in vocational opportunities in reducing the incidents of corruptive practices.

Now, in such a scenario, the sustainable development of these nations is dependent on how the corruptive practices can be controlled, so that the implementation of renewable energy and cleaner production processes can be carried out. Once these processes are in place, it will be possible for these nations to achieve the objectives of the following sustainable development goals (SDGs): (i) Goal 7, i.e. inexpensive renewable energy, (ii) Goal 8, i.e. stable job and economic growth, and (iii) Goal 13, i.e. climate action (UNDP, 2017). In presence of the market-driven energy demand, removal of harmful subsidies, and ease of licensing process, the renewable energy will be affordable to the people (Roy and Singh, 2017). Once the renewable energy implementation gains pace, fossil fuel consumption will be gradually reduced, and it will consequently reduce the level of ambient air pollution. In presence of the newly formed renewable energy firms, these nations might experience a rise in green jobs, which will further help in sustaining the economic growth. This might be a possible way of achieving the mentioned SDG objectives. Once discovery and implementation process for alternate energy in these nations can be carried out endogenously, then not only these nations will experience sustainable job creation, but also the rise in awareness might lead to a reduction in the corruptive practices, and consequent environmental degradation.

7. Conclusion

By far, this study has analyzed the association between carbon emissions, GDP, fossil fuel consumption, renewable energy consumption, trade openness, urbanization, and corruption for the period of 1990-2017 in the N11 and BRICS countries. This study has shown the presence of inverted N-shaped EKCs, and how corruption changes the turnaround points of EKCs. Moreover, this study has also shown how corruption can alter the behaviour of other model variables. Lastly, the impact of corruption has been found to be severer in case of the BRICS countries than in case of N11 countries.

In such a scenario, in order to restore the environmental balance, it is the responsibility of the government to set up an independent regulatory body to look into renewable energy solution projects in a country. This regulatory body should be provided with the autonomy so that the members of that body can be free from political influence and rent-seeking behavior. In order to reduce the level of corruption, this regulatory body can influence the interest rate of loans for energy projects, i.e. the channel partners for fossil fuel energy distribution system will have to pay more interest in lieu of the ecological loss triggered by fossil fuel consumption, whereas the channel partners for renewable energy generation and distribution system will have to pay less interest as an incentive to promote clean energy solutions. Having restricted access to funds related to the consequential environmental damage can have a possible control over the corruptive practices in the government bodies and the channel partners. Moreover, access to funding in this nature will discourage the fossil fuel energy distribution partners to get involved in more projects, whereas it will incentivize renewable energy generation and distribution process in the nation.

Along with the formation of a regulatory body, strict anti-corruption practices should also be enforced by the government, so that the actions taken by the regulatory body can be complemented. This is especially necessary if the economy is allowed to be market-driven, rather than pegged. Once the market-driven forces can shape the dynamics of the market, then the biggest impact might be seen on the energy demand. Now, in presence of high energy demand and lowering in the incidents of rent-seeking behaviour, the existing fossil fuel-based solutions will prove to be insufficient in catering to the increase in the demand, and that is when the role of renewable energy solutions will be recognized. In order to make this implementation possible, the government should also make the licensing process for the renewable energy firms hassle-free, and they should be able to avail cheap loan from the banks and other financial institutions for their project implementation purpose. Once these things are in place, the government can protect the rights of public goods, e.g. mineral and forest resources, more effectively, owing to the existing people-public-private partnerships.

Lastly, the policymakers should also mull over increasing the level of awareness among the citizens, so that (a) corruptive practices can be controlled at the grassroots level, (b) benefits of renewable energy and energy efficiency can be understood, (c) educational curriculums can be designed in keeping with the motive of sustainable development of these nations. Affordable and clean energy will help the industrialization gaining pace, which will be followed by a higher number of vocational opportunities, and gradual lowering in the level of environmental degradation. With higher level of income, the educational attainment might rise, along with the sense of responsibility towards society and ecology. This will not only help in reducing the social imbalances, but also will help these nations in sustaining the ecosystem. Reduction in pegging the market forces will allow the foreign investment to flow in, and it will help the nations to gradually build the capacity endogenously. Following these policies might help these nations not only in having control over the incidents of corruption, but also in achieving the SDG objectives by 2030.

