Do Foreign Capital and Financial Development affect Clean Energy Consumption and Carbon Emissions? Evidence from BRICS and Next-11 Countries

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Abstract: This study investigates the main interrelations generated by the impact of foreign capital along with financial development on clean energy consumption and environmental degradation proxied by the inclusion of CO_2 emissions. In doing so, we used panel data techniques targeted at BRICS and Next-11 countries spanning the period 1992-2016. Our paper strongly accounts for the existence of cross-sectional dependence and non-stationarity usually ignored by the other empirical studies. In case of BRICS, the empirical findings reveal that economic growth increases clean energy consumption while financial development reduces it. On the contrary, foreign capital inflows do not appear to have a statistically significant effect on clean energy. We argue that, economic growth, foreign capital inflows and financial development increase CO_2 emissions, while clean energy consumption reduces environmental degradation by mitigating carbon emissions in BRICS countries. In case of Next-11 countries, empirical findings indicate that economic growth and foreign capital have positive effect on clean energy consumption. However, economic growth and financial development increases CO_2 emissions in N-11 countries.

Keywords: Foreign Capital, Financial Development, Clean Energy, CO_2 emissions, Panel Data

JEL Classifications: G1, Q4, Q5

1. Introduction

There is no doubt that assessing the role of Financial Development and Foreign Direct Investment (FDI) on cleaner energy is an interesting endeavour that has been examined by the researchers (Al Mamun et al, 2018; Paramati et al, 2017). Specifically, the increase in the Greenhouse Gas Emissions (GHGs) has resulted a shift in environmental policies towards addressing rapid climate change without sacrificing long-term economic growth targets. This is evident from the fact that an increasing number of countries are adopting sustainable long-term growth strategies and a shift towards Sustainable Development Goals (SDGs) by the United Nations (UN). According to the latter, sustainable growth is achieved when an economy has reliable, affordable, economically viable, and socially acceptable renewable energy services (see UN, 2007). Countries around the globe are able to diversify their energy mix and improve energy security while at the same time, reducing GHG emissions and fossil fuel dependence due to rapid advancements in renewable energy technologies (RETs) (Rifkin, 2011). Consequently, the share of global clean energy consumption in global total energy consumption rose from 2.98% in 1970 to 8.90% in 2014 (WDI, 2018).

However, the adoption of RETs is more concentrated in developed countries, as evident from their share of global fossil energy consumption that reduced from 73.18% of global fossil energy consumption in 1970 to 40.34% in 2014. On the contrary, the share of global fossil energy consumption for developing countries increased from 40.34% to 55.37% during the same period (WDI, 2018). This clearly indicates the commitment to sustainable development and reducing environmental degradation by developed countries as opposed to developing countries which still seem to meet increasing energy demands with fossil energy. The primary reasons for the underdevelopment of clean energy production processes in the developing countries are its high upfront capital costs, information costs, and high specificity of assets (Kim and Park, 2016).

Energy economics literature claims that foreign capital inflows i.e. foreign direct investment (FDI) and financial market development are vital for developing countries to fund high-tech clean energy projects (Batten and Vo 2009, Fernandes and Paunov 2012, Kim and Park 2016). This view is mainly attributed to the possible positive externalities of foreign capital inflows in terms of foreign technology transfer and knowledge spill over effects (Batten and Vo 2009, Fernandes and Paunov 2012). Kim and Park (2016) on the other hand argue that developed financial market fosters the adoption of RETs that in turn leads to reduction in CO_2 emissions. The main reason for this positive association is that financial market development reduces information asymmetry and hence the cost of external financing on which most of the deployment of renewable energy relies on. Tamazian et al. (2009) argue that environmental quality may be positively affected by financial development by improving energy efficiency.

Against this backdrop, it is a crucial to understand the relative importance of foreign capital inflows and financial development in fostering clean energy usage and reducing environmental degradation in developing countries. This study investigates the effect of foreign capital inflows and financial development on clean energy consumption and CO_2 emissions in BRICS (Brazil, Russia, India, China and South Africa) and Next-11 countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey and Vietnam). The reason for focusing on these countries is due to their common characteristic of having high economic and demographic growth potential that separates them from other developing countries. The high growth potential of these countries both in economic and demographic terms implies that their energy consumption will also grow accordingly compared to other developing countries. Therefore, it is important to understand the role of foreign capital inflows and financial development in the adoption of clean energy projects in these countries. The analysis will not only result in more informed policy making regarding the adoption of cleaner technologies but also provide an understanding of how these countries can achieve their high economic growth potential without sacrificing the environment and reducing global CO_2 emissions. So that these countries are able to achieve high economic and demographic growth rates sustainabliy without sacrificing environment.

This study contributes the existing literature in many fronts. Firstly, this is the first study to the best of our knowledge that investigates the relative effects of foreign capital inflows and financial development on clean energy consumption and CO_2 emissions using data for BRICS and Next-11 countries. Secondly, this study employs panel unit root testing along with cointegration methodology in order to account for the existence of cross-sectional dependence. These issues have been over-looked by similar empirical studies. Thirdly, we perform several panel data methodologies such as CCE-MG and AMG in order to deal with the existence of cross-sectional dependence and confirm the robustness of our findings. Lastly, we supplement our analysis by investigating the causal relationship between the sample variables by performing heterogeneous panel causality tests.

The empirical results reveal that the level of clean energy consumption seems to have reached an effective level in reducing environmental degradation in BRICS and Next-11 countries. In case of Next-11 countries, financing of clean energy projects benefited considerably from foreign capital whereas financial development tends to exacerbate environmental degradation in these countries. This empirical finding indicates that financial system does not have the capacity to fund such projects because of the high costs of clean energy projects. This calls for the encouragement of domestic investment in clean energy projects in these countries. In the case of BRICS countries, foreign capital does not support clean energy projects significantly. Whereas similar to Next-11 countries, financial development reduces the share of clean energy usage in total energy consumption. Therefore, it is imperative that BRICS countries should implement extra tax incentives to encourage both domestic and foreign capital in order to overcome the capital shortage for clean energy projects.

The rest of paper is organised as following: Section-2 reviews the literature. Section-3 explains methodological framework and data collection. Section-4 provides the institutional background on the Next-11 countries. Section-5 reports empirical results and their discussion. Finally, conclusion and policy implications are drawn in Section-6.

2. Literature review

During the last decade, various studies have investigated the effect of foreign capital inflows (proxied by foreign direct investment) and financial development on energy consumption and environmental degradation. For this reason, we have categorised the existing literature into two sections. In the first section, we focused on the studies examining the effect of foreign direct investment or financial development on clean energy consumption. In the second section, we reviewed the studies investigating the impact of foreign direct investment and financial development on CO_2 emissions.

2.1. Foreign Direct Investment, Financial Development and Clean Energy Consumption

Despite, the fact that there is a vast majority of studies examining the relationship between foreign direct investment and energy consumption, a small number of empirical papers have tried to explore the relationship between foreign direct investment and clean energy consumption. Empirically, the association between foreign direct investment and energy consumption is investigated by Hübler and Keller (2010) in case of developing economies. They applied simple OLS approach and reported that foreign direct investment declines energy intensity via adoption of energy efficient technology during the production process. Later on, Ting et al. (2011) decomposed effect of foreign direct investment on energy consumption into scale, technique and composition effects for Jiangsu (China) by applying LMDI model. Their results indicate that technique and composition effects have an insignificant effect on energy intensity, but scale effect is negatively linked with it. Jiang et al. (2014) employed energy demand function for Chinese economy using provincial data by applying spatial panel approach. They reported that foreign direct investment lowers energy consumption in the presence of environmental Kuznets curve between economic growth and energy consumption. Adom (2015) examined the asymmetric effect of foreign direct investment, trade openness and industrialisation on energy intensity for Algerian economy. The empirical results indicate that foreign direct investment and trade openness are negatively linked with energy intensity, i.e. foreign direct investment and trade openness save energy consumption. Adom and Amuakwa-Mensah (2016) examined the effect of foreign direct, trade openness and economic growth on energy intensity using data from African countries. They found that foreign direct investment reduces energy consumption but economic growth and trade openness increases energy intensity. Salim et al. (2017) employed energy demand function by apply bounds testing approach to cointegration for the Chinese economy. Their results indicate that in the long run, foreign direct investment declines energy intensity by adopting energy efficient technology. On contrarily, Petrovic et al. (2018) examined the determining factors affecting energy intensity for European Union. They found that foreign direct investment is helping in reducing energy demand, i.e. foreign direct investment has an insignificant effect on energy intensity.

