Considering the effect of biomass energy consumption on economic growth:fresh evidence from BRICS region

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Considering the Effect of Biomass Energy Consumption on Economic Growth: Fresh Evidence from BRICS Region

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Abstract: This paper investigates the relationship between biomass energy consumption and economic growth by incorporating capital and trade openness in production function for the case of BRICS countries. In doing so, unit root and cointegration tests have been used in order to examine unit root properties and long run relationship between the series for the period of 1991Q1-2015Q4. The results confirm the presence of long-run equilibrium relationship between the variables. Moreover, biomass energy consumption stimulates economic growth. Capital increments economic growth and trade openness spurs economic growth. The feedback effect exists between biomass energy consumption and economic growth. Trade openness Granger causes economic growth, capital and biomass energy consumption. The policy to adopt biomass as the primary source of renewable energy helps BRICS countries to achieve sustainable development goal in both short-run and long-run. However, the key innovative point of this study is to establish the sign for Granger causality test.

Keywords: Biomass energy, Growth, Capital, Trade

1. Introduction

The oil crisis of 1970's led economies to transfer their dependence from fossil fuel energy consumption to renewable energy consumption. The adoption of renewable energy sources benefits industrialized and emerging economies in two ways (Ozturk [56]). First, it has less price volatility risk compared to non-renewables energy mix i.e. coal, oil and gas (IEA [87]). Second, it is less pollution intensive (IEA [87]). Hence, the rising concerns about energy security and environmental degradation in newly industrialized and transition economies such as BRICS (Brazil, Russia, India, China and South Africa) has increased renewable energy demand and alternate energy resources (IEA [88]). The year 2009 is embarked with the highest energy generation in BRICS countries and it was almost double than in 2000 (IEA [88]). The total production accounted 6,335 TWH that makes 31.6% of world's total. Considering the rapid growth in energy demand, the share of renewable energy accounted for 21.5% of total energy consumption. Historically, hydro was the major renewable resource in BRICS but; over the last two decades, biomass has been replacing the most of renewable mix (IEA [87]). Brazil, China and India have introduced various financial incentives for grids generating electricity through renewable and Brazil is also leading alternative electricity capacity in terms of biomass energy (IEA [87]). However, during the same period, Russia and South Africa remained stagnant in the share of renewable energy mix but, the proportion of biomass energy generation has increased (IEA [87]). There are also regulatory and institutional developments in India, China and Brazil to promote the biomass energy projects. For Example; Brazil has initiated the program of Incentives and Alternative Electricity Sources (PROFINA) during 2002-2003 and similarly, Chinese central government introduced fix feed-in tariffs strategy to enhance biomass energy production with reduced investment cost across the country (IEA [88]). In addition, 12^{th} five years plan (2011-2015) aims to install additional biomass projects of 5 GW capacity. Moreover, biomass energy is common and can be produced easily[1]. It fulfills the variety of household, commercial and industrial energy needs, including cooking, space heating, electricity generation, industrial processes, etc. The International Energy Agency [88] reports that biomass energy consumption accounted 36.8% of total renewable energy consumption in BRICS countries. If the modern biomass energy techniques are taken in practice then countries have potential to increase

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[1] http://www.eria.org/publications/research_project_reports/sustainability-assessment-of-biomass-energy-utilisation-in-selected-east-asian-countries.html

such ratio to 61% by 2030. Various sources of biomass energy in BRICS countries are divided into three main categories; wood, non-wood and waste. The wood source is found in forests and include – trees, plants, leaves, bush trees; non-wood source is mainly comprised of – husk, saw dust, plant stems, biogases, hemp, nutshell, grass and other crop residual garbage; and the waste includes - food waste, sewage, animal waste (Payne [62]; Bildirici and Özaksoy [15]; Bildirici [13]).

BRICS economies have attended marvelous economic growth over the past three decades; today, these economies account for 21% of world GDP, 40% of world energy consumption, substantial proportion of global CO_2 emissions and also hold more than 40% of world population. However, these economies still mainly rely on conventional energy sources which in one way increase economic growth and on other way reduce environmental quality. Hence, BRICS countries are encountering dual nature of socio-economic challenges – energy security and environmental degradation (Asif and Muneer [82]; Vivoda [83]; Ahmed and long [4]; Ahmed [3] Ahmed et al. [5]). The possible way-out in such situation is to opt renewable and alternate energy sources as a key driver of future household, commercial and industrial engines in BRICS region. Biomass energy is readily available in the region and production can be started quickly. That is why; biomass energy has become the most prioritized area in the recent BRICS's sustainable development policy agenda.