The focus of our study is BRICS and N11 countries only, and that is a limitation of our study. As a future direction of research, we are intending to extend the study by creating a composite environmental indicator, which will incorporate both the local and global pollutants. The future direction of research on this theme might also consider the political ideologies of various countries, so that the analysis can be conducted at multiple levels. Incorporation of income inequality in the model might bring forth significant insights regarding the sustainable development of the nations.

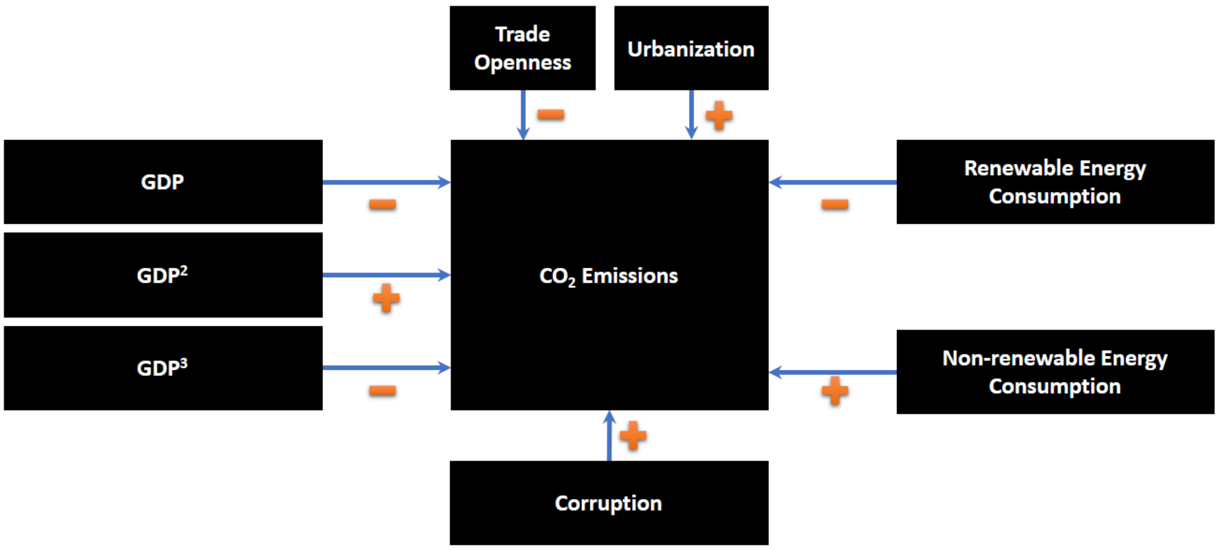

Figure 1: Theoretical schema of the study

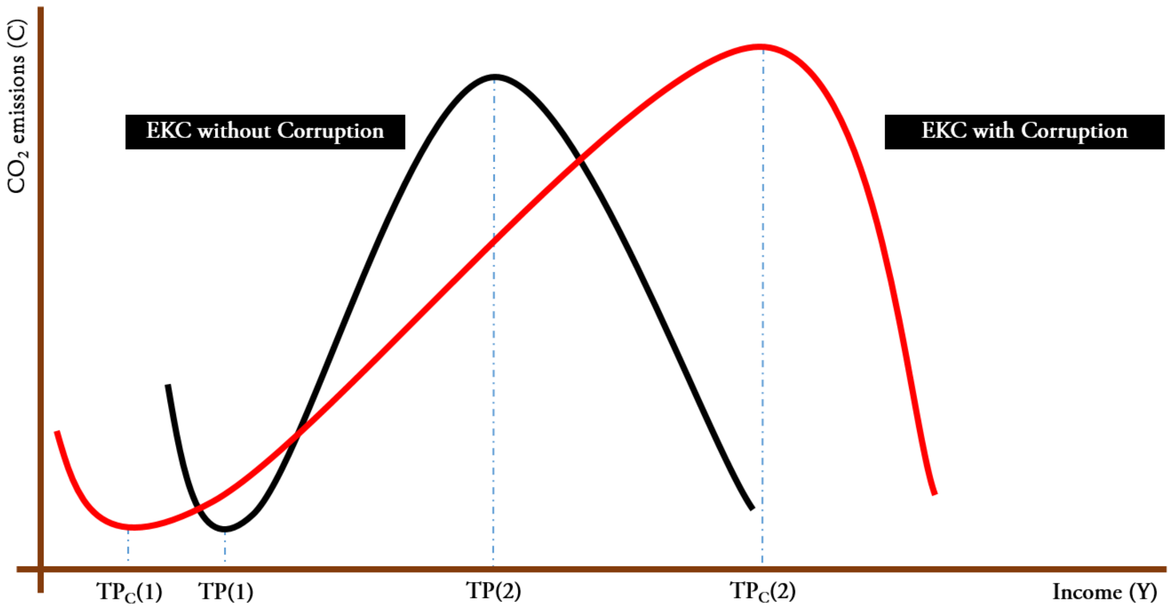

Figure 2: EKCs (without and with corruption) for Next 11 countries

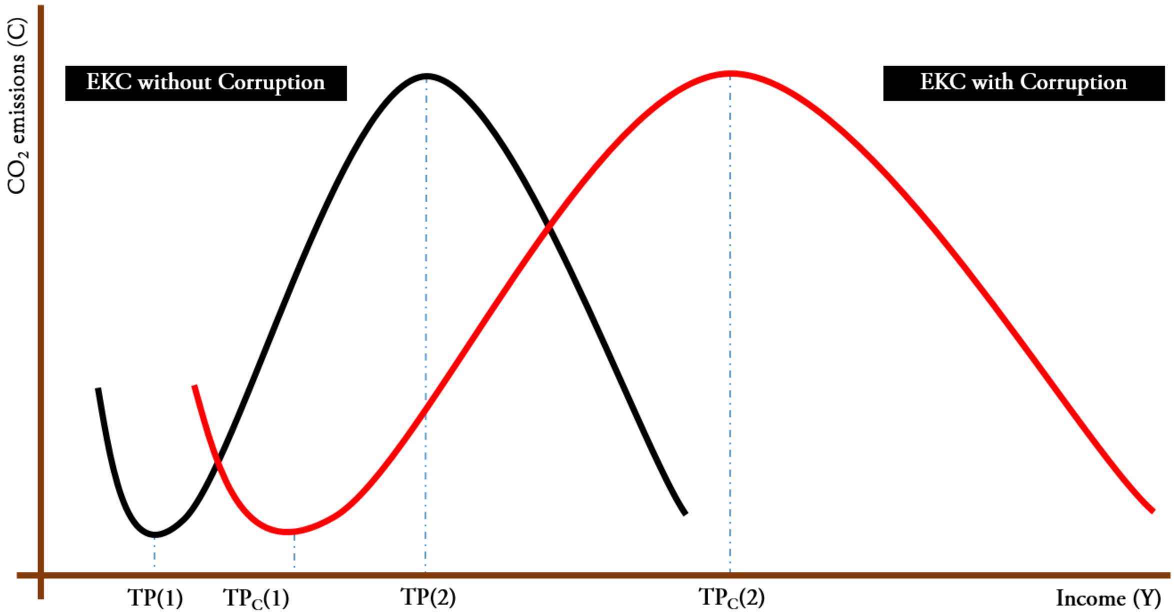

