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RESEARCH ARTICLE

Modelling the Linkages between Financial Development, Economic Growth, Energy Use, Globalization and Carbon Dioxide Emissions: Evidence from BRICS Countries

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ABSTRACT

This research empirically investigates the relationship between financial development, economic growth, energy consumption, globalization and carbon emissions in Brazil, Russia, India, China, and South Africa (BRICS countries). The study utilizes annual panel data retrieved from World Bank, Swiss Economic Institute, and International Energy Agency for the period 1990-2022. A range of econometric techniques robust to heterogeneity and cross-sectional dependence is employed in the analysis. The empirical estimation methods employed in the analysis include Breusch and Pesaran cross-sectional dependence tests, the Pesaran panel unit root test, and the Pooled Mean Group (PMG)/ Auto-Regressive Distributed Lag (ARDL) model, developed by Pesaran and Smith. The findings reveal that economic growth, energy consumption, and economic globalization have a long-run positive and significant relationship with CO_2 emissions. In contrast, a long-run negative and significant relationship between political globalization, social globalization and CO2 emissions is observed. Moreover, the financial development is negatively co-integrated with CO_2 emissions in the long run. These results suggest that the economic and political aspects of globalization have a profound impact on the environment. Therefore, governments and policymakers in BRICS countries should formulate environmentally sustainable policies that carefully consider the effects of globalization on carbon emissions.

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Keywords

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Introduction

The environmental sustainability is one of the main components of the development strategies of different economies. The continuous growth of population, urbanization and industrialization has led to an increase in global energy consumption, enhancing global warming. Global warming is one of the most critical challenges it degrades environmental quality. Currently, global warming affects emerging, industrialized and developing countries alike. According to previous research, CO_2 emissions are a major contributor to global warming that reduced the ozone layer (Alam et al., 2012). Currently mutual dependence and connectivity of peoples and countries have increased through globalization.

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The globalization has increased the international movement of goods, services, capital, and technologies, leading to the expansion of markets and dependency among world economies. However, it also has had significant effects on the environment. This raises an important question: How does globalization impact the environment? The relationship between globalization and environment remains inconclusive. Literatures show that globalization affects the environment both in short and long-run. Rafindadi and Usman (2019) found that in the long-run, globalization decreased CO_2 emissions, while it increased CO_2 emissions in the short-run.

Globalization impacts the environment through different channels. First, it leads to economic growth and high energy consumption which cause environmental degradation. Second, due to globalization the energy consumption declines and economic activities increases because the use of carbon intensive goods diminishes in the production process. Third, globalization leads to the transfer of sophisticated technologies and enhances technical knowledge that will accelerate the economic growth. Finally, the consumption of energy and environmental deterioration will decline (Dollar & Kraay, 2004; Dedeoğlu & Kaya, 2013; Stern, 2007). Moreover, globalization also impacts the financial sector, which includes financial institutions, financial instruments and financial markets. The financial markets and institutions work together during financial development to reduce transaction, administrative and information cost (World-Bank-Group, 2013).

A well-developed financial sector serves as a driving force behind economic growth by boosting local savings and enhancing business activities. Globalization contributes to financial development, and financial development influences the environment. Recently, the performance of financial sector is attached with other main economic sectors that use up huge amount of energy, affecting the environment. The relationship between financial development and environment is widely discussed by many researchers, yielding divergent results. Some studies suggest that financial development has a positive impact on carbon emissions in both short and long-run (Khan, 2019; Ali et al., 2019). In contrast, a negative relationship between financial development and CO_2 emissions is concluded through utilizing panel data and time series data framework (Mrabet and Alsamara, 2017; Sheraz et al., 2021; Zaidi et al., 2019). Similarly, Baloch et al. (2021) considered OECD countries and deduced that financial development negatively affect greenhouse gas emissions. The logic behind this is that financial development will enable the firms and individuals to buy energy efficient technologies and will reduce greenhouse gas emissions.

The economic growth also affects the environment. One of the most prominent studies in this area was conducted by Grossman and Krueger (1995) who found that economic growth and environmental degradation is linearly and nonlinearly inter-linked, and latterly this concept is introduced as an Environmental Kuznets curve (EKC) hypothesis. According to Al-mulali et al. (2015) the inverted U-shaped relationship between economic growth and environment is not found in countries having low and lower middle-income. On contrary, countries having high and upper middle-income have an inverted U-shaped association between economic growth and environmental degradation.