In 2009, BRICS region accounted 31.6% of total global electricity consumption. In addition, the demand for electricity in BRICS accounted 65% of global increase. During 2000-2009, the demand for electricity in BRICS grew at an average of 7.2%. In China alone, the electricity sector grew at an average of 11.6% per anum during same period. Given the increasing trend, the share of renewables has also increased in total energy mix (EIA, [89]). China, India and Brazil consistently developed the renewable energy sector but South Africa and Russia remained conservative for renewable market. Brazil possesses strong increase in biomass energy generation. As a policy tool, all BRICS countries except Russia provide financial incentives to grids connected to renewables. The biomass energy accounts 1% of total energy consumption in Russia. Such policy support has created substantial market growth for renewables in BRICS while considering the potential for biomass energy in BRICS countries, it is projected that Russia dominates the potential for bio-energy with 48% of total renewables. However, Petrie and Macqueen [89] consider biomass as the largest source of renewable energy source in South Africa. Furthermore, South Africa did attempt to set up biomass energy plants (i.e. the Howick wood pellet plant, and the Tstsikamma biomass plant) but failed due to local market conditions. In a recent attempt, the Ministry of Energy of South Africa has approved another Biomass energy plant of 17 MW capacity as part of renewable energy projects. Moreover, South Africa approved the use of industrial biofuel in 2007 and exempts 100% fuel levy to encourage the ethanol. The establishment of BRICS development bank with USD 100 billion capital envisages BRICS' primary focus on sustainable development projects.

Nevertheless, existing literature depicts mix opinion on the relationship between economic growth and renewable energy sources. Traditionally, there are two aspects of energy-growth nexus – direct and/or indirect. The direct effect is analyzed through gross domestic output Bildirici [13] and indirect effect is checked in terms of greenhouse emissions (Payne [62]). Largely, the emphasis on adoption of renewable energy sources is an outcome of environmental externality and climate change (Tahvonen [76]). Renewable energy sources yet to develop technologically than fossil fuel, to be more competitive in terms of energy efficiency (Koroneos et al. [41]). Therefore, the direct effect of renewable energy consumption on economic growth is subject to the modernization of technique under practice for the utilization of renewable energy sources in an economy. Apergis et al. [10] studied the data of OECD countries and found the bidirectional causality between renewable energy consumption and economic growth. Soytas and Sari [73] suggested that the impact of energy consumption on economic growth depends upon the development stages of an economy. Tahvonen and Salo [76] studied the transition between renewable and non-renewable energy sources and stated that historically, non-renewable energy may evolve from renewable and now again it is moving towards renewable energy mix. This phenomenon is justified by the price mechanism that helps to gain equilibrium and as a result both energy sources exist simultaneously (Tahvonen and Salo [76]; Menanteau et al. [53]). Developing economies require focusing on renewable energy sources to achieve sustainable development goal, but it may come with some economic cost in short-run Pearce et al. [63]. In this line, Goldemberg and Coelho [27] also distinguish between 'modern biomass' and 'traditional biomass' in terms of sustainability. Furthermore, the study defines that the traditional biomass may be more pollution intensive than fossil fuel; therefore, it requires careful statistical information while establishing the link between biomass and renewable energy sources.

In light of the above discussion, this study is an attempt to visit the impact of biomass energy consumption on economic growth of BRICS economies. This study incorporates capital and trade openness as the potential explanatory variables to remove specification bias in the production function. There are some recent studies investigating the relationship between energy consumption and economic. For example, Cowman et al. [24] examined the relationship between electricity consumption, economic growth and CO_2 emissions and they found that the relationship between electricity consumption and economic growth is independent in Brazil, India and China. Further, Wu et al. [79] modeled the CO_2 emissions function and noted that urban population leads energy demand which in resulting, increases CO_2 emissions in BRICS region. To the best of our knowledge, we did not find studies that focus on the impact of biomass energy on economic growth in BRICS region. This study contributes to the existing literature by filling the widening gap on the direct link of biomass energy consumption-growth nexus in BRICS region. An additional justification of undertaking first time empirical attempt for BRICS region is due to the fact that BRICS economies are at energy as well as environmental security cross-roads, indicating that they are under internal and external pressure of maintaining high pace of continued economic growth with reduced pollution intensity, respectively. The key findings of this study reveal that biomass energy consumption plays a role key driver of economic growth via enhancing domestic output. Trade openness increases economic growth. Capital stimulates domestic production and hence economic growth. Biomass energy consumption causes economic growth and economic growth also causes biomass energy consumption in Granger sense. The unidirectional causality is found running from trade openness to biomass energy consumption. Taken these findings together, we believe that our study offers vital policy implications for BRICS economies in order to have sustainable energy-driven higher economic growth and development.

The remainder of this study is structured as follows. Section-2 discusses the review of relevant literature. Section-3 presents data, empirical model construction and estimation strategy. Section-4 analyses interpretation of results. Finally, Section-5 summarizes concluding remarks and policy recommendations.