Figure 3: EKCs (without and with corruption) for BRICS countries

Table 1: Results of cross section dependence tests

Variables	N-11 Countries		BRICS Countries	
	Pesaran (2004) test			
	Test statistics	ρ	Test statistics	ρ
C	25.82[a]	0.726	5.57[a]	0.541
Y	32.05[a]	0.901	13.05[a]	0.860
Y^2	32.25[a]	0.907	13.28[a]	0.876
Y^3	32.39[a]	0.911	13.48[a]	0.889
R	23.35[a]	0.665	1.73[c]	0.473
F	31.88[a]	0.896	7.41[a]	0.517
T	32.68[a]	0.919	13.97[a]	0.921
U	35.35[a]	0.994	3.35[a]	0.975
CORR	35.77[a]	0.880	-2.83[a]	0.598
	Chudik and Pesaran (2015)			
	Test statistics	p-value	Test statistics	p-value
C	3.45[a]	0.001	2.86[a]	0.004
Y	-1.83[c]	0.066	-2.01[b]	0.044
Y^2	-2.72[a]	0.006	-1.78[c]	0.074
Y^3	-2.80[a]	0.005	7.06[a]	0.000
R	-2.33[b]	0.019	-2.42[b]	0.016
F	3.53[a]	0.000	3.64[a]	0.000
T	2.69[a]	0.007	1.68[c]	0.093
U	4.24[a]	0.000	-2.15[b]	0.032
CORR	2.22[b]	0.026	-2.61[a]	0.009