Initially, Lee (2013) probed the relationship between FDI inflows and clean energy consumption in G20 countries from 1971 to 2009. The empirical results of fixed effect regression model show that FDI inflows have no significant effect on clean energy consumption. Later on, Sbia et al. (2014) probed the causal relationship between FDI inflows and clean energy consumption by using quarter frequency data from 1975 to 2011 in the United Arab Emirates. They applied bounds testing approach and VECM Granger causality approaches in order to examine cointegration and causal relationship between the variables. Their empirical results show the presence of a bidirectional causal relationship between FDI inflows and clean energy consumption i.e. FDI inflows and clean energy consumption are inter-dependent. In addition, various studies argue that FDI inflows are one of the main sources to obtain required technology to finance clean energy projects (Stern 2015, Mazzucato and Semieniuk 2018). For instance, Azam et al. (2015) determined factors affecting energy demand in Thailand, Malaysia and Indonesia. Their empirical analysis indicated economic growth attracts foreign direct investment which in resulting, stimulates energy consumption. Doytch and Narayan (2016) examined the effect of FDI inflows on renewable and non-renewable energy consumption for the period of 1985-2012 using data of 74 countries. They applied the Blundell-Bond dynamic panel estimator and found that increase in FDI stimulates renewable energy consumption for high-income and upper middle income countries. However, Kutan et al. (2017) investigated the relationship between FDI inflows, stock market development and renewable energy consumption for the period of 1990-2012 in 4 countries namely Brazil, China, India and South Africa. They applied panel FMOLS (fully modified ordinary least squares) and reported that FDI inflows and stock market development promote renewable energy consumption.

In energy economics literature, the relationship between financial development and energy consumption is explained with various arguments. The first and mostly accepted argument is that financial development increases energy consumption by facilitating the access of consumers to durable goods, catalysing the access of businesses to financial capital in order to increase the production level, etc. This argument is supported by many recent studies such as Sadorsky (2010, 2011), Shahbaz and Lean (2012), Ozturk and Acaravci (2013), Aslan et al. (2014), Komal and Abbas (2015), Mahalik et al. (2017). On the other hand, the alternative view that financial development reduces energy consumption through increasing the efficient use of energy is also empirically confirmed by Islam et al. (2013), Destek (2015), Topcu and Payne (2017), Destek (2018). However, it is more accurate to measure the role of financial development in the efficient use of energy with funds created by financial instruments in accessing clean energy technologies. In this regard, the studies investigating the effect of financial development on clean energy usage are very limited and obtained results from these studies are mixed. For instance, Burakov and Freidin (2017) probed the causal relationship between financial development and renewable energy consumption for the period of 1990-2014 in Russia. Their empirical results confirm the neutral connection between financial development and renewable energy usage. However, Paramati et al. (2016) explored the relationship between FDI, stock market development and clean energy consumption in 20 emerging economies for the period of 1991-2012 by utilising with panel ARDL method. They concluded that FDI inflows and stock market development positively affect clean energy consumption. Similarly, Paramati et al. (2017) examined the relationship between FDI inflows, the stock market and clean energy consumption in European Union countries, the G20 countries and OECD countries. They applied panel ARDL approach and showed that FDI inflows and stock market capitalisation increases clean energy consumption.

Similarly, Shahbaz et al. (2017) investigated the role of financial development in domestic production function in case of India. They reported that financial development attracts foreign direct investment and leads economic growth which, stimulates energy demand. Gamoori et al. (2017) investigated the factors, i.e. financial development, foreign direct investment and trade openness affecting energy demand in case of Islamic countries for the period of 2000-2014. Their empirical analysis confirms the presence of cointegration between the variables. Further, financial development, foreign direct investment and trade openness have a positive effect on energy consumption. Quyang and Li (2018) examined the role of financial development in energy consumption considering economic growth as an additional determinant of financial development and energy consumption as well. They applied panel structural VAR model and found that financial development provides access of foreign investors to financial resources for adopting energy efficient technology in the production process which leads to decline in energy intensity.

2.2. Foreign Direct Investment, Financial Development and CO_2 Emissions

It is widely accepted that increasing foreign direct investment increases national output and energy consumption, therefore, has a positive effect on CO_2 emissions. This view is supported by many studies (Baek, 2016). For example, Lee (2009) examined the causal relationship between foreign direct investment inflows and CO_2 emissions in Malaysia for the period of 1970-2000 by applying the VECM Granger causality approach. Lee found that foreign direct investment causes carbon emissions. Later on, Pao and Tsai (2011) used the panel VECM Granger causality to investigate causality between foreign direct investment and CO_2 emissions in BRIC countries. Their empirical results show that foreign direct investment causes CO_2 emissions. Lau et al. (2014) applied ARDL bounds testing approach to examine the relationship between foreign direct investment and CO_2 emissions in Malaysia. Their empirical analysis confirmed the presence of cointegration between the variables and foreign direct investment increases carbon emissions. Ren et al. (2014) examined the relationship of foreign direct investment and industrialisation with carbon emissions in case of China for the period of 2000-2010. They applied the GMM estimation and found that foreign direct investment leads industrialisation which in resulting increases CO_2 emissions. Tang and Tan (2015) applied the VECM Granger causality approach for examining causality between foreign direct investment and carbon emissions for Vietnam. They found that foreign direct investment cause carbon emissions and in resulting, carbon emission foreign direct investment, i.e. feedback effect. Behera and Dash (2017) investigated the relationship between foreign direct investment and CO_2 emissions in SSEA (South and Southeast Asian) region for the period of 1980-2012 by applying FMOLS and DOLS estimators. Their empirical results indicated the positive effect foreign direct investment on CO_2 emissions. Similarly, Kocak and Sarkgunesi (2018) also reported the positive relationship between foreign direct investment and CO_2 emissions for Turkish economy for the period 1974-2013. On the contrary, it is also claimed that foreign direct investment allows firms to develop new energy-saving technologies in their production activities and support the development of alternative energy sectors to reduce CO_2 emissions.

The accuracy of this view is also supported by some empirical studies (Hoffmann et al. 2005, Al-Mulali and Tang 2013). For instance, Hao and Liu (2015) investigated the effect of the foreign direct investment on CO_2 emission for 29 Chinese provinces. They applied GMM procedure and found that foreign direct investment reduces carbon emissions. Similarly, Zhang and Zhou (2016) investigated the impact of foreign direct investment on CO_2 emissions for the period of 1995-2010 in China and found that foreign direct investment saves energy via adopting energy efficient technology that in resulting, reduces emissions.

Various studies investigated foreign direct investment-emissions nexus but provided mixed empirical findings. For instance, Hoffmann et al. (2005) applied the Granger causality method to examine the causal relationship between FDI and pollution in 112 countries. They found that CO_2 emissions Granger cause foreign direct investment in low-income countries but foreign direct investment causes CO_2 emissions in middle-income countries, and the neutral effect is valid between the variables in high-income countries. Later on, Kivyiro and Arminen (2014) investigated the relationship between foreign direct investment and CO_2 emissions for Sub-Saharan African countries by applying the ARDL bounds testing approach. They found that foreign direct investment reduces carbon emissions in the Democratic Republic of the Congo and South Africa, but it increases emissions in Kenya and Zimbabwe. Shahbaz et al. (2015) examined the nexus between foreign direct investment and CO_2 emissions for 99 countries. They noted that foreign direct investment reduces emissions for global level and high-income countries, however, foreign direct investment increases CO_2 emissions in middle and low-income countries.

The relationship between financial development carbon emissions in existing energy economics literature also provides mixed results (Halkos and Polemis, 2017). For instance, Jalil and Feridun (2011) investigated the impact of financial development on environmental degradation for the period of 1953-2006 in China. They applied ARDL bounds testing approach to cointegration and found the presence of long-run relationship between the variables. Their empirical analysis indicates that financial development reduces CO_2 emissions. Similarly, Shahbaz et al. (2013a) explored the relationship financial development and CO_2 emissions in South Africa by including coal consumption as an additional determinant of environmental degradation by applying ARDL bounds testing approach. They found that financial development improves environmental quality by lowering carbon emissions. Shahbaz et al. (2013b) examined the financial development-environmental degradation nexus in Indonesia using quarter frequency data for the period of 1975-2011. Their empirical analysis posits an inverted-U shaped relationship between financial development and carbon emissions. On the contrary, Boutabba (2014) applied the bounds testing approach and reported that financial development increases carbon emissions. Ziaei (2015) examined the causal relationship between financial development and CO_2 emissions in 13 European and 12 East Asia and Oceania countries. They reported the feedback between financial development and carbon emissions. Charfeddine and Khediri (2016) investigated the relationship between financial development and CO_2 emissions in UAE and reported the presence of an inverted U-shaped relationship between financial development and CO_2 emissions. On the contrary, Dogan and Turkekul (2016) applied the ARDL bounds testing approach to determine the impact of financial development on CO_2 emissions in the US. They found that financial development affects carbon emissions insignificantly. By apply DOLS, Katircioglu and Taspinar (2017) reported that financial development impedes environmental quality by increasing CO_2 emissions.