2. Review of relevant literature

Although the literature on energy-growth nexus is very vast, yet it seems insufficient due to rapid technological advancement and changing dimension of economic development. The last decade witnessed with proliferating economic growth and development at global scale. In order to fuel such a massive global economic transformation, energy scientists did not only explore the new and alternative means of energy resources, but also invented efficient ways to utilize such resources (Jaffe and Stavins, [34]; Sagar and Van der Zwaan [67]; Herring and Roy [30]). However, the world soon realizes that such tremendous growth also has its cost in the shape of environmental degradation (Stern [75], Ahmed and Long [4], Shahbaz et al. [84]). Hence, once again the topic of energy-growth nexus is revitalized when growth and energy scientists have turned their emphasis on sustainable development and alternative energy resources, respectively.

Nonetheless, the study of Kraft and Kraft [42] is referred as the first and the most comprehensive effort on energy-growth relationship. Their study explores the causal relationship between energy consumption and economic growth for the USA. They found the presence of unidirectional causality running from economic growth to energy consumption. Viewing the important policy implications of Kraft and Kraft [42], Akarca et al. [6] explored the same variables using Sim's technique developed by Sims [71] for the USA. However, their study found no causal links between the variables in case of USA. Abosedra et al. [1] conducted the similar study, but applied both cointegration and Granger [28] causality approaches to investigate the both long-run association and causal link between the variables. Their results confirmed the long-run association between the variables and found the unidirectional causality running from economic growth to energy consumption. While comparing the empirical findings of above mentioned studies, it is clear that they reported contradictory results due to change in data set and empirical techniques. The similar evidence is noticed in the studies of Hwang and Gum [32] and Cheng and Lai [21], who investigated energy-growth nexus in case of Taiwan using cointegration with Error-Correction Model and Granger causality test. The former study found no causal links; however, the later found the unidirectional causality running from GDP to energy consumption. The similar evidences are recoded, i.e. for Turkey Soytas et al. [74] and

Jobert and Kranfil, [35]; for Malaysia Masih [51] and Ang [7]; for Japan Soytas and Sari, [73] and Lee, [45]; for Russia Zhang, [91] and for South Africa Menyah and Wolde-Rufael [92]. In summary; the difference in short-run, long-run and causality results is based on the change in data span and the type of energy proxy used (i.e. electricity, nuclear, crude oil, natural gas, coal, or overall fossil fuel). The results also vary significantly, if the study is on a panel data or a country specific (Ozturk [56]). Therefore, the broad literature suggests that it is imperative to take the particular source of energy to investigate its effect on economic growth. On the other side, whether it should be a country specific, or if it is panel study, the cross-section countries should be with identical economic structure/transition.

Narayan and Smyth [54] particularly explored the relationship between electricity consumption and exports by arguing that electricity is an important input in the production function. Their empirical findings show the existence of significant feedback effect exports and electricity consumption for the panel of six Middle Eastern countries. However, Sadorsky [65] investigated the link between energy consumption and trade (exports + imports) for eight Middle Eastern countries. He found the short-run Granger causality running from exports to energy consumption and the feedback effect between imports and energy consumption. Lean and Smyth [43] and Lean and Smyth [44] also noticed the bidirectional relationship between electricity generation and exports for Malaysia. Hence; Sadorsky [66], Shahbaz et al. [68] and Shahbaz et al. [69] suggested that energy consumption is an appropriate proxy that examines impartial effect, because trade includes several types of energy usage from production to final export/import destination. Trade openness is an important intermediating factor in energy-growth nexus for export-led industrializing economies Shahbaz et al. [68].

Since the growing trend in renewables and other alternative energy sources is observed in industrialized and industrializing economies, energy-growth nexus has included various renewables as the proxy of energy consumption to check its growth implications. The study of Trainer [77] analyzed the growth consequence of solar source of renewable energy consumption. The empirical results found that renewables have the capacity to replace the conventional energy sources without compromising economic development. Byrne et al. [17] researched the energy related policy change in China to attend the balance between economic growth and environmental protection. They studied solar energy source and found its positive correlation with economic growth in China. Painuly [58] referred wind energy source and suggested that it is a very convenient source of renewable which lights in the rural and remote areas and in many developed countries; wind energy is still a key source and adds economic growth, i.e. Netherlands. Berndes et al. [12] presented a survey on the contribution of biomass energy source in future energy use. Their study argued that biomass energy is the most convenient source of renewable, commonly available and does not require an initial cost. Hoogwijk et al. [31] surveyed the 17 cities and concluded that it is not sure that how large will the contribution of biomass energy in future, but its proper managements plays a decisive role for it.