The environmental degradation will cause a huge cost to different governments. Therefore, all the economies worldwide are trying to take care of the environmental decay. Currently, BRICS countries contribute 50 % of the global economic growth and 40% of the world's population. Besides this, considering the world total emission of carbon, more than 40 % is emitted by BRICS in 2013. Considering the world total energy consumption, more than 35% is consumed by BRICS economies in 2013 (Haseeb et al., 2018). Besides this, BRICS countries have experienced an exceptional growth and development in different sectors of their economies as well, particularly the financial sector of these countries has developed more over the past two decades. Some new development banks are developed in order to make financial linkages among countries (Bonga, 2016). Considering this background, the main objective of this study is to investigate the linkages between financial development, economic growth, energy use, globalization, and carbon emissions in BRICS countries. Different researchers have studied the relationship of globalization and financial development on environmental degradation in detail, but the relationship between different aspects of globalization and environment is ignored in BRICS countries. Keeping in view this gap, the current study also investigates the effect of economic, social and political globalization on CO2 emissions for the period 1990 -2022 by using the Pooled Mean Group (PMG) Auto-Regressive Distributed Lag (ARDL) model. The findings of this study are useful, because the previous studies have used traditional methods of estimation, such as Levin et al. (2002) and Pesaran and Shin (2003) non-stationarity tests. The

heterogeneity and cross-sectional dependence is not considered in these tests. But the current study used some advanced methods of estimation such as unit root test developed by Pesaran (2007) which assume cross sectional dependence and the Pooled Mean Group/ARDL model developed by Pesaran et al. (1999).

Literature Review

In recent decades, the global warming and climate change have emerged as some of the most critical global challenges. It is estimated that the global temperature may rise from 1.1 to 6.4 ^{0}C if we maintain the current level of greenhouse gases (Barker et al., 2007). Further, by the year 2100 the sea level will rise from 16.5 to 53.8 cm. Economic growth is one of the key macroeconomic indicators that affect the environment and is considered significant for policy formulation. The remarkable studies by Kuznets, Grossman and Krueger in 1995 have attracted many researchers and economists to work on environment growth relationship (Charfeddine and Khediri, 2016).

The performance of financial sector and other economic sectors is highly interlinked. These sectors consume a significant amounts of energy which can influence sectorial and overall economic growth, in spite of the environment. Ali et al. (2019) utilized time series data, in order to see the association of carbon emissions and financial development. Their findings revealed that considering short and long-term, financial development positively affect CO_2 emissions. Similarly, Bui (2020) examined the transmission channels between financial development and CO2 emissions across 100 countries for the period 1990 to 2012. The study found a positive correlation between financial development and CO2 emissions. Financial development leads to energy consumption and CO2 emissions. Further the financial development will reduce inequality of income that leads to environmental degradation. The negative effects of financial development on environment is greater than its positive effects.

Over the past few decades, the carbon emissions and economic growth relationship is discussed by many researchers. The study conducted by Fang et al. (2020) analyzed the relationship between financial scale, urbanization, securities size, economic growth and carbon emissions. The study utilized the time series data and ARDL-ECM model. The results of ARDL model indicated that scales of financial development and economic growth have long period Co-integration with carbon emissions. Similarly, Khan et al. (2019) examined the effects of financial development, economic growth, carbon emissions and energy consumption on each other considering a panel of 193 countries. Their findings indicated that financial development, carbon emissions and energy consumption increase economic growth. Further, the economic growth and energy consumption positively affected CO2 emissions.

Additionally, Liu et al. (2020) found a positive relationship between economic growth and carbon emissions in G7 countries using time series data for the period 1970 to 2015. In a case study of India Sethi et al. (2020) also concluded a long-run positive relationship of economic growth with carbon emissions. Similarly, in the case of Nigeria, a positive impact of GDP per capita on carbon emissions is concluded during the period 1981 to 2015 (Lukman et al., 2019). Keeping in view the above mentioned studies, it is found that the relationship between economic growth and environment degradation appears to be inconclusive. However, in the context of BRICS countries, our findings suggest a significant and positive relationship of economic growth with carbon emissions.

In the last decade, numerous studies have focused on either single country or panels of countries to test the relationship between globalization and CO2 emissions. Most of these studies examined the influence of the overall globalization index on CO2 emissions. Using panel data some studies concluded that, an increase in globalization would decrease CO_2 emissions in the future (Shahbaz et al., 2019). Similarly, Rafindadi and Usman (2019) revisited the EKC hypothsis by incorporating the effect of the use of energy and globalization in South Africa. The results of the study suggested that globalization decreased CO_2 emissions in the long-run, while it increased CO_2 emissions in the Short-run. In contrast, however, few studies have investigated the impact of different aspects of globalization (such as political, social, and economic globalization) on carbon emissions in Pakistan. These studies concluded that economic, social and political globalization have positively affected carbon emissions both in the short and long-run (Khan and Ullah, 2019).