Ignoring the role of financial development in carbon emissions function may provide biased empirical results on foreign direct investment-environmental degradation. This issue solved by Tamazian et al. (2009) who investigated the effect of the foreign direct investment on environmental degradation by considering the role of financial development as additional determinant into carbon emissions function in case of BRIC countries. They found that financial development attracts foreign direct investment for applying energy-efficient technology for production that in resulting, reduces CO_2 emissions and improves environmental quality. Using data from 24 emerging markets, Tamazian and Rao (2010) examined the relationship between financial development and CO_2 emissions by applying the GMM estimation approach. They concluded that financial development and foreign direct investment promote environmental quality by decreasing carbon emissions. Later on, Zhang (2011) investigated the relationship between financial development, FDI and CO_2 emissions in China by considering financial development and FDI as important drivers for CO_2 emissions. Zhang noted that foreign direct investment affects carbon emissions less compared to financial development in China. Recently, Solarin et al. (2017) examined the impact of foreign direct investment and financial development on CO_2 emissions in Ghana by applying the bounds testing approach. They found that foreign direct investment and financial development increase CO_2 emissions. Sapkota and Bastola (2017) applied the panel regression to examine the effect of the foreign direct investment on CO_2 emissions in 14 Latin American countries and evidenced that foreign direct investment increases CO_2 emissions. Salahuddin et al. (2018) investigated the impact of foreign direct investment and financial development on CO_2 emissions in Kuwait by applying DOLS estimator. They noted that foreign direct investment increases CO_2 emissions, but financial development reduces it.

This shows that a limited number of studies examined the impact of foreign direct investment and financial development on clean energy consumption. Conversely, there are numerous studies to observe the effect of foreign direct investment or financial development on environmental degradation. In addition, the contradictory findings from previous studies may be sourced from ignoring the cross-sectional dependence across countries which is a main rationale for further investigating the relationship with recent methodologies.

3. Data and Empirical Strategy

3.1. Data

Based on the data availability, the data used for empirical in the study consists of annual observations for the period of 1992-2014 for BRICS (Brazil, Russia, India, China and South Africa) and Next-11 countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey and Vietnam). The data on real gross domestic product, carbon dioxide emission, clean energy consumption, foreign direct investment and financial development are obtained from World Development Indicators (CD-ROM, 2017) by World Bank. These variables are measured as follows; gross domestic per capita (GDP) is measured in 2010 constant US dollar. Carbon dioxide emission (CO) is measured in metric tons. Clean energy consumption (CEC) is non-carbohydrate energy that does not produce carbon dioxide while generated. It includes hydropower and nuclear, geothermal, and solar power. This variable is used as the share of clean energy use in total energy consumption. Foreign direct investment (FDI) is measured as net inflows percentage of GDP. Financial development (FD) is represented with domestic credit to private sector share in GDP and refers to financial resources provided to the private sector by financial corporations. Total population is used to convert all the variables into per capita units. To avoid the problems associated with distributional properties of the data, all variables are used in natural logarithmic form.

3.2. Empirical strategy

In order to examine the long-run effects of foreign direct investment and financial development on clean energy consumption and CO_2 emissions, we utilize empirical equations of energy demand and carbon emissions functions are as following:

$$CEC_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 CO_{it} + \alpha_3 FDI_{it} + \alpha_4 FD_{it} + \mu_{it} \qquad (1)$$

$$CO_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 CEC_{it} + \beta_3 FDI_{it} + \beta_4 FD_{it} + \mu_{it} \qquad (2)$$

where, CEC, GDP, CO, FDI and FD show natural-log of clean energy consumption, gross domestic product, carbon dioxide emissions, foreign direct investment and financial development, respectively. In addition, *i* refers to cross-section and *t* indicates the time period. u_{it} and ε_{it} are residual terms. The equation-1 and 2 show energy demand and carbon emissions functions respectively.

We have included squared term of GDP to capture the phenomenon of energy-environmental Kuznets curve between economic growth and energy consumption. The energy-environmental Kuznets curve reveals that energy consumption is accompanied with economic growth initially and after threshold level of real GDP per capita, energy consumption declines as energy efficient technology is applied for enhancing domestic production. Similarly, environmental Kuznets curve shows an inverted-U shaped relationship between economic growth and carbon emissions. To capture, energy and environmental curves, we model energy demand and carbon emissions functions as following:

$$CEC_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDP_{it}^2 + \alpha_3 CO_{it} + \alpha_4 FDI_{it} + \alpha_5 FD_{it} + \mu_{it} \qquad (3)$$

$$CO_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}^2 + \beta_3 CEC_{it} + \beta_4 FDI_{it} + \beta_5 FD_{it} + \mu_{it} \qquad (4)$$

where, $\alpha_1(\beta_1) > 0$ and $\alpha_2(\beta_2) < 0$ show the phenomenon of environmental Kuznets curve between eocnomic growth and carbon emisisons (economic growth and energy consumption) otherwise relationship between both variables is U-shaped. It is claimed by Cole et al. (2006) that use of quartratic specifictaion between eocnomic growth and carbon emissions (energy consumption) reports ambeguous ambiguous empirical findings. They opine that carbon emissions (energy consumption) become zero or turn negative after having new threshold level of income per capita. Similarly, Sengupta (1996) argues that quardratic association between eocnomic growth and carbon emissions (energy consumption) is termed symetric as income per capita reached to threshold level and in resulting, fall or rise in carbon emissions stay constant. In such circumstances, Moomaw and Unruh, (1997) suggested to employ the cubic specification to exmaine relationship between economic growth and carbon emissions (energy consumption). The augmented EKC empirical equations for energy demand and carbon emissions functions are modeled as follwoing:

$$CEC_{it} = \delta_0 + \delta_1 GDP_{it} + \delta_2 GDP_{it}^2 + \delta_3 GDP_{it}^3 + \delta_4 CO_{it} + \delta_5 FDI_{it} + \delta_6 FD_{it} + \mu_{it} \tag{5}$$

$$CO_{it} = \rho_0 + \rho_1 GDP_{it} + \rho_2 GDP_{it}^2 + \rho_3 GDP_{it}^3 + \rho_4 CEC_{it} + \rho_5 FDI_{it} + \rho_6 FD_{it} + \mu_{it} \tag{6}$$

where $\delta_1(\rho_1) > 0$, $\delta_2(\rho_2) < 0$ and $\delta_3(\rho_3) > 0$ show N-shaped association between eocnomic growth and carbon emisisons (economic growth and energy consumption) otherwise linkage between both variables is inverted N-shaped for energy demand and carbon emissions.

3.2.1. Cross-Sectional Dependence and Unit Root Tests

The panel unit root test ignores the presence of cross-sectional dependence may lead to unreliable empirical results (Polemis 2018, Halkos and Polemis 2018, Polemis and Stengos 2018). Globally, countries are highly integrated due to globalization (economically, socially and politically). In such circumstances, ignorance of cross-sectional dependence in data further misleads us for applying cointegration approach for determining long run relationship between the variables. Therefore, we first test the existence of cross-sectional dependence among BRICS and N-11 countries using with Pesaran's (2004) cross-sectional dependence (CD hereafter) test[1].

It is an also crucial issue that determining the stationary properties of the variables to examine the long-run relationship between the variables. We used CIPS unit root test[2] developed by Pesaran (2007) which considers the cross-sectional dependence in the data.

3.2.2. Panel Cointegration Test

To test the validity of the long-run relationship between clean energy consumption, economic growth, CO_2 emissions, foreign direct investment and financial development, we employ an error correction based cointegration method proposed by Westerlund (2007). The major benefit of Westerlund cointegration test is that it accommodates the heterogeneity and cross-sectional dependence by means of application of bootstrapping. It is based on structural dynamics, and

[1] See Appendix A for detailed description for cross-sectional dependence test.
[2] See Appendix B for detailed explanation for CIPS unit root test.

therefore, does not require the common factor restriction. The test statistics are normally distributed and have good small-sample properties. Moreover, this error-correction based test show better size accuracy and higher power than the residual-based cointegration methods in case of the regressors are weakly exogenous (Westerlund, 2007). In testing procedure, there is four statistics (G_t, G_α, P_t, P_α) to test the null hypothesis of there is no cointegration. G_t and G_α statistics are mean-group statistics that are constructed with the assumption of unit-specific error correction parameters. The latter two statistics are computed under the assumption of common error-correction parameters across cross-sections[3].