Nevertheless, the existing literature on the relationship between biomass energy consumption and economic growth has used both panel and individual country data sets. The studies with panel data include both homogenous and heterogeneous panels and their empirical findings not only vary with the difference in data set but also the methodology applied within same data set (Ozturk and Bilgili [57]). For example; Shahbaz et al. [70], Ocal and Aslan [55], Erdal et al. [25], Paul and Bhattacharya [60], Chang [20], and Masih [51] utilized the number of causality tests and mostly found inconclusive results. Furthermore, the pertinent survey studies of Löschel [49], Carrasco et al. [19], and Payne [61] emphasize to conduct more investigations in order to establish stronger connection between data and theory.

However, considering biomass as renewable, existing literature on energy-growth nexus is developing. For example, Payne [62] investigated the biomass energy-growth nexus for the United States by applying the Toda-Yamamoto [85] causality test on the data from 1949-2007 using a multivariate framework where capital and labor are used as additional determinants of economic growth. The empirical findings indicated that the unidirectional causality exists running from biomass energy consumption to economic growth supporting the growth-hypothesis. By analyzing the possible presence of a long run and causality relationship between biomass energy consumption and economic growth for seven countries for the period of 1980-2009, Bildirici [13] found that there is a long run relationship between both variables in Bolivia, Brazil, Chile, Colombia and Guatemala. Furthermore, the results also detected the unidirectional causality running from biomass energy consumption to economic growth in Bolivia, Brazil and

Chile, and causality running from economic growth to biomass energy consumption in Colombia.

Bildirici and Özaksoy [15] analyzed the linkage between biomass energy consumption and economic growth for Austria, Finland, France, Hungary, Poland, Portugal, Romania, Spain, Sweden and Turkey using the bivariate model over the period of 1960-2010. They confirmed the existence of long-run relationship between biomass energy consumption and economic growth. Their empirical evidence revealed the unidirectional causality running from biomass energy consumption to economic growth in Hungary and Poland, from economic growth to biomass energy consumption in Austria and Turkey, and the feedback effect exists between biomass energy consumption and economic growth for Finland, France, Portugal, Spain and Sweden in the short run. Moreover, they noted that the bidirectional causality is present between biomass energy consumption and economic growth for long span of time.

Bildirici [13] investigated the cointegration and causality linkages between biomass energy consumption and economic growth for 10 developing and emerging countries by applying the bounds testing and VECM Granger causality approaches for the years of 1980-2009 using the bivariate model. The empirical results reported the presence of long-run dynamic relationship biomass energy consumption and economic growth in Argentina, Bolivia, Cuba, Costa Rica, El Salvador, Jamaica, Nicaragua, Panama and Peru. Additionally, biomass energy consumption Granger causes economic growth found in Argentina, Bolivia, Cuba, Costa Rica, Jamaica, Nicaragua, Panama and Peru, and economic growth Granger causes biomass energy consumption in El Salvador.

Bildirici [14] also examined the possible existence of a long run and Granger causality relationship between biomass energy consumption and economic growth for transition countries using the annual data from 1990-2011 employing the bivariate model. The author found the presence of cointegration and long run relationship between the variables using the Johansen and Fisher cointegration tests as well as Pedroni panel cointegration test and the feedback effect exists between biomass energy consumption and economic growth confirmed by the Granger causality test in a vector error correction mechanism. Additionally, results show that biomass energy consumption positively impacts economic growth corroborated by applying the Fully Modified Ordinary Least Squares method. Ozturk and Bilgili [57] examined the long run linkages between biomass energy consumption and economic growth using multivariate framework by including openness and population as additional variables. Their results from the homogeneous Ordinary Least Squares (OLS), homogenous adjusted OLS, homogenous Dynamic Ordinary Least Squares (DOLS) and heterogeneous DOLS exhibit that the impact of biomass energy consumption, trade openness and population on economic growth is positive and statistically significant. Bilgili and Ozturk [94] investigated the relationship between biomass energy consumption and economic growth in G-7 countries by applying the heterogeneous OLS and dynamic OLS approaches. Their empirical analysis noted that biomass energy consumption contributes to economic growth like other factors of production such as capital and labor. Recently, Aslan [95] investigated the association between biomass energy consumption and economic growth for the US economy by applying the bounds testing and VECM Granger causality approaches. The results showed that biomass energy consumption stimulates economic growth as well as causes economic growth.

From the above discussion of the literature survey, we notice the existence of several studies in exploring the linkage between biomass energy consumption and economic growth for developed and developing economies. From a panel perspective, we also observe that till date no single study has been established in BRICS region of empirically understanding the impact of biomass energy consumption on economic growth of BRICS region by incorporating capital use and trade openness in the production function. In this context, our study is considered as a significant contribution to the existing literature because of the fact that we exercise the empirical investigation for BRICS region in a panel framework. An application of panel framework appears to be beneficial for policy implications of sustainable development in emerging economies like BRICS because it derives potential information from studying both cross section and time series data.