Similarly, Xu et al. (2018) also examined the impact of political, social and economic globalization on carbon emissions throough a case study of Saudi Arabia.Their findings revealed that only economic globalization significantly contributes both in the short and long-run to CO_2 emissions, while political, social and overall globalization do not increase CO_2 emissions. In case of India, a long-run positive relationship of globalization

with carbon emissions is concluded. Further, a short-run one-way causality running from globalization to carbon emissions is also deduced (Sethi et al., 2020). On the other hand, Wang et al. (2020) found that carbon emissions is adversely affected through economic globalization. Additionally, Yang et al. (2019) explored the impacts of globalization on environment considering 21 cities of China for the period of 1990 to 2015. The study found that globalization has negative and positive effects on city environment, considering long-run the negative impacts are transformed to positive effects. Which indicates a U-shaped relationship between environment and globalization. The study also found that, not only economic factors but different aspects of globalization affected the environment.

Conducting case study of Japan, a long-run relationship between ecological footprint and economic globalization is found. Based on symmetric ARDL results a positive relationship between economic globalization and footprint is concluded. While the asymmetric ARDL indicated that changes in economic globalization leads to decrease footprint (Ahmed et al., 2021). Similarly, Ghosh (2018) considered low and low-middle income and upper-middle income and high income countries of Asia, to investigate the causal relationship between globalization and carbon emissions. The study found a one-way causality running from globalization to carbon emissions in a panel of seventeen low and lower-middle income countries. While in remaining eleven countries upper-middle income and high income countries there is no Granger causality running from globalization to carbon emissions. Additionally, Kalaycı and Hayaloğlu (2019) investigated the effects of economic globalization and trade openness on carbon emissions. The study considered NAFTA countries for the period 1990 – 2015. It is found that economic globalization and carbon emissions are positively related. Moreover, Mehmood (2021) examined the relationship between different aspects of globalization, economic growth and carbon emissions. The study considered Singapore and collected time series data for the period 1970 – 2014. Based on the analysis of real data it is deduced that economic and social globalization reduced carbon emissions while political globalization has increased carbon emissions. It is shown that in long-run 1 percent increase in political globalization will increase carbon emissions by 2.06 percent.

Similarly, in case of our study we have found a positive relationship between economic globalization and CO_2 emissions and a negative relationship between economic globalization and N_2O emissions. Further a negative and statistically significant relationship of political and social globalization with carbon and nitrous oxide emission is also established. Many studies have conducted about energy consumption and CO_2 emissions nexus in different countries. The results of these studies are in controversy; some studies established a positive and direct link between energy consumption and CO_2 emissions e.g. studies conducted by, Begum et al. (2015) in Malaysia, Farhani and Rejeb (2012) considered MENA countries, Al-mulali et al. (2015) in the case of ninety-three countries based on their income levels: low income, lower-middle income, and upper-middle income and high-income countries , Xu et al. (2018) in Sudia Arabia, Ali et al. (2019) in Nigeria, Khan et al. (2019) undertaken case study of Pakistan, Rafindadi and Usman (2019) investigated about South Africa. Similarly, Abokyi et al. (2019) found that there exists a one causality between fossil fuel consumption and CO_2 emissions because fossil fuel Granger-causes CO_2 emissions.

Considering 46 sub-Saharan Africa countries it is concluded that economic growth and energy consumption are indirectly affected by financial development to influence carbon emissions. The energy consumption is complemented by indicators of domestic financial development in order to positively and significantly affect carbon emission (Acheampong, 2019). Similarly, Baek (2015) found that energy consumption positively affects CO_2 emissions in most Arctic countries. Boutabba (2014) examined the long-run equilibrium and causal relationship between CO_2 emissions, economic growth, financial development, trade openness and energy consumption for the period 1971- 2008 in India. The study concluded that, per capita energy consumption and per capita carbon emissions have bidirectional causality in the long-run. Additionally, considering a panel data, it is found that financial development cause energy consumption to raise and further energy consumption increases CO_2 emissions (Bui, 2020).

Likely, conducting case study of Nigeria the significant short and long-run positive effect of urbanization and energy use on carbon emissions is also concluded (Lukman et al., 2019). Le (2019) considered few ASEAN countries such as Myanmar, Malaysia, Philippines, Singapore, and Thailand for the period 1971 - 2014. The study found a long-run positive and significant relationship between energy consumption and carbon emissions. Similarly, in Japan, the energy consumption and ecological footprint are positively related as energy consumption increases the environmental degradation which also increases due to raise in ecological footprint

(Ahmed et al., 2021). Kalaycı and Hayaloğlu (2019) considered NAFTA countries for the period 1990 – 2015, and concluded a positive correlation between carbon emissions and energy consumption. Taking into account the aforementioned studies we deduce that there is a positive relationship between energy consumption and environment in most cases. We also discovered a positive relationship between energy uses, CO_2 and N_2O emissions in BRICS countries.