a significant at 1% level

b significant at 5% level

c significant at 10% level

Table 2: Results of second generation unit root tests

Variables		N-11 Countries		BRICS Countries	
		CIPS	CADF	CIPS	CADF
Level	C	-2.304	-1.547	-1.342	-2.173
	Y	-2.973	-1.452	-2.112	-1.740
	Y^2	-2.936	-2.057	-2.207	-1.360
	Y^3	-2.912	-1.931	-2.232	-1.358
	R	-2.794	-1.993	-1.932	-0.477
	F	-2.112	-1.299	-0.485	-1.950
	T	-2.443	-2.094	-1.119	-1.655
	U	-2.838	-1.973	-1.216	-1.773
	CORR	-2.423	-1.828	-1.748	-1.438
First Difference	C	-4.152[a]	-2.731[a]	-3.135[a]	-2.864[a]
	Y	-4.277[a]	-2.585[a]	-3.676[a]	-2.688[b]
	Y^2	-4.270[a]	-2.629[a]	-3.570[a]	-2.744[b]
	Y^3	-4.244[a]	-2.467[a]	-3.453[a]	-2.619[b]
	R	-4.660[a]	-3.443[a]	-3.640[a]	-2.490[b]
	F	-4.061[a]	-2.716[a]	-3.525[a]	-2.208[c]
	T	-4.669[a]	-2.562[a]	-4.430[a]	-4.594[a]
	U	-4.275[a]	-2.201[c]	-3.244[a]	-2.895[a]
	CORR	-4.752[a]	-3.019[a]	-3.358[a]	-3.175[a]

a significant at 1% level

b significant at 5% level

c significant at 10% level

Table 3: Results of Westerlund and Edgerton (2007) cointegration test

	Test Statistic (1)	p-value	Test Statistic (2)	p-value	Test Statistic (3)	p-value
N-11 Countries						
LM_τ	-4.931	0.000	-2.267	0.012	-2.684	0.004
LM_ϕ	-10.266	0.000	-3.767	0.000	-5.499	0.000
BRICS Countries						
LM_τ	-1.604	0.054	-2.397	0.008	-2.126	0.017
LM_ϕ	-5.575	0.000	-4.936	0.000	-2.893	0.002

Note:

Model (1): model with a maximum number of 5 factors and no shift

Model (2): model with a maximum number of 5 factors and level shift

Model (3): model with a maximum number of 5 factors and regime shift

Table 4: Results of Continuously Updated FMOLS test

Variables	LSDV	Bai-FM	CUP-FM	CUP-BC
	N-11 Countries			
C	2.0693[a]	1.9857[a]	2.0164[a]	2.0393[a]
Y	1.9975[a]	2.0166[a]	2.0023[a]	2.0302[a]
Y^2	1.9490[a]	1.9453[a]	2.0437[a]	2.0399[a]
Y^3	1.9623[a]	1.9805[a]	1.9081[a]	1.9496[a]
R	2.0788[a]	2.0899[a]	2.0501[a]	2.0489[a]
F	1.9718[a]	1.9783[a]	2.0816[a]	2.0467[a]
T	2.0461[a]	2.0735[a]	1.9337[a]	1.9435[a]
U	1.9551[a]	1.8899[a]	1.9598[a]	1.9654[a]
CORR	2.0299[a]	2.0566[a]	2.0299[a]	1.9893[a]
	BRICS Countries			
C	1.9158[a]	1.8571[a]	1.4533[a]	1.7981[a]
Y	1.9483[a]	2.0235[a]	2.0944[a]	1.9111[a]
Y^2	2.0233[a]	2.1150[a]	2.6605[a]	2.2086[a]
Y^3	2.0065[a]	2.0649[a]	2.3413[a]	2.0983[a]
R	2.0328[a]	1.9293[a]	1.4335[a]	1.9759[a]
F	1.8647[a]	1.9403[a]	2.0935[a]	1.8762[a]
T	2.0201[a]	2.0482[a]	2.5067[a]	2.1063[a]
U	2.0362[a]	1.9756[a]	1.9164[a]	1.9621[a]
CORR	2.0753[a]	2.0486[a]	1.9706[a]	2.0212[a]