3. The Data, Empirical Model Construction and Estimation Strategy

3.1 Data and Variables

This study uses quarterly time series data over the period of 1991Q1-2015Q4 for 5 BRICS countries. In order to empirically investigate the impact of biomass energy consumption on economic growth, we opt set of four variables, i.e. economic growth, biomass energy consumption, gross fixed capital formation measure for capital and trade openness. Economic growth (Y_t) is taken as the dependent variable and biomass energy consumption (E_t), capital use (K_t) and trade openness (O_t) are considered as independent variables in the production estimation model. The annual data available from 1991-2015 on real GDP, gross fixed capital formation and trade in current U.S. dollars are collected from world development indicators (CD-ROM, 2016). The annual data on biomass energy consumption is also collected from materialflows.net. The series of total population is used to convert the variables into per capita units[2]. We further transformed all variables annual data from 1991-2013 into quarter frequency following the studies of Romero, [64], McDermott and McMenamin [52], and Shahbaz et al. [69]. Using quarterly frequency data in the empirical analysis has two advantages: first, it increases the degrees of freedom, and second, it increases the statistical power of estimation. This leads the estimated panel model could be robust.

3.2 Empirical Model Construction

The objective of this study is to examine the linkages between biomass energy consumption and economic growth using production function. We have incorporated capital and trade openness as additional determinants biomass energy and hence economic growth[3].
Therefore, the log-linear form of the model can be written as follows:

$$Y_{it} = f(E_{it}, K_{it}, O_{it}) \tag{1}$$

The equation-1 is transformed into log-linear specification by transforming all the variables into logarithmic. Shahbaz et al. [70] and Ahmed et al. [5] argue that the log-linear specification provides consistent and reliable results. The series are also converted into per capita units by dividing the variables on total population series. The equation-1 is further modeled for panel analysis as following:

$$\ln Y_{it} = \beta_1 + \beta_2 \ln E_{it} + \beta_3 \ln K_{it} + \beta_4 \ln O_{it} + \mu_i \tag{2}$$

where, subscript 'i' stands for the number of cross-section of (i = 1,...,5) and t is time period. ln is for natural-log, Y_{it} shows economic growth and measures by real GDP per capita, K_{it} is for capitalization proxies by real capita use per capita, O_{it} is for trade openness and measured by real trade (export + imports) per capita. μ is normally distributed error term.

3.3 **Estimation Strategy**

3.3.1 Panel unit root

[2] The data are obtained from world development indicators (CD-ROM, 2015).
[3] This inclusion of capital and trade openness in production function also handles the issue of biasedness.

Following the empirical methodology of Asafu-Adjaye [11], Soytas and Sari [73], Lee and Chang [46], Zhang and Cheng [81], Apergis et al. [9] and Bildirici [13, 14]; we employ the dynamic panel data approach to examine the long-run association between biomass energy consumption and economic growth by endogenizing capital use and trade openness in the production function in BRICS region. However, the panel data approach necessitates that each underlying series must be stationary[4] in order to avoid the spurious regression Nelson and Ploser [86]. Therefore, this study uses several unit root tests to examine the unit root properties of the variables. These panel unit root tests are Levin et al. [47] (LLC) test, Breitung [16] (Breitung) test, Im et al. [33]) (IPS) test, Maddala and Wu [50] (Fisher-ADF) test, and Choi [22] (Fisher-PP) test[5].

3.3.2 Panel cointegration

In recent years, time series econometrics literature suggests several approaches to examine panel cointegration. For example, Pedroni [59] proposes seven residual-based cointegration tests that allow heterogeneity and distinguish itself from Kao [40]. However, Maddala and Wu [50] propose to apply Johansen [37] approach with Fisher effect called Fisher-type panel cointegration test. This test uses maximum likelihood procedure which possesses significantly large and finite sample size and provides robust empirical evidence than Engle and Granger [78] panel cointegration method. Therefore, we preferred Johansen panel cointegration approach to investigate whether biomass energy consumption and economic growth are cointegrated or not. This procedure is composed of two tests statistics: Trace test and Maximum eigen value test. Each test separately determines the number of cointegrating vectors. If the number of cointegrating vectors reported appears to be different, then the results of Maximum eigen value test are preferred.