The economic development and growth of industries adversely influence the environment (Sharma, 2011). Further, majority of the studies confirmed that carbon emissions and economic growth are positively linked with each other (Ardakani and Seyedaliakbar, 2019). Considering different studies, we deduce that globalization led to financial sector development and economic growth. As a result of this overall economic activities enhances and affect the environment.

Overall, the above literature focuses on the impacts of different macroeconomic variables on CO_2 and N_2O emissions in different developed and developing countries. Keeping in view the above-mentioned literatures, it is inferred that the relationship of environment with macro-economic variables (such as urbanization, globalization, economic growth, financial development, and others) is inconclusive. Because some studies found positive while others found a negative relationship of mentioned variables with environment. Besides this, few studies support the EKC hypothesis such as Altıntaş and Kassouri (2020) in 14 European countries, Kasman and Duman (2015) in European union member countries, Javid and Sharif (2016) in Pakistan and Ridzuan et al. (2020) in Malaysia. While some studies reject the validity of EKC hypothesis, such as Lee et al. (2015) in 25 OECD countries, Abokyi et al. (2019) in Ghana and Begum et al. (2015) in Malaysia. But still, the relevant studies provide an important theoretical value for environmental policy-making.

The literature discussed above lack in certain areas. First, the majority of these studies considered the overall index of globalization and ignored sub-indices of globalization. Second, only few studies have considered sub-indices of globalization conducting single country analysis using time series data but ignored cross country analysis using panel data.

Materials and Methods

The current study used annual panel data covering the period from1990 to 2022, retrieved from the World Bank, World Development Indicators, the Swiss Economic Institute, and the International Energy Agency. The analysis focuses on BRICS countries- Brazil, Russia, India, China, and South Africa. In this study, the CO_2 emissions serves as a dependent variable while financial development, Globalization, energy use and economic growth are treated as independent variables. The measurement of CO_2 is in metric tons per capita; the data on this variable is collected from World Development Indicators.

To examine the impact of financial development, economic growth, energy use and economic, political and social globalization on CO_2 emissions, this study follows the empirical approaches of Haseeb et al. (2018), Usman et al. (2021), Saud et al. (2020) and Sinha and Sengupta (2019) who have employed similar variables in their analyses. Based on the above mentioned studies, we develop the following empirical model.

$$CO_2 \text{ emissions} = f(FD, EG, EU, GLB)$$

$$\textbf{CO}_2 \textbf{ emissions} = \beta_0+\beta_1(LNFD_{it})+\beta_2(EG_{it})+\beta_3(LNEU_{it})+\beta_4(LNEGLB_{it})+\beta_5(LNPGLB_{it})+\beta_6(LNSGLB_{it})+\varepsilon_{it} \quad (1)$$

In the above equations EGLB, PGLB, SGLB, EU, EG, FD and ε_{it} indicates economic globalization, political globalization, social globalization, energy use, economic growth, financial development, and error term respectively. And this is in consensus with the study of Haseeb et al. (2018), Naradda et al. (2017), Nasir and Rehman (2011), Selden and Song (1995), Roca et al. (2001), Stern and Common (2001) and Ansuategi et al. (2002). The natural logarithm of all variables is taken to normalize the variances of the series. The growth rate in GDP per capita is taken to measure economic growth, therefore its log is not taken. The study utilized cross sectional dependence tests, panel unit-root tests and PMG/ARDL model. The equation (1) is extended to PMG/ARDL model as following considering the CO_2 emissions as a dependent variable.

$$\Delta CO_{2it} = \alpha_{1i} + \beta_{1i}CO_{2it-1} + \beta_{2i}FD_{it-1} + \beta_{3i}EG_{it-1} + \beta_{4i}EU_{it-1} + \beta_{5i}GLB_{it-1} + \sum_{j=1}^{p}\gamma_{1i}\Delta CO_{2it-j} + \sum_{i=0}^{q}\gamma_{2i}\Delta FD_{it-j} + \sum_{i=0}^{q}\gamma_{3i}\Delta EG_{it-j} + \sum_{i=0}^{q}\gamma_{4i}\Delta EU_{it-j} + \sum_{i=0}^{q}\gamma_{5i}\Delta GLB_{it-j} + \varepsilon_{1it} \quad \ldots\ldots (2)$$

$$\Delta FD_{it} = \alpha_{1i} + \beta_{1i}FD_{it-1} + \beta_{2i}CO_{2it-1} + \beta_{3i}EG_{it-1} + \beta_{4i}EU_{it-1} + \beta_{5i}GLB_{it-1} + \sum_{j=1}^{p}\gamma_{1i}\Delta FD_{it-j} + \sum_{i=0}^{q}\gamma_{2i}\Delta CO_{2it-j} + \sum_{i=0}^{q}\gamma_{3i}\Delta EG_{it-j} + \sum_{i=0}^{q}\gamma_{4i}\Delta EU_{it-j} + \sum_{i=0}^{q}\gamma_{5i}\Delta GLB_{it-j} + \varepsilon_{1it} \quad \ldots\ldots (3)$$