3.2.3. Long-Run Coefficient Estimation

Pesaran (2006) developed a new estimator that takes into account the cross-sectional dependence. If we combined our main panel models as follows:

$$Y_{it} = \delta_0 + \delta_1 X_{it} + e_{it} \tag{7}$$

where Y_{it} is dependent variable, $X_{i,t}$ is the vector of explanatory variables and residual term (e_{it}) is a multifactor residual term. The multifactor residual terms is constructed as follows:

$$e_{it} = \lambda_i' UF_t + u_{it} \tag{8}$$

where UF_t is the $m\ x\ 1$ vector of unobserved common factors. In addition, Pesaran (2006) utilizes with cross-sectional averages, $\bar{Y}_t = \frac{1}{N}\sum_{i=1}^{N} Y_{it}$ and $\bar{X}_t = \frac{1}{N}\sum_{i=1}^{N} X_{it}$ to deal with cross-sectional dependence of residuals as observable proxies for common factors. In the next step, slope coefficients and their cross-sectional averages are consistently regressed as follows:

$$Y_{it} = \delta_0 + \delta_1 X_{it} + a\bar{Y}_t + c\bar{X}_t + \varepsilon_{it} \tag{9}$$

Pesaran (2006) refers to the computed OLS estimator $\hat{B}_{i,CCE}$ of the individual slope coefficients $B_i = (\delta_1, .., \delta_n)$ as the "Common Factor Correlated Effect" estimator:

$$\hat{B}_{i,CCE} = (Z_i' \bar{D} Z_i) Z_i' \hat{D} Y_i, \tag{10}$$

[3] See Appendix C for detailed informations for error correction based panel cointegration test.

where $Z_i = (z_{i1}, z_{i2}, \dots, z_{iT})'$, $z_{it} = (X_{it})'$, $Y_i = (Y_{i1}, Y_{i2}, \dots, Y_{it})'$, $\bar{D} = I_T - \bar{H}(\bar{H}'\bar{H})^{-1}\bar{H}$, $\bar{H} = (h_1, h_2, \dots, h_T)'$, $h_t = (1, \bar{Y}_t, \bar{X}_t)$ as the CCE estimators. The CCE-Mean Group estimator is obtained with the average of the individual CCE estimators as follows:

$$\hat{B}_{CCEMG} = \sum_{i=1}^{N} \hat{B}_{i,CCE}. \tag{11}$$

3.2.4. Heterogeneous Panel Causality Test

We apply the heterogeneous panel causality approach developed by Dumitrescu and Hurlin (2012) which is the modified version of Granger (1969) non-causality test. This heterogeneous panel is to investigate the causal relationship between variables. The reasons for choosing this methodology are that using this methodology leads to consistent results in case of both small samples and cross-sectional dependence. In addition, this procedure is suitable if all the variables are stationary at same level, in other words, in case of variables are integrated in order one $I(1)$. The other advantages of this methodology are that the test is appropriate for the unbalanced panels and panels with different lag order for each individual. The main model of panel heterogeneous causality method is constructed as follows:

$$W_{N,T}^{HNC} = \frac{1}{N}\sum_{i=1}^{N} W_{i,t} \tag{12}$$

where $W_{i,t}$ is the Wald statistic for the country *i* therefore equation-17 shows the first statistic computed with the simple means of Wald statistic, individually. In addition, Dumitrescu and Hurlin (2012) suggested another statistic which is obtained with standardized statistic for $W_{N,T}^{HNC}$ statistic by using estimated values of mean and variance of each Wald statistic with a small sample for T. The computation of this statistic is as following:

$$Z_{N,T}^{HNC} = \frac{\sqrt{N}\,[W_{N,T}^{Hnc} - \sum_{i=1}^{N} E(W_{i,t}]}{\sqrt{\sum_{i=1}^{N} Var(W_{i,t})}} \tag{13}$$

In this procedure, the null of there does not exist a homogeneously causality in the panel is tested against the alternative hypothesis. It is argued by Granger (1969) that there must be causality at least from one-side if variables have cointegration with integrating order of I(1).

4. Institutional Background

4.1. The Significances of the BRICS and Next-11 Countries within the Global Economy

To observe the importance of the BRICS and Next-11 countries in global economy, we present the performance of macroeconomic indicators of BRICS and Next-11 countries within global indicators. The significance of BRICS countries in the world is shown in Table-1. These statistics present that national output of BRICS countries constituted 10.48% of global output in 1992 but reached 20.39% in 2014. Similarly, based on the increasing output and production, the percentage of CO_2 emissions of BRICS countries has increased from 26.98% in 1992 to 42.20% in 2014. Clean energy usage share in total energy consumption has increased from 25.92% to 32.42 over the same period. Although the share of population of BRICS countries in total global population declined from 1992 to 2014, the share is fairly high with 42.10%. The FDI inflows percentage seems to be fluctuating for observed period but domestic credits percentage has increased greatly from 5.07% in 1992 to 17.55% in 2014 in BRICS region.

The trends of selected variables for Next-11 countries over the period of 1992-2014 are presented in Table-2. The statistics show that the share of output of Next-11 countries in global output has increased from 6.61% in 1992 to 8.56% in 2014. The percentage of CO_2 emissions has also increased from 6.72% in 1992 to 9.23% in 2014. The share of clean energy consumption in total energy consumption has grown from 5.21% in 1992 to 6.50% in 2014. This means that despite the increasing share of clean energy, the contribution of these countries to global CO_2 emissions has been increasing for observed period. Financial sector development of Next-11 countries is compared with global financialization, it can be seen that domestic credits of these countries have been constantly increasing in the domestic loans provided at the global level. However, the share of foreign direct investment inflows in global FDI is following a fluctuating trend for sampled period.

The statistics are evaluated in terms of the growth rates and, the significance of BRICS countries in the global output increased by 94.49% and the share of Next-11 countries in the global output increased by 29.6% over the observed period. Similarly, CO_2 emissions percentage of BRICS countries has increased by 56.42% and responsibility of Next-11 countries for increasing global CO_2 emissions has increased by 37.3%. However, both country groups are aware of the importance of clean energy technologies as the percentage of clean energy usage in total energy consumption has grown by 25.05% and 24.7%, respectively. It seems that FDI inflows share in global FDI has slightly decreased over the period of 1992-2014 for both country groups. On the other hand, domestic credits to private sector of BRICS and Next-11 countries have increased by 245.94% and 149.85%, respectively. To sum up, this statistics point that if mentioned country groups maintain the growth rate of respective variables, then in near future, these countries will become significantly responsible for global environmental degradation. Based on this reason, the successful implementation of effective energy policies by these countries is crucial to the achievement of targets to reduce CO_2 emissions globally.

Table-1. Variables' Trends for BRICS Countries

Year	GDP	CO	CEC	FDI	POP	FD
1992	10.485	26.980	25.925	23.912	44.223	5.074
1993	10.635	27.467	25.600	38.088	44.175	6.939
1994	10.645	27.037	26.663	37.628	44.137	5.243
1995	10.842	27.686	27.621	28.391	44.090	4.496
1996	10.948	28.007	27.702	28.948	44.052	4.711
1997	11.093	27.501	28.500	29.632	44.012	4.891
1998	11.125	26.704	29.383	22.017	43.969	0.082
1999	11.347	27.156	29.336	17.116	43.913	4.917
2000	11.594	27.115	30.659	11.851	43.845	5.379
2001	11.969	26.851	30.136	23.185	43.765	6.206
2002	12.405	27.846	30.915	22.992	43.677	6.964
2003	12.871	29.429	31.398	22.339	43.579	7.504
2004	13.316	30.874	31.152	19.675	43.472	7.735
2005	13.870	32.175	31.202	15.390	43.362	7.881
2006	14.533	33.655	31.721	13.675	43.242	8.400
2007	15.428	35.040	31.864	11.784	43.115	9.215
2008	16.218	36.395	31.185	15.674	42.980	10.175
2009	17.231	38.182	33.056	20.047	42.842	12.088
2010	17.992	39.001	32.212	21.847	42.699	13.532
2011	18.720	40.875	33.284	18.323	42.561	14.598
2012	19.324	41.759	32.429	16.668	42.410	15.761
2013	19.930	41.960	32.335	18.485	42.256	16.584
2014	20.392	42.204	32.421	20.669	42.101	17.555
Average	14.040	32.256	30.291	21.667	43.412	8.519

Note: GDP: Percentage of global GDP, CO: Percentage of global CO_2 emission, CEC: Percentage of clean energy consumption in total energy consumption, FDI: Percentage of global foreign direct investment inflow, POP: Percentage of global population, FD: Percentage of global credit to private sector.