3.3.3 Panel Causality Test

In order to examine the direction of casual relationships between the variables, numerous causality tests are used but providing conflicting empirical results. Granger [28] suggested to apply the vector-error-correction-model (VECM) once variables are cointegrated and having unique order of integration between the level series. This test examines the direction of causality between the variables not only in the long-run but also in the short-run. The empirical model for panel VECM framework is specified as following:

$$\Delta \ln Y_{it} = \theta_{1i} + \sum_{j=1}^{m} \theta_{11ij} \Delta \ln Y_{i,t-j} + \sum_{j=1}^{m} \theta_{12ij} \Delta \ln E_{i,t-j} + \sum_{j=1}^{m} \theta_{14ij} \Delta \ln K_{i,t-j} + \sum_{j=1}^{m} \theta_{15ij} \Delta \ln O_{i,t-j} + \lambda_{1i} e_{i,t-1} + \varepsilon_{it} \quad (3)$$

In equation-3, λ_{1i} adjusts the coefficients that weight the cointegrating vectors, e_{it-1} and θ_{12ij} represent the short-run coefficients that weigh the lagged growth trend in all the dependent variables in the model. Each variable constitutes the similar equation and the number of equations will be equal to the number of variables. The selection of lag length is a critical part and we select Schwarz Information Criterion (SIC = 2) while estimating the direction of causality between the variables. The short-run causality is checked using the F-statistic based on

[4]The test of cointegration is applied when the series are integrated at the same order and series is said to be stationary.

[5] We have not provided theoretical and mathematical explanation but are available in existing applied economics.

Wald test where "null-hypotheses" of model is specified as $H_0 : \theta_{12ij} = 0$. Similarly, the long-run causality test between the variables is also examined and "null-hypothesis" is $H_0 : \lambda_{1i} = 0$. It is imperative to conduct the joint short-run and long-run causality test to evaluate whether both tests are jointly significant. Further, the joint causality test indicates whether variables bear the burden of short-run adjustment to re-establish long-run equilibrium considering the shocks in the system. To test Granger causality, it is also desirable to check whether the two sources of causations are jointly significant. This can be done by testing the joint hypothesis of short-run and long-run causality.

4. Results and their interpretations

Table-1 reports descriptive statistics and pair-wise correlation between the variables. More deviations have been found in trade openness compared to capital use in BRICS region. Less deviation is noted in economic growth compared to biomass energy consumption. The correlation analysis exposes that biomass energy consumption is positively correlated with economic growth. The positive association exists between capital use (trade openness) and economic growth. Biomass energy consumption correlates positively with capital and trade openness. The correlation between capital use and trade openness is found to be positive.

Table-1: Pair-wise Correlations

Variables	Y_t	E_t	K_t	O_t
Mean	0.0347	0.0041	0.0415	0.0624
Median	0.0292	0.0086	0.0561	0.0622
Maximum	0.1276	0.1675	0.2807	0.2537
Minimum	-0.0682	-0.2404	-0.2180	-0.2164
Std. Dev.	0.0416	0.0523	0.0859	0.0874
Skewness	0.0455	-1.2943	-0.3830	-0.2167
Kurtosis	2.6898	8.4455	3.3710	3.1543
Y_t	1.0000			
E_t	0.2604	1.0000		
K_t	0.7350	0.1808	1.0000	
O_t	0.5905	0.1441	0.6049	1.0000

In order to test the integrating order of biomass energy consumption, economic growth, capital use and trade openness for BRICS region, we have applied LLC, Breitung, IPS, Fisher-ADF and Fisher-PP unit root tests developed by Levin et al. [47]; Breitung [16]; Im et al. [33]; Maddala and Wu [50], and Choi [22], respectively. The results reported in Table-2 show that biomass energy consumption, economic growth, capital use and trade openness contain unit root problem in levels series with intercept and trend. After 1st differencing, all the variables are found to be stationary. This indicates that biomass energy consumption, economic growth, capital use and trade openness have unique order of integration. We conclude that results are robust and consistent.

Table-2: Unit Root Tests Analysis

Variables	Y_t		E_t		K_t		O_t	
Tests	Level	1st diff.	Level	1st diff.	Level	1st diff.	Level	1st diff.
Levine, Lin & Chu(LLC)	-1.1215	-4.1779*	0.6985	-6.0109*	-1.6029	-2.5191*	-1.6018	-4.6081*
Breitung	0.9140	-4.1918*	0.4127	-6.8601*	0.2040	-3.2018*	0.3098	-4.2989*
Im, Pesaran, Shin (IPS)	-0.1909	-4.1215*	-1.8912	-7.9828*	-0.9067	-3.6026*	0.6700	-5.0009*
Fisher-ADF	10.1051	30.3316*	20.1513	62.4001*	12.2280	26.8906*	11.4502	37.5400*
Fisher-PP	4.7815	44.5647*	18.9000	33.7133*	6.2021	39.7163*	15.2607	48.0514*

Note: * represents significance at 1% level.