$$\Delta EG_{it} = \alpha_{1i} + \beta_{1i}EG_{it-1} + \beta_{2i}CO_{2it-1} + \beta_{3i}FD_{it-1} + \beta_{4i}EU_{it-1} + \beta_{5i}GLB_{it-1} + \sum_{j=1}^{p}\gamma_{1i}\Delta EG_{it-j} + \sum_{i=0}^{q}\gamma_{2i}\Delta CO_{2it-j} + \sum_{i=0}^{q}\gamma_{3i}\Delta FD_{it-j} + \sum_{i=0}^{q}\gamma_{4i}\Delta EU_{it-j} + \sum_{i=0}^{q}\gamma_{5i}\Delta GLB_{it-j} + \varepsilon_{1it} \quad \ldots\ldots (4)$$

$$\Delta EU_{it} = \alpha_{1i} + \beta_{1i}EU_{it-1} + \beta_{2i}CO_{2it-1} + \beta_{3i}EG_{it-1} + \beta_{4i}FD_{it-1} + \beta_{5i}GLB_{it-1} + \sum_{j=1}^{p}\gamma_{1i}\Delta EU_{it-j} + \sum_{i=0}^{q}\gamma_{2i}\Delta CO_{2it-j} + \sum_{i=0}^{q}\gamma_{3i}\Delta EG_{it-j} + \sum_{i=0}^{q}\gamma_{4i}\Delta FD_{it-j} + \sum_{i=0}^{q}\gamma_{5i}\Delta GLB_{it-j} + \varepsilon_{1it} \quad \ldots\ldots (5)$$

$$\Delta GLB_{it} = \alpha_{1i} + \beta_{1i}GLB_{it-1} + \beta_{2i}CO_{2it-1} + \beta_{3i}EG_{it-1} + \beta_{4i}FD_{it-1} + \beta_{5i}EU_{it-1} + \sum_{j=1}^{p}\gamma_{1i}\Delta GLB_{it-j} + \sum_{i=0}^{q}\gamma_{2i}\Delta CO_{2it-j} + \sum_{i=0}^{q}\gamma_{3i}\Delta EG_{it-j} + \sum_{i=0}^{q}\gamma_{4i}\Delta FD_{it-j} + \sum_{i=0}^{q}\gamma_{5i}\Delta EU_{it-j} + \varepsilon_{1it} \quad \ldots\ldots (6)$$

Where, CO_2 , FD, EG,EU,GLB and Δ indicates carbon dioxide, financial development, economic growth, energy use , globalization (economic,political and social) and first difference operator respectively. Further, the error term is shown by ε . For selecting the lag length selection the Akaike information criterion and Schwarz Bayesian information criteria is implemented. The null hypothesis of equation (2) up to (6) gives:

$H0: \beta_{1i} = \beta_{2i} = \beta_{3i} = \beta_{4i} = \beta_{5i} = 0$. it means there is no cointegration

$H1: \beta_{1i} \neq \beta_{2i} \neq \beta_{3i} \neq \beta_{4i} \neq \beta_{5i} \neq 0$. Which indicates the existence of cointegration.

Further, error correction mechanism (ECM), considering CO_2 as a dependent variable is performed to study the short-run deviation of the series:

$$\Delta CO_{2it} = \alpha_{1i} + \sum_{j=1}^{p-1}\beta_{1ij}\Delta CO_{2it-j} + \sum_{i=0}^{q-1}\beta_{2ij}\Delta FD_{it-j} + \sum_{i=0}^{q-1}\beta_{3ij}\Delta EG_{it-j} + \sum_{i=0}^{q-1}\beta_{4ij}\Delta EU_{it-j} + \sum_{i=0}^{q-1}\beta_{5ij}\Delta GLB_{it-j} + \mu_{1i}ECT_{1,it-1} + \varepsilon_{1it} \quad \ldots\ldots (7)$$

$$\Delta FD_{it} = \alpha_{1i} + \sum_{j=1}^{p-1}\beta_{1ij}\Delta FD_{it-j} + \sum_{i=0}^{q-1}\beta_{2ij}\Delta CO_{2it-j} + \sum_{i=0}^{q-1}\beta_{3ij}\Delta EG_{it-j} + \sum_{i=0}^{q-1}\beta_{4ij}\Delta EU_{it-j} + \sum_{i=0}^{q-1}\beta_{5ij}\Delta GLB_{it-j} + \mu_{1i}ECT_{1,it-1} + \varepsilon_{1it} \quad \ldots\ldots (8)$$