Table-2. Variables' Trends for Next-11 Countries

Year	GDP	CO	CEC	FDI	POP	FD
1992	6.611	6.725	5.217	6.622	17.468	1.665
1993	6.804	7.141	5.141	5.757	17.543	1.683
1994	6.843	7.297	5.231	8.965	17.620	1.812
1995	6.868	7.406	5.319	6.943	17.693	1.728
1996	7.087	7.741	5.400	7.022	17.775	1.782
1997	7.208	8.062	5.302	6.056	17.856	1.983
1998	6.970	7.779	5.860	3.779	17.939	0.028
1999	6.961	8.399	6.258	2.870	18.022	1.444
2000	7.079	8.815	6.451	2.208	18.104	1.620
2001	7.033	8.843	6.457	5.222	18.183	2.197
2002	7.191	8.987	6.431	5.489	18.258	2.478
2003	7.289	8.927	6.496	4.812	18.331	2.454
2004	7.463	8.885	6.588	5.234	18.400	2.495
2005	7.539	8.816	6.595	5.045	18.466	2.590
2006	7.645	8.844	6.734	3.821	18.530	2.816
2007	7.736	9.045	6.498	3.432	18.593	3.121
2008	7.819	9.145	6.524	4.483	18.655	3.553
2009	7.970	9.299	6.575	5.358	18.720	3.524
2010	8.120	9.184	6.316	4.480	18.791	3.646
2011	8.277	9.651	6.585	4.176	18.875	3.963
2012	8.336	9.694	6.575	4.267	18.956	3.979
2013	8.453	9.232	6.427	5.896	19.037	4.039
2014	8.568	9.235	6.508	6.041	19.117	4.159
Average	7.473	8.572	6.152	5.130	18.301	2.555

Note: GDP: Percentage of global GDP, CO: Percentage of global CO_2 emission, CEC: Percentage of clean energy consumption in total energy consumption, FDI: Percentage of global foreign direct investment inflow, POP: Percentage of global population, FD: Percentage of global credit to private sector.

Table-3 presents the summary statistics with the average of the variables of BRICS and Next-11 countries over the period of 1992-2014. It seems that there is a huge variation of per capita income among BRICS countries with the highest 9603 US dollars in Brazil and the lowest 964 US dollars in India. Nonetheless, Brazil and India have almost the same CO_2 emissions per capita and Russia is the biggest emitter among BRICS countries. The environmental achievement of Brazil can be explained with clean energy because Brazil has the biggest percentage of clean energy usage in total energy use. In addition, the share of foreign direct investment in GDP of BRICS countries ranges from 1.208% in India to 3.919% in China. In case of financial development, it seems China and South Africa are the leading countries among BRICS. Namely, domestic credit to private sector equals 110.54% of gross domestic product of China and this rate has reached the 130.74 percent of South Africa's GDP.

Table-3. Summary Statistics of BRICS Countries

Countries	GDP	CO	CEC	FDI	FD
BRICS Countries					
Brazil	9603.113	1.899	14.297	2.638	49.527
China	2809.470	4.346	2.885	3.919	110.542
India	964.139	1.121	2.621	1.208	36.586
Russia	8431.249	11.484	7.778	1.857	26.001
S.Africa	6406.177	8.684	2.710	1.407	130.748
Descriptive Statistics					
Mean	5642.830	5.507	6.058	2.206	70.681
Median	5876.145	3.524	3.187	2.030	51.889
Maximum	11912.150	13.980	15.561	6.187	160.125
Minimum	548.896	0.772	1.311	0.002	8.330
Std.Dev.	3588.487	4.125	4.636	1.546	45.503
Next-11 Countries					
Bangladesh	601.109	0.278	0.313	0.625	28.173
Egypt	2098.014	1.996	2.263	2.382	39.967
Indonesia	2574.882	1.527	6.017	1.088	33.052
Iran	5327.593	6.178	0.632	0.645	34.099
Mexico	8555.276	3.988	6.016	2.509	21.433
Nigeria	1731.492	0.550	0.552	3.572	15.503
Pakistan	926.641	0.826	3.864	1.233	23.409
Philippines	1812.184	0.880	22.254	1.535	34.360
South Korea	17158.829	9.627	15.193	0.934	100.679
Turkey	9279.842	3.539	5.876	1.188	28.106
Vietnam	977.097	1.009	4.689	6.136	55.779
Descriptive Statistics					
Mean	4640.269	2.763	6.152	1.986	37.687
Median	2190.766	1.508	4.199	1.332	28.247
Maximum	24323.570	11.803	26.670	11.939	148.341
Minimum	416.181	0.153	0.127	-2.590	9.014
Std. Dev.	5148.670	2.857	6.622	2.132	28.548

Note: GDP: GDP per capita in constant 2010 US dollar, CO: CO_2 emissions per capita in metric tons, CEC: Clean energy consumption share in total energy consumption, FDI: Foreign direct investment inflows share in GDP, FD: Domestic credit to private sector share in GDP.

In case of Next-11 countries, we find the existence of great variation of income per capita with the highest 17158 US dollars in South Korea and the lowest 601 US dollars in Bangladesh, with the average of 4640 US dollars. Similarly, Bangladesh has the lowest CO_2 emissions per capita with 0.278 metric tons and South Korea is the biggest CO_2 emitter with 9.627 metric tons. On the other hand, despite the relatively low national income of the Philippines, this country seems the most conscious country with regard to clean energy. Namely, the share of clean energy consumption in total energy consumption ranges from 0.313% in Bangladesh to 22.254% in Philippines.

Moreover, given the low level of income, the percentage of clean energy consumption in total energy usage of Vietnam is surprisingly so close to Turkey which has the second highest GDP. This situation may be associated with foreign direct investment because Vietnam has the largest share of foreign direct investment in national income among Next-11 countries. In addition, it seems Pakistan is one of the most conscious countries in terms of clean energy. Because the average clean energy consumption of Pakistan is relatively high than the average of Next-11 countries while its national income, foreign direct investment and domestic loans are lower than the average of this country group. In case of financial development, the share of domestic credit to private sector in GDP has great variation, with the highest 100.6% occurring in South Korea and the lowest 15.5% occurring in Nigeria, with an average of 37.6% in Next-11 countries.

5. Empirical Results and Discussion

In the first step, we examine the cross-sectional dependence among observed countries using with CD test developed by Pesaran (2004). The empirical findings are illustrated in Table-4 and show that the null hypothesis of cross-sectional independence is clearly rejected at 1 percent significance level for BRICS and Next-11 country-groups. Therefore, the alternative hypothesis of cross-sectional dependence is accepted. This finding means that a shock in one of BRICS countries may be easily transmitted to other BRICS countries and similar conclusion is drawn for Next-11 countries

Table-4. Cross-Sectional Dependence and Unit Root Analysis

	GDP	CO	CEC	FDI	FD
BRICS Countries					
Pesaran CD test	14.440***	7.810***	3.170***	4.640***	6.950***
CIPS test (level)	-2.218	-1.521	-2.086	-1.089	-1.974
CIPS test (first difference)	-2.904***	-3.016***	-4.213***	-4.431***	-4.434***
Next-11 countries					
Pesaran CD test	33.420***	25.380***	21.070***	3.320***	3.100***
CIPS test (level)	-2.047	-1.850	-1.398	-1.340	-1.394
CIPS test (first difference)	-3.382***	-3.940***	-4.888***	-5.196***	-3.501***

Note: The critical values of CIPS test for BRICS countries are -2.12, -2.25 and -2.51, for the Next-11 countries are -2.07, -2.17 and -2.34 at 10, 5 and 1 percent level, respectively. *** indicates the statistical significance at 1 percent level.

Since the existence of cross-sectional dependence, it is necessary to apply panel unit root test that takes into account the cross-sectional dependence among countries. We have applied CIPS unit root test developed by Pesaran (2007) to examine stationary properties of the variables. The empirical results of panel unit root test are also shown in Table-4. We find that null hypothesis of unit root is not rejected for the level form of variables for BRICS and Next-11 countries. However, the null hypothesis is strongly rejected in first differenced form and CO_2 emissions, economic growth, clean energy consumption, foreign direct investment and financial development have become stationary. Therefore, it is concluded that all variables are integrated of order one, namely $I(1)$.

Based on the findings from panel unit root test i.e. I(1), the existence of long-run relationship between variables can be examined with panel cointegration test. In doing so, we employ the ECM-based panel cointegration test developed by Westerlund (2007). The empirical results are shown in Table-6. The validity of cointegration is examined with two models and for BRICS and Next-11 country groups. In case of BRICS countries, in the first model that CEC is used as the dependent variable, we find that the null hypothesis of no cointegration is rejected by G_a and P_a statistics. However, the test results from Model II where CO is used as dependent variable show that the null hypothesis can only be rejected by P_t statistic.