The unique order of integration of the variables leads us to examine long-run cointegration by applying Johansen panel cointegration. The results are shown in Table-3. We find that null hypothesis of no cointegration is rejected as trace statistics exceed critical value at 1% level of significance. This shows the presence of two cointegrating vectors in the estimated model. The similar outcome is found from maximum-eigen test. This leads to conclude that cointegration is present amid biomass energy consumption, economic growth, capital use and trade openness as two cointegrating vectors are confirmed not only by trace test as well as maximum-eigen value test. This also shows the robustness of empirical findings. Finally, this leads us to conclude that there is a cointegration relationship between biomass energy consumption, economic growth, capital use, and trade openness in BRICS countries for the quarterly period of 1991-2015.

Table-3: Johansen Cointegration Test

Hypothesis	Trace Test	Prob. value	Max-eigen Test	Prob. value
$R = 0$	43.62*	0.0000	28.85*	0.0003
$R \leq 1$	20.78*	0.0078	20.14*	0.0098
$R \leq 2$	8.727	0.3658	6.425	0.5998
$R \leq 3$	11.56	0.1721	11.56	0.1721

Note: * and ** represent significant at 1% and 5% levels, respectively.

The results reported in Table-4 reveal that biomass energy consumption spurs economic growth significantly at 1% level of significance. A 1 percent increase in biomass energy consumption leads economic growth by 0.601 percent keeping other things same in the long run production function. This long run finding is consistent with the recent studies of Payne [62] for US economy, Bildirici [13] for Bolivia, Brazil, Chile, Colombia, and Guatemala, Bildirici and Özaksoy [15] for European countries, Bildirici [14] for transition economies and, Ozturk and Bilgili [57] for Sub-Saharan African countries. Economic growth is positively linked with capital use and it is also statistically significant at 1% level. All else is same, a 1 percent increase in capital use increases economic growth by 0.178 percent in the long run. This empirical evidence is similar with the recent finding of Payne [62] for US economy. Trade openness affects economic growth positively and significantly at 1% level. Keeping other things constant, a 1 percent increase in trade openness enhances domestic output by 0.481 percent in the long run. This empirical result is same with Ozturk and Bilgili [57] for Sub-Saharan African countries.

Table-4: Testing Fixed Effect Models

Variable	Long Run	Short Run

	Coefficient	Prob. value	Coefficient	Prob. value
Constant	2.5401*	0.0000	0.0190*	0.0000
E_t	0.6022*	0.0000	0.0744***	0.0450
K_t	0.1873*	0.0093	0.2309*	0.0000
O_t	0.4824*	0.0000	0.1103*	0.0006
ECM_{t-1}	….	….	-0.0700*	0.0000
R-squared	0.9700		0.7066	
F-Statistic	12.4086*		7.3000*	

Note: * and ** represent significance levels at 1% and 10%.

Table-4 also reports the results of short-run analysis and we find that biomass energy consumption leads economic growth at 10% level of significance. The relationship between capital use and economic growth is positive and significant at 1% level. Trade openness stimulates economic growth significantly. The coefficient of ECM_{t-1} is negative and statistically significant at 1% level, indicating that the estimated model is robust. This corroborates the established cointegration relationship between biomass energy consumption and economic growth including capital use and trade openness. This reveals that speed of adjustment to move from short run towards long run is 7% for production function in case of BRICS region[6].

The direction of causal relationship between biomass energy consumption, capital use, trade openness and economic growth is investigated by applying the panel VECM Granger causality and results are reported in Table-5. In long run, we find the bidirectional causal relationship between biomass energy consumption and economic growth i.e. biomass energy consumption causes economic growth and in resulting, economic growth causes biomass energy consumption in Granger sense. This finding is consistent with the recent findings of Bildirici and Özaksoy [15], and Bildirici [13] who noted the feedback effect existing between biomass energy consumption and economic growth but found to be contradictory with the result of Payne [62] who reported that economic growth is outcome of biomass energy consumption. Moreover, the feedback effect exists between capital use and biomass energy consumption. The relationship between capital use and economic growth is bidirectional. The unidirectional causality is noted running from trade openness to economic growth, capital use and biomass energy consumption. Contrarily, Ozturk and Bilgili [57] noted the neutral effect exists between trade openness and biomass energy consumption.

[6] It will take almost 14 years for BRICS countries to reach long run equilibrium path.

Table-5: Panel Granger Causality Analysis

Dependent Variable	Type of Causality				
	Short Run				Long Run
	$\sum \Delta \ln Y_{t-1}$	$\sum \Delta \ln E_{t-1}$	$\sum \Delta \ln K_{t-1}$	$\sum \Delta \ln O_{t-1}$	ECM_{t-1}
$\Delta \ln Y_t$	…	5.4570* [0.0051]	16.5004* [0.0000]	9.2300* [0.0001]	-0.0350* [-3.1269]
$\Delta \ln E_t$	2.7800*** [0.0663]	…	0.8313 [0.4370]	0.0890 [0.9165]	-0.0485** [-2.2809]
$\Delta \ln K_t$	28.2098* [0.0000]	0.6200 [0.5411]	…	6.2009* [0.0023]	-0.0829* [-4.0798]
$\Delta \ln O_t$	7.9882* [0.0006]	0.0122 [0.9801]	8.0118* [0.0003]	…	0.0533 [1.5975]

Note: * and ** denote the significance at the 1 and 5 per cent levels, respectively.