$$\Delta EG_{it} = \alpha_{1i} + \sum_{j=1}^{p-1}\beta_{1ij}\Delta EG_{it-j} + \sum_{i=0}^{q-1}\beta_{2ij}\Delta CO_{2it-j} + \sum_{i=0}^{q-1}\beta_{3ij}\Delta FD_{it-j} + \sum_{i=0}^{q-1}\beta_{4ij}\Delta EU_{it-j} + \sum_{i=0}^{q-1}\beta_{5ij}\Delta GLB_{it-j} + \mu_{1i}ECT_{1,it-1} + \varepsilon_{1it} \quad \ldots\ldots (9)$$

$$\Delta EU_{it} = \alpha_{1i} + \sum_{j=1}^{p-1}\beta_{1ij}\Delta EU_{it-j} + \sum_{i=0}^{q-1}\beta_{2ij}\Delta CO_{2it-j} + \sum_{i=0}^{q-1}\beta_{3ij}\Delta FD_{it-j} + \sum_{i=0}^{q-1}\beta_{4ij}\Delta EG_{it-j} + \sum_{i=0}^{q-1}\beta_{5ij}\Delta GLB_{it-j} + \mu_{1i}ECT_{1,it-1} + \varepsilon_{1it} \quad \ldots\ldots (10)$$

$$\Delta GLB_{it} = \alpha_{1i} + \sum_{j=1}^{p-1}\beta_{1ij}\Delta GLB_{it-j} + \sum_{i=0}^{q-1}\beta_{2ij}\Delta CO_{2it-j} + \sum_{i=0}^{q-1}\beta_{3ij}\Delta FD_{it-j} + \sum_{i=0}^{q-1}\beta_{4ij}\Delta EG_{it-j} + \sum_{i=0}^{q-1}\beta_{5ij}\Delta EU_{it-j} + \mu_{1i}ECT_{1,it-1} + \varepsilon_{1it} \quad \ldots\ldots (11)$$

Using Pooled Mean Group (PMG) method, the estimators and parameters of the equations are acquired. This approach assumes the identical and homogenous long-run coefficients across all panels and further assumes the heterogeneity of the short-run coefficients. The ECM is used to find out the impact of individual characteristics, which gives good insight on the long-run relationship.

Empirical results and discussion

This part explains panel estimation techniques used in this research paper and presents the empirical results obtained through cross-sectional dependence tests, panel unit root tests and PMG/ARDL model.

4.1. Cross sectional dependence tests

As a first step of the analysis, we test the cross sectional dependence of error terms among sample countries, the study utilized Breusch and Pagan (1980) Lagrange multiplier test, Pesaran (2004) scaled Lagrange multiplier test and Pesaran et al. (2008) cross sectional dependence tests.

Table 1: Cross Sectional Dependence Tests Results

Breusch-Pagan LM		Pesaran Scaled LM	Pesaran CD
Variables	**Statistic**	**Statistic**	**Statistic**
CO_2	84.259***	16.604***	4.539***
EG	45.840***	8.014***	4.800***
FD	118.793***	24.327***	9.098***
EU	150.790***	31.481***	9.401***
EGLBF	220.296***	47.023***	14.819***
PGLBF	120.082***	24.615***	8.182***
SGLBF	285.531***	61.610***	16.896***
Note: *** shows significance level at 1%, the above cross sectional dependence tests have HO: No cross-section dependence.			

The above table 1 shows the results of cross-sectional dependence for the series of CO_2 emissions, economic growth, financial development, energy use, economic globalization, political globalization and social globalization. The result indicates, that there exists a cross sectional dependence in this panel data series among all the sample countries.

4.2. Panel Unit root tests

To use panel data for empirical model, it is favorable that the data set is stationary. The modelling of stationary series is both easier and statistically more robust. Based on the above-mentioned results of cross-sectional dependence tests, we found that there exists cross-sectional dependence in data series. Therefore, we have used Pesaran (2007) 2nd generation panel unit root test. Because this test will provide reliable and consistent results in case of cross-sectional dependence as compare to 1st generation unit root tests.

Table 2: M.H. Pesaran, Unit root test results

Variables	Pesaran-Statistics (At level)		Pesaran-Statistics (At First Difference)	
	Constant	Constant & Trend	Constant	Constant & Trend
CO_2	-2.470**	-1.574	-3.512***	-3.933***
FD	-0.416	-0.852	-4.075***	-4.242***
EG	-3.209***	-3.618***	-5.138***	-5.265***
EU	-1.200	-0.891	-3.364***	-3.754***
EGLBF	-2.413**	-2.431	-4.712***	-4.706***
SGLBF	-2.955***	-2.953	-5.334***	-5.511***
PGLBF	-2.106	-1.618	-4.712***	-4.707***
Note: ***, and ** shows significance level at 1%, and 5% respectively. Levin, Lin, Chu null hypothesis is that there is UR, while alternative says that there is no UR.				