Table-6. Panel Cointegration Analysis

	BRICS		*Next-11*	
	Model I	Model II	Model I	Model II
G_t	-2.603	-1.065	-3.176**	-2.980**
G_a	-1.117*	-0.919	-5.750***	-5.522***
P_t	-2.652	-1.545**	-12.727***	-7.234
P_a	-1.429**	-0.456	-6.040**	-4.181**

Note: *, ** and *** indicates statistically significance at 10, 5 and 1 percent level, respectively. Model-I indicates *CEC=f(GDP,CO,FDI,FD)* and Model-II indicates *CO=f(GDP,CEC,FDI,FD).*

In case of Next-11 countries, first CEC is used as dependent variable and null hypothesis is strongly rejected by all statistics. In the second model, CO is used as dependent variable and all statistics except Pt reject the null of no cointegration. To sum up, we conclude that carbon emissions, economic growth, clean energy consumption, foreign direct investment and financial development are cointegrated for BRICS and Next-11 countries. After confirming cointegration between the variables, we examine the long-run effect of FDI inflows and financial development on clean energy consumption and CO_2 emissions using with mean group estimator (CCE-MG) which take into account the cross-sectional dependence among countries. In addition, we also employed AMG (Augmented Mean Group) estimator (Eberhardt and Bond 2009, Eberhardt and Teal 2010) to robustness of empirical findings. The empirical results are reported in Table-6.[4]

In case of clean energy demand function, for BRICS countries, we find that a 1% increase in economic growth increases clean energy consumption by 0.856-1.131%. This empirical finding shows that clean energy projects are benefitted from increasing prosperity of BRICS countries. This finding is consistent with the studies of Paramati et al. (2016) and Kutan et al. (2017). However, we also find that a 1% increase in domestic credit reduces the share of clean energy consumption in total energy usage by 0.139-0.237%. It can be interpreted as the firms benefitted from financial system of BRICS countries have still tendency to use more fossil energy sources in production process. Similarly, the findings reveal that FDI inflows have no statistically significant effect on clean energy usage. This finding is consistent with Lee (2013) who argued that there is no relationship between FDI inflows and clean energy consumption.

The empirical findings CO_2 emissions function for BRICS countries show that CO_2 emissions are positively affected by economic growth. This finding indicates that increasing output reduces environmental quality confirmed by the studies of Chiu and Chang (2009), Apergis et al. (2010), Al-Mulali et al. (2015) and Paramati et al. (2017). In addition, it can be said that clean energy consumption has reached an important level to reduce CO_2 emissions of BRICS countries as a 1% increase in clean energy usage reduces emissions by 0.262-0.303%. The positive effect of clean energy consumption on environmental quality is also found by Lopez-Menendez et al. (2014), Al-Mulali and Ozturk (2016) and Bilgili et al. (2016). On the other hand, FDI inflows and financial development seems harmful on environmental quality as FDI inflows and financial development increases CO_2 emissions. This empirical evidence for FDI inflows and financial development increases environmental degradation is consistent with Solarin et al. (2017). The negative effect of FDI inflows on environmental quality can be explained with the “pollution haven hypothesis” which argues that highly pollution intensive industries are migrated from developed countries to developing countries where environmental regulations are laxer.

[4] Given the characteristics of the data, we have estimated our models with the CS-ARDL approach and the results are quite similar. Due to space constraints, the results are available from the authors upon requst.

In case of clean energy demand function for Next-11 countries, it is found that a 1% increase in economic growth increases clean energy consumption by 0.811-1.284%. It can be interpreted as Next-11 countries recognize the importance of clean energy, allocate more resources to clean energy projects in order to meet the demand for energy to sustain industrial production and to reduce CO_2 emissions. In addition, a 1% increase in foreign direct investment increases clean energy consumption by 0.083-0.092%. This empirical finding is consistent with Doytch and Narayan (2016), Paramati et al. (2016) and Kutan et al. (2017). This reveals that foreign capital creates additional funds which contribute to the development of clean energy technologies and supports clean energy projects in observed countries. However, 1% increase in CO_2 emissions reduces clean energy use by 0.626-0.782 %. Moreover, it seems the negative coefficient of financial development is statistically insignificant. This evidence is consistent with that provided by Burakov and Freidin (2017) who found the statistical insignificant relationship between financial development and clean energy usage. This result may be sourced from two main reasons: The first is that the sectors benefiting from financial system may not consider investment in clean energy projects and clean energy technologies advantageous in terms of cost-benefit analysis. Second, financial system of mentioned countries has not yet developed enough to fund such high-cost technologies.

Table-6. Mean Group Estimation Analysis

BRICS Countries	Coefficient	*t*-statistics		Coefficient	*t*-statistics
	CCE-MG			AMG	
Dependent Variable: CEC					
GDP	1.131***	2.830		0.856***	5.090
CO	-0.862***	-5.070		-0.640***	-2.820
FDI	0.022	1.270		0.005	0.350
FD	-0.237**	-2.020		-0.139*	-1.730
Dependent Variable: CO					
GDP	0.498*	1.680		0.503***	3.470
CEC	-0.262*	-1.820		-0.303***	-3.370
FDI	0.021**	2.150		0.016*	1.810
FD	0.055*	1.750		0.022**	2.130
NEXT-11 Countries	Coefficient	*t*-statistics		Coefficient	*t*-statistics
	CCE-MG			AMG	
Dependent Variable: CEC					
GDP	1.284**	2.270		0.811*	1.940
CO	-0.782***	-2.880		-0.626**	-2.050

FDI	0.083**	2.340		0.092**	2.120
FD	-0.111	-1.190		-0.118	-0.520
Dependent Variable: CO					
GDP	0.916***	5.290		0.737***	5.810
CEC	-0.135***	-2.790		-0.106**	-2.330
FDI	-0.023**	-2.380		-0.017**	-2.420
FD	0.093*	1.930		0.110**	2.030

Note: *, ** and *** indicates statistically significance at 10, 5 and 1 percent level, respectively.

In case CO_2 emissions' function for Next-11 countries, the empirical findings show that a 1% increase in economic growth increases CO_2 emissions by 0.737-0.916%. Similarly, a 1% increase in financial development increases CO_2 emissions by 0.093-0.110 %. Similar results are documented by Zhang (2011), Boutabba (2014). On the other hand, a 1% increase in clean energy consumption reduces CO_2 emissions by 0.106-0.135 %. This empirical evidence is also consistent with Paramati et al. (2016, 2017). In addition, it is found that a 1% increase in foreign direct investment reduces CO_2 emissions by 0.017-0.023%. Similarly, Hao and Liu (2015) and Zhang and Zhou (2016) also found that FDI inflows improves environmental quality. However, our findings contradict with Tamazian et al. (2009). This evidences that negative effect of foreign direct investment and positive effect of financial development are mainly associated with clean energy demand function' findings. The increase in clean energy in meeting the energy demand of foreign capital-related productions and the inadequacy of financial system sourced funds on clean energy projects can be seen as one of the main reason for this result. This implies that domestic capital-related firms concentrate only on economic factors in their production. Contrarily, foreign capital-related companies evaluate economic and environmental factors in their production and then, pay attention to sustainable development targets.

Table-7. Mean Group Estimation Analysis

BRICS Countries	Coefficient	*t*-statistics	Coefficient	*t*-statistics
	CCE-MG		AMG	
Dependent Variable: CEC				
GDP	1.344***	2.899	0.876***	4.291
GDP^2	-0.456**	-2.583	-0.323**	-2.335
GDP^3	0.123*	1.957	0.103**	2.014
CO	-0.781***	-3.171	-0.455**	-2.908
FDI	0.121*	1.850	0.051**	2.350
FD	-0.312**	-2.224	-0.121*	-1.885
Dependent Variable: CO				
GDP	2.482**	2.585	1.566***	3.272
GDP^2	-0.876**	-2.215	-0.953**	2.087
GDP^3	0.456**	2.568	0.345**	2.078
CEC	-0.222***	-2.890	-0.313***	-3.377
FDI	0.024**	2.252	0.019*	1.995
FD	0.043*	1.858	0.027**	2.230
NEXT-11 Countries				
Dependent Variable: CEC				
GDP	1.814**	2.259	0.895**	2.409
GDP^2	-0.564**	-2.056	-0.349**	-2.534
GDP^3	0.098	1.056	0.045	1.197
CO	-0.723***	-2.908	-0.563**	-2.251
FDI	0.090**	2.444	0.099**	2.229
FD	-0.101	-2.090	-0.120	-2.027
Dependent Variable: CO				
GDP	1.817***	3.933	1.3777**	2.515
GDP^2	-0.978**	-2.548	-0.876**	-2.809
GDP^3	0.456**	2.339	0.333***	2.987
CEC	-0.122***	-2.970	-0.111**	-2.344
FDI	-0.026**	-2.400	-0.020**	-2.525
FD	0.100**	2.030	0.142**	2.232

Note: *, ** and *** indicates statistically significance at 10, 5 and 1 percent level, respectively.