a significant value at 1%

Table 5: GMM model estimates for N-11 and BRICS countries

	N-11 Countries		BRICS Countries	
Parameters	Model I	Model II	Model I	Model II
Y	-5.7457[a]	-6.4228[a]	-9.5516[a]	-3.9066[a]
Y^2	0.7646[a]	0.9268[a]	1.0442[a]	0.3435[b]
Y^3	-0.0333[a]	-0.0401[a]	-0.0373[a]	-0.0099[c]
R	-0.2343[a]	-0.0724[c]	-0.0451[b]	-0.0592[c]
F	0.4090[a]	0.1085[c]	1.0840[a]	0.2643[a]
T	-0.3145[a]	-0.2675[a]	-0.0811[a]	-0.1453[a]
U	0.0768[c]	0.1418[b]	0.0474[a]	0.0678[a]
CORR	-	0.0469[b]	-	2.1555[c]
CORR*Y	-	0.2251[b]	-	0.2473[a]
CORR*R	-	0.5347[a]	-	0.0165[a]
CORR*F	-	0.5671[a]	-	0.7485[a]
Intercept	10.7397[a]	11.2224[a]	7.0576[c]	13.2351[a]
Hansen's J statistics	0.4286	1.9211	0.8969	0.8438
DWH Test statistics	6.9366[a]	8.4978[a]	3.2963[a]	4.4944[a]
Shape of EKC	Inverted N-shaped	Inverted N-shaped	Inverted N-shaped	Inverted N-shaped
Turnaround point(s)	751.60 5,914.18	192.90 25,488.30	3,042.06 41,890.03	23,686.33 469,141.48
Inflection point	2,108.33	2,217.36	11,288.57	105,414.61

a significant at 1% level

b significant at 5% level

c significant at 10% level

Table 6: Robustness check by taking distinct model variables using CCE

Parameters	N-11 Countries			
Y	-5.9966[b]	-2.3782[a]	- 2.3413[a]	-2.9668[c]
Y^2	-0.1778[c]	0.4828[a]	0.9053[c]	1.1738[a]
Y^3	0.0901[c]	-0.0434[c]	-0.0494[a]	-0.0953[b]
R	-	-0.0920[c]	-0.2231[b]	-1.1193[c]
F	-	0.5837[a]	0.5422[a]	0.6116[b]
T	-	-0.0855[c]	-0.1130[c]	-0.0930[c]
U	-	1.9897[b]	1.6149[c]	8.1419[b]
CORR	-	-	0.0425[b]	3.0448[b]
CORR*Y	-	-	-	1.2488[c]
CORR*R	-	-	-	0.5771[c]
CORR*F	-	-	-	1.5512[a]
Intercept	3.4779[c]	4.4712[c]	5.0435[c]	4.1431[b]
Parameters	BRICS Countries			
Y	-5.6444[c]	-1.0610[b]	-2.3306[b]	-3.3293[b]
Y^2	0.3904[b]	0.4042[a]	0.5006[b]	0.7297[a]
Y^3	-0.0032[c]	-0.0419[c]	-0.0308[c]	-0.0218[c]
R	-	-0.9863[b]	-0.1734[c]	-1.8177[c]
F	-	0.7147[c]	0.7394[a]	3.4108[a]
T	-	-0.0341[b]	-0.0171[b]	-0.0241[c]
U	-	0.5341[c]	0.8269[c]	5.9104[a]
CORR	-	-	0.0999[a]	2.9745[b]
CORR*Y	-	-	-	0.5245[c]
CORR*R	-	-	-	2.7724[c]
CORR*F	-	-	-	1.8671[b]
Intercept	14.4567[c]	50.7118[a]	55.2738[b]	16.2749[b]