The above table 2 presents the results of M. Hashem Pesaran panel unit root test, considering the variables at level and at 1st difference. All series are stationary at 1st difference with or without linear time trend, considering 1% level of significance. While the economic growth series is level stationary at 1% significance level considering constant and trend. Considering constant the CO_2 emissions, economic globalization and social globalization are also level stationary at 5%, 5% and 10% respectively.

4.3. Long-run and short-run estimates

To find out the long-run and short-run relationship between the variables we applied the PMG/ARDL model. This model is suitable model if some series are I (0), and some series are I (1). The PMG/ARDL model assume that the long-run relationship between the variables is constant across countries. To adapt the ARDL model for a panel setting we leave the intercepts, short-run coefficients and co-integrating terms to change across cross sections through taking the co-integration form of the simple

ARDL model (Pesaran et al., 1999). In this study some series are I (0), while others are I (1) therefore we have used PMG/ARDL model. This is in line with the studies conducted by Baloch et al. (2021) in case of OECD countries, Saud et al. (2020) considering few one belt-one-road initiative countries and Asongu et al. (2016) in case of 24 African countries.

Table 3: PMG/ARDL long & short-run parameters estimations

Dependent variable		D(CO_2) emissions	
Variables	**Coefficients**	**Standard Error**	**t-statistics**
Long-run coefficients			
EG	0.0373***	0.0152	2.4494
EU	0.8902***	0.1411	6.3055
FD	-0.6452***	0.2644	-2.4401
EGLBF	2.6778***	0.5133	5.2163
PGLBF	-2.3292***	0.2388	-9.7507
SGLBF	-0.5468***	0.1723	-3.1734
ECT	-0.0727***	0.0301	-2.4122
Short-run coefficients			
D(CO_2(-1))	-0.0723	0.3117	-0.2321
D(CO_2(-2))	-0.0173	0.1524	-0.1139
D(EG)	-0.0074	0.0059	-1.2585
D(EG(-1))	0.0016	0.0029	0.5400
D(EU)	0.8076***	0.1634	4.9406
D(EU(-1))	-0.3782	0.4529	-0.8351
D(FD)	0.0599	0.1122	0.5340
D(FD(-1))	-0.0578	0.0632	-0.9133
D(EGLBF)	-0.1250***	0.0555	-2.2528
D(EGLBF(-1))	-0.2616	0.2075	-1.2609
D(PGLBF)	-0.1345	0.6182	-0.2175
D(PGLBF(-1))	-0.8525	0.3959	-2.1530
D(SGLBF)	0.2287	0.2179	1.0493
D(SGLBF(-1))	0.1225	0.1617	0.7578
Note: * indicates significance level at 1%. Estimations are done using the (PMG/ARDL) in EViews. The lag structure is ARDL (3, 2, 2, 2, 2, 2, 2) and is determined by Akaike info criterion (AIC).**			

The empirical results from the Pooled Mean Group (PMG)-ARDL (3,2,2,2,2,2,2) model indicate a significant long-run positive relationship between economic growth, energy use, economic globalization, and CO_2 emissions at 1% level of significance. This positive relationship of economic globalization, economic growth and energy use with CO_2 is logical because the globalization will enhance the investment flow and trade among countries and as a result the economic growth will be motivated. Further due to economic growth economic activities, investment level and production level inside the economy will be enhanced. All economic activities need energy; therefore, energy use will be increased. And finally due to economic growth, energy use and globalization, the carbon emissions will be increased. BRICS are emerging economies that are rich in resources and have profound development in different aspects of their economies (Radulescu et al., 2014). Further, the long-run association between financial development, political globalization, social globalization, and CO_2 emission is significant and negative. Considering the negative relationship between financial development and carbon emissions we can say that, financial development will lead to low cost of financing that will enable the firms to purchase energy efficient technologies and will reduce carbon emissions. During the period of 2000-2010, the capitalization of BRICS countries in equity market has increased from 1.2 trillion dollars to 6.4 trillion dollars (Delhi, 2012). The social globalization will cause the transfer of ideas and information from developed to developing countries. This flow of ideas and information will cause social awareness in people about different aspects of life. Further, social globalization will result the flow of advanced methods and techniques of production among the countries, that are environment friendly and reduces carbon emissions. BRICS are also developing countries which are copying the developed countries through social globalization and this aspect of globalization improved the quality of environment in BRICS.