The empirical results testing whether energy-environmental Kuznets curve between economic growth and energy consumption and environmental Kuznets curve between economic growth and carbon emissions are present reported in Table-A (see Appendix). We find that relationship between economic growth and energy consumption is inverted-U for BRICS and N-11 countries. This reveals that energy consumption is positively linked with economic growth and it starts to decline as real income per capita achieved threshold level. This phenomenon termed as energy-environmental Kuznets curve or energy Kuznets curve. These empirical findings are not consistent with Pablo-Romero and Jesus (2017) who reported the invalidation of energy Kuznets curve in Caribbean region. Similarly, relationship between economic growth and carbon emissions is inverted-U shaped. This relationship between economic growth and carbon emissions is termed as environmental Kuznets curve which is empirically validated for BRICS and N-11 countries. Our empirical results are similar with Jardon et al. (2017) who reported the validation of environmental Kuznets curve in Latin American and Caribbean regions.

We have inserted curbic term of real GDP per capita in energy demand and carbon emissions functions to test if relationship between economic growth and energy consumption (carbon emissions) is inverted-N or N-shaped following the recommendtaions by Moomaw and Unruh (1997) and later on, Friedl and Getzner (2003). The empirical results are reported in Table-7. İn energy demand function, we find that linear, quarratic and cubic terms of real GDP per capita are linked with energy consumption positively, negatively and positively in case of BRICS (significant) and N-11 countries (insignifiacnt). This confirms the existnce of N-shaped assoiciation between economic growth and energy consumption. This shows that rather than eocnomic growth, other factors contribute to energy demand on temporary basis. This empirical evidence is similar to Hao et al. (2016) for China and Pablo-Romero and Jesus (2017) for Caribbean region but contrary with Menegaki and Tsagarakis (2015) who found N-shaped relationship economic growth and energy consumption. Simialary, linear, quadratic and cubic terms of real GDP per capita contribute to carbon emissions positively, negatively and positively. This empirical evdence validates an N-shaped relationship between economic growth and CO_2 emissions for BRICS and N-11 countries. It is reported by Friedl and Getzner, (2003) that eoncomic growth contributes to carbon emissions permanantly but rest of factors are temporary determinants of CO_2 emissions. These empirical findings are simialr to Shahbaz et al. (2017) and Allard et al. (2018) for the USA and 74 developed and developing countries.

In order to examine the causal relationship between variables, we utilized with panel heterogeneous causality test developed by Dumitrescu and Hurlin (2012). In doing so, we used the stationary variables (first differenced form) based on the requirement of the methodology. The results are shown in Table-7. In case of BRICS countries, we find the evidence of bidirectional causal relationship between economic growth and CO_2 emissions. This finding supports the empirical results of Omri (2013), Shahbaz et al. (2013), Al-Mulali (2014) and Dogan and Turkekul (2016). The feedback effect exists between economic growth and clean energy consumption. This finding is also consistent with Tugcu et al. (2012), Apergis and Payne (2012) and Pao and Fu (2013). Foreign direct investment causes economic growth and economic growth causes foreign direct investment in Granger sense. The bidirectional causality is found between financial development (economic growth) and foreign direct investment.

Further, we confirm the existence of the unidirectional causality from clean energy consumption (foreign direct investment) to CO_2 emissions. That one-way causal relationship from clean energy consumption to CO_2 emissions is also found by Dogan and Seker (2016). Financial development causes CO_2 emissions and opposite is not true. In consistent with the finding from estimators, there is no causal relationship between FDI inflows and clean energy consumption for BRICS countries. This finding is consistent with the study of Paramati et al. (2017) that found no causal connection between FDI inflows and clean energy usage.

In case of Next-11 countries, we find is the presence of unidirectional causality running from clean energy consumption to CO_2 emissions. Foreign direct investment causes economic growth and CO_2 emissions. Financial development causes CO_2 emissions and foreign direct investment causes financial development. The feedback effect exists between economic growth and CO_2 emissions. Clean energy consumption causes economic growth and economic growth causes clean energy consumption in Granger sense i.e. feedback effect. The bidirectional causality is also noted between foreign direct investment (financial development) and economic growth.

Table-7. Heterogeneous Panel Causality Analysis

	BRICS		Next-11	
Null Hypothesis	Zbar-stat.	*p*-value	Zbar-stat.	*p*-value
GDP does not homogeneously cause CO	3.605***	0.000	3.784***	0.000
GDP does not homogeneously cause CEC	2.699***	0.006	3.394***	0.000
GDP does not homogeneously cause FDI	3.616***	0.000	1.620	0.105
GDP does not homogeneously cause FD	5.993***	0.000	11.861***	0.000
CO does not homogeneously cause GDP	2.694**	0.007	3.048***	0.002
CO does not homogeneously cause CEC	1.128	0.259	0.764	0.444
CO does not homogeneously cause FDI	0.635	0.525	1.364	0.173
CO does not homogeneously cause FD	0.690	0.489	3.870***	0.000
CEC does not homogeneously cause GDP	2.549**	0.010	2.396**	0.016
CEC does not homogeneously cause CO	2.544**	0.011	3.048***	0.002
CEC does not homogeneously cause FDI	-0.332	0.739	1.665*	0.095
CEC does not homogeneously cause FD	2.677***	0.007	0.384	0.701
FDI does not homogeneously cause GDP	3.398***	0.000	2.821***	0.004
FDI does not homogeneously cause CO	2.069**	0.038	3.260***	0.001
FDI does not homogeneously cause CEC	0.263	0.792	1.954*	0.051
FDI does not homogeneously cause FD	2.055**	0.039	-0.379	0.704
FD does not homogeneously cause GDP	3.050***	0.002	0.711	0.476
FD does not homogeneously cause CO	2.257**	0.024	2.023**	0.043
FD does not homogeneously cause CEC	-0.296	0.767	0.759	0.447
FD does not homogeneously cause FDI	1.705*	0.088	1.361	0.173

Note: *, ** and *** indicates statistically significance at 10, 5 and 1 percent level, respectively. The optimum lag length is chosen based on SIC.

Our results also give us the chance to compare the financing of clean energy projects for BRICS and Next-11 countries. Namely, the empirical findings suggest that clean energy sector is benefitted from foreign capital in Next-11 countries while foreign capital does not have a significant effect on clean energy in BRICS countries. These findings indicate that there is considerable amount of foreign direct investment inflows into clean energy projects and that foreign direct investment help Next-11 countries to increase energy efficiency through technology transfer. Moreover, the positive impact of foreign direct investment on clean energy appears to have reached the level of reducing carbon emissions in Next-11 countries. Nevertheless, clean energy projects are not adequately financed by financial sector in both groups of countries. In fact, financial development increases the share of fossil energy in total energy consumption in BRICS countries. These findings also show that financial instruments are not sufficiently directed to access clean energy technologies in both country groups.

6. Concluding Remarks and Policy Recommendations

This paper examines the relative effects of foreign direct investment and financial development on clean energy consumption and environmental degradation in BRICS and Next-11 countries. In doing so, annual data for the period of 1992-2014 is used by applying second generation panel data approaches to take into account cross-sectional dependence among countries. For empirical purpose, we construct two empirical models: clean energy demand and CO_2 emissions functions to examine effect of foreign direct investment, and financial development on clean energy consumption and carbon emissions by considering role of economic growth for BRICS and Next-11 group of countries.

In case of clean energy demand function, the empirical findings reveal that clean energy consumption is positively affected by economic growth in BRICS and Next-11 countries. Increasing foreign direct investment promotes clean energy consumption in Next-11 countries but foreign direct investment affects clean energy consumption insignificantly in BRICS countries. Clean energy consumption is negatively affected by financial development in BRICS countries but financial development affects clean energy consumption insignificantly in Next-11 countries. The empirical results of CO_2 emissions function reveal that economic growth and financial development increase CO_2 emissions in BRICS and Next-11 countries. Further, clean energy consumption and foreign direct investment reduce environmental degradation in Next-11 countries but foreign direct investment accelerates environmental degradation in BRICS countries.

The causality analysis reveals the bidirectional causal relationship between economic growth and CO_2 emissions, economic growth and clean energy consumption in BRICS countries. Moreover, we confirm the existence of the unidirectional causality runs from clean energy consumption to CO_2 emissions, from foreign direct investment and financial development to CO_2 emissions for BRICS countries. In case of Next-11 countries, the existence of the unidirectional causality from clean energy consumption to CO_2 emissions, from foreign direct investment and financial development to CO_2 emissions is confirmed. The evidence of bidirectional causal relationship between economic growth and CO_2 emissions, clean energy consumption and real economic growth in Next-11 countries

Our findings suggest that the level of clean energy consumption seems to have reached an effective level in reducing environmental degradation in BRICS and Next-11 countries. In case of Next-11 countries, it has been seen that the financing of clean energy projects has benefited considerably from foreign capital and that foreign capital has increased clean energy consumption and reduced environmental degradation in Next-11 countries. However, the contribution of financial instruments on clean energy projects is inadequate and financial development seems to accelerate environmental degradation in these countries. This finding can be explained by the fact that financial system does not have the capacity to fund such projects because of the high costs of clean energy projects. In this respect, these countries should encourage especially domestic capital to invest in clean energy projects. In case of BRICS countries, it seems clean energy projects do not supported from foreign capital significantly. In addition, financial development reduces the share of clean energy usage in total energy consumption. This means the funds supported by the development in financial system tend to focus on areas based on fossil energy consumption in BRICS countries. As a natural consequence of this situation, environmental quality is adversely affected both by financial development and by the increase in foreign direct investment. As seen, unlike Next-11 countries, BRICS countries fail not only to encourage domestic capital but also to encourage foreign capital to invest in clean energy projects. Therefore, it is imperative that BRICS countries should implement extra tax incentives to encourage both domestic and foreign capital in order to overcome the capital shortage for clean energy projects.