a significant at 1% level

b significant at 5% level

c significant at 10% level

Appendix 1: Snapshot of the EKC literature on N11 and BRICS countries

Literature of N11 Countries				
Author (Year)	**Methodology**	**Country**	**Year**	**Verdict**
Sharker et al. (2010)	Bootstrap Technique	Bangladesh	1972-2000	Not Supported
Rabbi et al. (2015)	Cointegration Analysis	Bangladesh	1972-2012	Supported
Faridul and Muhammad (2012)	Granger Causality + ARDL	Bangladesh	1971-2010	Supported
Abdou and Atya (2013)	Cointegration Analysis	Egypt	1961-2008	Not Supported
Sugiawan and Managi (2016)	ARDL	Indonesia	1971-2010	Supported
Saboori and Soleymani (2011)	ARDL	Indonesia	1971-2007	Not Supported
Lotfalipour et al. (2010)	Granger Causality	Iran	1967-2007	Not Applicable
Zamani (2007)	Cointegration Analysis	Iran	1967-2003	Not Applicable
Omisakin and Olusegun (2009)	Cointegration Analysis	Nigeria	1970-2005	Not Supported
Chuku (2011)	Cointegration Analysis	Nigeria	1960-2008	Supported
Akpan and Chuku (2011)	ARDL	Nigeria	1960-2008	Supported
Ahmed and Long (2012)	ARDL	Pakistan	1971-2008	Supported
Nasir and Ur Rehman (2011)	VECM	Pakistan	1972-2008	Partially Supported
Shahbaz et al. (2012)	Cointegration Analysis	Pakistan	1971-2009	Supported
Halicioglu (2009)	Augmented Granger Causality	Turkey	1960-2005	Supported
Ozturk and Acaravci, 2013	Cointegration Analysis	Turkey	1960-2007	Supported
Shahbaz et al. (2013)	VECM	Turkey	1970-2010	Supported
Yavuz (2014)	Cointegration Analysis	Turkey	1960-2007	Supported
Tutulmaz (2015)	Cointegration Analysis	Turkey	1968-2007	Supported
Akbostancı et al. (2009)	Cointegration Analysis	Turkey	1968-2003	Not Supported
Lise and Van Montfort (2007)	Cointegration Analysis	Turkey	1970-2003	Not Supported
Park and Lee (2011)	Panel Regression	South Korea	1990-2005	Partially Supported
Baek and Kim (2013)	ARDL	Korea	1971-2007	Supported
Al-Mulali et al. (2015)	ARDL	Vietnam	1981-2011	Not Supported
Tang and Tan (2015)	Cointegration Analysis	Vietnam	1976-2009	Supported
Esfahani and Rasoulinezhad (2016)	DOLS+FMOLS	N11	1980-2013	Supported
Sinha et al. (2017)	GMM	N11	1990-2014	Supported

Chen and Huang (2013)	Cointegration Analysis	N11	1981-2009	Not Applicable
Yıldırım et al. (2014)	Granger Causality	N11	1971-2011	Not Applicable
Paramati et al. (2017)	Cointegration Analysis	N11	1990-2012	Not Applicable
Literature on BRICS Countries				
Author (Year)	**Methodology**	**Country**	**Year**	**Verdict**
Chousa et al. (2008)	FGLS	BRIC	1992-2004	Not Supported
Pao and Tsai (2010)	Error Correction Model	BRIC	1990-2005	Supported
Rashid (2009)	Panel Regression	USA + BRIC	1981-2006	Supported
Tamazian et al. (2009)	Panel Regression	BRIC	1992-2004	Supported
Mehrara and Rezaei (2013)	Cointegration Analysis	BRICS	1960-1996	Partially Supported
Bakirtas et al. (2014)	Dynamic Panel Regression	OECD + BRICS	NA	Supported
Chang (2015)	DEA-DDF Model	G7 + BRICS	2000-2010	Not Supported
Chakravarty and Mandal (2016)	Dynamic Panel Regression	BRICS	1997-2011	Partially Supported
Ahmed et al. (2016)	FMOLS	BICS	1970-2013	Supported
Sinha and Sen (2016)	GMM	BRIC	1980-2013	Supported
Tedino (2017)	Panel Regression	BRICS	1992-2012	Partially Supported
Nassani et al. (2017)	Panel Fixed Effect Regression	BRICS	1990-2015	Supported

Appendix 2: Structural breaks in the dataset

N11 countries				*BRICS countries*			
Countries	*No Shift*	*Mean Shift*	*Regime Shift*	*Countries*	*No Shift*	*Mean Shift*	*Regime Shift*
Bangladesh	1993	2002	2002	Brazil	1993	2006	2006
Egypt	1993	2002	2002	China	1993	2006	2006
Indonesia	1993	2002	2002	India	1993	2006	2006
Iran	1993	2002	2002	Russia	1993	2006	2006
South Korea	1993	2002	2002	South Africa	1993	2005	2005
Mexico	1993	2002	2002				
Nigeria	1993	2002	2002				
Pakistan	1993	2002	2002				
Philippines	1993	2001	2001				
Turkey	1993	2001	2001				
Vietnam	1993	2001	2001				

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