For short-run results reported in Table-5, we note the presence of bidirectional causality between biomass energy consumption and economic growth. Capital use causes economic growth and economic growth cause capital use in Granger sense. The feedback effect exists between trade openness and economic growth. The relationship between capital and trade openness is also found to be bidirectional in short-run.

5. Concluding Remarks and Policy Implications

This paper investigates the relationship between biomass energy consumption and economic growth for the panel of BRICS region. For this purpose, we incorporate capital use and trade openness in production function as additional determinants of economic growth. We use time series quarterly frequency data for the period of 1991Q1-2015Q4. This study offers two key innovative findings: first, it establishes the sign for long-run and short-run analysis and second, it identifies the direction of causality between biomass-energy consumption and economic growth not only for long-run but also for short-run.

After confirming the presence of cointegration between biomass energy consumption and economic growth, we note that biomass energy consumption increases economic growth. Trade openness spurs domestic output and hence economic growth. Economic growth is positively linked with capital use. The panel causality test shows the presence of feedback effect between biomass energy consumption and economic growth. The causal relationship between capital use and biomass energy consumption is bidirectional. Trade openness causes biomass energy consumption in Granger sense.

In light of the above empirical results, it is concluded that the biomass is such type of renewable energy source that brings sustainable economic growth and development for BRICS region. Capitalization is a catalyst between the economic growth, trade openness and biomass energy use in BRICS countries. The findings also suggest that policy option to promote biomass energy consumption in Brazil, Russia, India, China and South Africa helps to achieve sustainable development goal in both short-run and long-run. However, Havlik et al. [29] suggest that extensive use of biomass energy has global land use implications and indirectly hurts the environmental quality. Similarly, Lopez [48] found negative environmental impacts of biomass energy use in Ghana, because it exceeds social optimal level.

In line with above arguments of Havlik et al. [29] and Lopez [48], our study further suggests that governments of BRICS countries need to put more concerns on the appropriate use of biomass energy in the production of economic output as we note that biomass energy consumption adds in economic growth in BRICS region. Without proper intervention of governments in conserving biomass energy in long-run, it has adverse implication on the value of biomass energy in the sense that overuse of biomass energy will underestimate its true scarce value in terms of losing efficiency. It is often said in economics theory that once efficiency of biomass energy is lost due to excessive use in the process of producing higher output in BRICS region, then BRICS governments under great fiscal pressure will continue to provide subsidy to energy intensive industries. These practices will send wrong signals to the corporate managers, motivating them to investment too much for extensive use of renewable biomass energy and risking overcapacity in the aggregate production process. This will result in lingering problem for renewable resource companies to under-invest, leading to electricity shortages. Hence, the shortage of electricity derived from overuse of biomass energy will lead to produce mismatch between higher demand for and lower supply of renewable energy and thereby hampering long run production activity in emerging economies. From this line of perspective, there is a growing recognition that without respecting scarce value of renewable energy and promoting biomass energy which is considered as key driver of enhancing economic output and growth found in this study, this kind of growing output and economic growth in BRICS region cannot sustain in long-run. Therefore, our study suggests that in order to prevent efficiency loss of biomass energy from its overuse, growing BRICS economies should find a way of promoting greater availability of biomass energy for sustaining long run economic growth and development.

As an extension, our study further raises an interesting question that what kind of output and long-run economic growth required for sustainable development of BRICS region. Because if BRICS countries tend to produce output with excessive use of biomass energy, no doubt about higher output will be taking place but at the cost of environmental quality in these economies. Thus, the environmental degradation due to biomass energy consumption beyond threshold will definitely deny environmentally sustainable economic growth in BRICS countries. This again puts a serious concern before the governments and fiscal policy makers of BRICS economies to proper use of renewable (biomass) energy without hurting environmental quality and at the same time provides them a space to think about developing institutional quality that will help further to promote conservation of biomass energy for its efficient use in the long run production of economic output. Moreover, CO_2 emissions from biomass energy is less but not zero Yoshida et al. [80], has potential pollution intensity and harms conservation area Field et al. [26] and its carbon quarantine has not been examined yet Cannell [18]. Hence, this study opens up the future research direction to further investigate the relationship between biomass energy consumption, economic growth, and CO_2 emissions in BRICS countries.

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