Overall, it can be suggested that policy makers and governments of BRICS and Next-11 countries should encourage private investments to move towards clean energy projects and should not directly finance such projects. Because, in case of the clean energy projects are directly funded by public financed instruments, the assumption that public financing will generally be lower cost than private financing may lead to the risk of crowding out private sector, even if the project is more appropriate for private financing (Hussain, 2013). Based on this reason, publicly financed financial instruments should target the risks that restrict or impede private investment instead of financing such project directly. In addition, the policy makers of these countries should implement some policies to ensure the conversion of fossil energy into clean energy, especially in production activities of the beneficiaries of financial system. Such policies and measures should be constructed as: i) providing the lowest interest credit facility to firms on condition of clean energy investments or clean energy based production activities, ii) offering tax benefits for investors in clean energy firms, iii) encouraging public-private partnership investments in clean energy projects, iv) providing incentives for activities related to this field and v) using clean energy portfolio standards to make energy suppliers obligated to purchase a part of their energy needs from clean energy sources.

Appendix A. Cross-sectional dependence test

The empirical equation of CD test is constructed as follows:

$$\mathrm{CD} = \sqrt{\left(\frac{2\mathrm{T}}{\mathrm{N}(\mathrm{N}-1)}\right)} \sum_{\mathrm{i}=1}^{\mathrm{N}-1} \sum_{\mathrm{j}=\mathrm{i}+1}^{\mathrm{N}} \left(\hat{\rho}_{\mathrm{ij}}\right) \mathrm{N}(0,1) \tag{1}$$

where *N* and *T* states respectively the cross-section dimension and the time period. In addition, $\hat{\rho}_{\mathrm{ij}}$ is the sample estimate of the pairwise correlation of the residuals.

Appendix B. Panel unit root test

The computation of the cross-sectional ADF (*CADF*) regression is as following:

$$\Delta y_{it} = a_i + \rho_i y_{it-1} + \beta_i \bar{y}_{t-1} + \sum_{j=0}^{k} \gamma_{ij} \Delta \bar{y}_{it-1} + \sum_{j=0}^{k} \delta_{ij} y_{it-1} + \varepsilon_{it} \tag{2}$$

where a_i is deterministic term, k is the lag order, $\bar{y}_t$ is the cross-sectional mean of time *t*. Following above equation, *t*-statistics are obtained with the computation of individual *ADF* statistics. As well as allowing the cross-sectional dependency, to give robust results in case of small sample size and validity for panels where *N* and *T* are of the same orders of magnitudes are the other main advantages of the CIPS unit root test (Pesaran, 2007). Furthermore, *CIPS* is retrieved from the average of *CADF* statistic for each *i* as follows:

$$CIPS = \left(\frac{1}{N}\right) \sum_{i=1}^{N} t_i \,(N, T) \tag{3}$$

The critical values of *CIPS* for different deterministic terms are given by Pesaran (2007).

Appendix C. Panel cointegration test

The test can be performed by testing the significance of error correction term in the constrained panel error correction model. The main error correction model of the test can be written as follows:

$$\Delta Y_{it} = \delta_i' d_t + a_i (Y_{i,t-1} - \lambda_i' X_{i,t-1}) + \sum_{j=1}^{p_i} a_{ij} \Delta Y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta X_{i,t-1} + \mu_{it} \tag{4}$$

where d_t refers to the deterministic terms; $d_t = 0$ (no deterministic term), $d_t = 1$ (with constant term) and $d_t = (1, t)'$ (with constant term and trend). Moreover, a_i determines the speed at which the system returns to the equilibrium, after an unpredictable shock. The variable Y_{it} is dependent variable and $X_{i,t}$ is the vector of explanatory variables. The mean group statistics (G_t and G_α) can be computed with three steps. In first step, for each cross-section equation-6 is estimated with least squares to obtain γ_{ij} and μ_{it}. Second, $\hat{u}_{it} = \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta X_{i,t-1} + \mu_{it}$ is calculated. After this, using with $\widehat{\omega}_{ui}$ and $\widehat{\omega}_{Ei}$ which are the usual Newey-West (1994) long-run variance estimators of $\hat{u}_{it}$ and ΔY_{it}, the formulation of $\hat{a}_i(1) = \widehat{\omega}_{ui}/\widehat{\omega}_{Ei}$ is computed. Finally, the mean group statistics are constructed as follows:

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{a}_i}{SE(\hat{a}_i)}, \; G_a = \frac{1}{N} \sum_{i=1}^{N} \frac{T \hat{a}_i}{\hat{a}_i(1)}, \tag{5}$$

where SE is standard error. In order to compute the panel statistics of P_t and P_a, first the projection errors $\Delta \tilde{Y}_{it}$ and $\tilde{Y}_{i,t-1}$ are computed as follows:

$$\Delta \tilde{Y}_{it} = \Delta Y_{it} - \delta_i' d_t - a_i \left(Y_{i,t-1} - \lambda_i' X_{i,t-1} \right) - \sum_{j=1}^{p_i} a_{ij} \Delta Y_{i,t-j} - \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta X_{i,t-1} \tag{6}$$

$$\tilde{Y}_{i,t-1} = Y_{i,t-1} - \delta_i' d_t - a_i \left(Y_{i,t-1} - \lambda_i' X_{i,t-1} \right) - \sum_{j=1}^{p_i} a_{ij} \Delta Y_{i,t-j} - \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta X_{i,t-1} \tag{7}$$

In the next step, the common error-correction parameter and its standard error are obtained as follows:

$$\hat{a} = \left(\sum_{i=1}^{N} \sum_{t=2}^{T} \hat{Y}_{i,t-1}^2 \right) \sum_{i=1}^{N} \sum_{t=2}^{T} \frac{1}{\hat{a}_i(1)} \tilde{Y}_{i,t-1} \Delta \tilde{Y}_{it}, \tag{8}$$

$$SE(\hat{a}) = \left(\left(\hat{S}_N^2 \right) \sum_{i=1}^{N} \sum_{t=2}^{T} \frac{1}{\hat{a}_i(1)} \tilde{Y}_{i,t-1}^2 \right)^{\frac{-1}{2}}, \tag{9}$$

where $\hat{S}_N^2 = 1/N \sum_{i=1}^{N} \hat{\sigma}_i / \hat{a}_i$, and the $\hat{\sigma}_i$ is the standard error of the regression of quation-6. Finally, the third statistic P_t is obtained with $P_t = \hat{a}/SE(\hat{a})$ and the fourth statistic P_α is computed as $P_a = T\hat{a}$.

Table-A. Mean Group Estimation Analysis

BRICS Countries	Coefficient	*t*-statistics	Coefficient	*t*-statistics
	CCE-MG		AMG	
Dependent Variable: CEC				
GDP	1.131***	2.830	0.856***	5.090
GDP^2	-0.9867**	2.567	-0.4567***	-3.253
CO	-0.760***	-5.175	-0.635**	-2.521
FDI	0.020	1.473	0.010	1.153
FD	-0.246**	-2.222	-0.128*	-1.789
Dependent Variable: CO				
GDP	0.469*	1.785	0.512***	3.070
GDP^2	-0.098**	-2.345	-0.101**	-2.556
CEC	-0.254*	-1.901	-0.227***	-3.175
FDI	0.018**	2.252	0.013*	1.901
FD	0.045**	2.551	0.019**	2.232
NEXT-11 Countries	Coefficient	*t*-statistics	Coefficient	*t*-statistics
	CCE-MG		AMG	
Dependent Variable: CEC				
GDP	1.134**	2.751	0.793**	2.410
GDP^2	-0.089**	-2.657	0.045**	-2.543
CO	-0.870***	-2.555	-0.556**	-2.522
FDI	0.101**	2.142	0.102**	2.211
FD	-0.091	-1.233	-0.115	-0.4507
Dependent Variable: CO				
GDP	0.101**	2.259	0.817***	3.478
GDP^2	-0.556**	-2.555	0.345***	3.091
CEC	-0.127***	-2.454	-0.110**	-2.444
FDI	-0.018**	-2.484	-0.020**	-2.033
FD	0.087**	2.335	0.101**	2.439

Note: *, ** and *** indicates statistically significance at 10, 5 and 1 percent level, respectively.

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