Besides this, the political aspect of globalization leads to political cooperation between countries and focuses on their policies. Recently, BRICS countries have signed different environmental agreements such as Paris agreement that focuses on minimization of pollution. Therefore, political globalization in BRICS countries caused reduction of carbon emissions and caused environmental improvement. Considering the above results, in the short-run energy use has a significant positive while EGLBF has a significant negative relationship with CO_2 emissions. The error correction term (ECT) indicates the level of co-integration among the variables. It is highly significant at 1% level of significance. In the short-run the estimated value of ECT is -0.072, this suggest the speed of convergence to long-run equilibrium which is around 7.2 % per year. The significant ECT also indicates that all independent variables (economic growth, energy use, financial development, economic

globalization, social globalization, and political globalization) jointly affect the dependent variable (CO_2 emissions) in the long-run.

These results are in accordance with Ali et al. (2019), Fang et al. (2020), Liu et al. (2020), Ridzuan et al. (2020), Sethi et al. (2020) and Wang et al. (2020), they found a significant long-run positive relationship between economic growth and CO_2 emissions. The long-run positive and statistically significant relationship between economic globalization and carbon emissions is in agreement with the studies conducted by Khan et al. (2019) and Khan and Ullah (2019) in case of Pakistan, Xu et al. (2018) in case of Saudi Arabia, Le (2019) in case of five Asian countries and Kalaycı and Hayaloğlu (2019) in case of NAFTA countries. The significant long-run negative relationship between financial development and carbon emissions is in consensus with different researches such as Adom et al. (2018) in case of Ghana, Lv and Li (2021) in case of 97 countries, Mrabet and Alsamara (2017) and Zaidi et al. (2019). Our results also show a significant long-run negative relationship between political globalization and carbon emissions which is consistent with Xu et al. (2018) and Sahu and Kumar (2020) they found that political globalization affect carbon emissions negatively. Few studies such as Le (2019) and Mehmood (2021) found that social globalization and carbon emissions are negatively linked with each other, which is same with our results. Our results indicate that economic and political globalization have a severe effect on carbon emissions as compared to social globalization. It is shown that in long-run 1 percent increase in economic globalization will increase carbon emissions by 2.67 percent, and on average 1 percent increase in political globalization will decrease carbon emissions by 2.32 percent in the long-run. But 1 percent increase in social globalization will decrease carbon emissions by 0.54 percent in the long-run.

Considering the above estimation and discussion, we conclude a positive and statistically significant long-run relationship between economic growth, energy use, economic globalization, and CO_2 emissions. While a negative and statistically significant long-run relationship is found between financial development, political globalization, social globalization, and CO_2 emissions. Further it is concluded that economic growth, energy use and financial development are positively co-integrated with nitrous oxide emissions in the long-run at 1% level of significance. A significant long-run negative relationship of economic, political, and social globalization with nitrous oxide emissions is also found. Finally, it is concluded that economic and political globalization have more severe effect on carbon emissions and N_2O emissions as compared to social globalization. This result is in line with Khan et al. (2019) and Khan and Ullah (2019) in case of Pakistan.

Conclusion and policy recommendations

This paper primarily investigates the linkages between financial development, economic growth, energy use, globalization and carbon emissions in BRICS countries. To achieve this, a range of econometric techniques has been applied to test cross-sectional dependence, unit root and long-run relationship among the selected variables.

Based on the estimated results a significant long-run positive relationship of economic growth, energy use and economic globalization with CO_2 emissions is concluded. It is deduced that the relationship between financial development, political globalization, social globalization and CO_2 emission is negative and significant in the long-run. The short-run estimated value of ECT is -0.072, this explains the convergence speed to long-run equilibrium which is around 7.2 % per year. The significant error correction reveals that all independent variables jointly affect the dependent variable in the long-run.

Moreover, the results highlight that economic and political globalization have stronger impact on carbon emissions as compared to social globalization. This study can be helpful for the government and other policymakers. Based on our results we recommend few points for further improvement. We found that economic and political globalization have a profound effect on the environment, therefore the governments and policy makers of BRICS countries may formulate some environmental protection unions and may share the environment friendly ideas and technologies with each other. BRICS countries have enough renewable energy resources (that is wind, solar, geothermal, hydropower) the policy makers may attract foreign investors through economic globalization to invest in these resources, in order to minimize carbon emissions.

Furthermore, the economies of these countries should facilitate access to affordable loans and financing to manufacturers, enabling them to import environmentally efficient technologies. Because in BRICS financial development decreases carbon emissions. Considering these economies, the energy use and economic growth enhances carbon emissions. Therefore, the policymakers of these countries should motivate individuals and firms to follow environmental standards and install renewable energy systems, because renewable energy is

environmentally friendly and it is not causing environmental degradation.

Additionally, the political and social aspect of globalization increases environmental quality in BRICS countries. Therefore, the policymakers may formulate the policies to motivate participation in regional environmental protection unions and enhance the social awareness in individuals about the environment. The current study has considered the de facto measures of globalization, while future research on this topic could be more beneficial for researchers by considering both de facto and de jure measures of globalization.

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