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Does financial inclusion promote a green economic system? Evaluating the role of energy efficiency

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ABSTRACT

There are very few studies on the role of financial inclusion and energy efficiency in promoting a sustainable environment in the existing literature. These studies do not address or link financial inclusion to CO₂ emissions in any way. Therefore, the purpose of this study is to look into the role of financial inclusion and energy efficiency on carbon emissions, as well as exports, imports, and gross domestic product (G.D.P.) in the BRICS economies from 1990 to 2020. The study additionally considers the panel data's integration, cointegration, cross-country interdependence, and heterogeneity features, resulting in reliable findings and well-founded policy recommendations. The panel Westerlund cointegration tests confirm the long-run relationships among CO₂ emissions, financial inclusion, energy efficiency, exports, imports, and G.D.P. Furthermore, the long and short-run outcomes of CS-ARDL revealed that financial inclusion, imports size, and G.D.P. raise CO₂ emissions, while energy efficiency and exports size reduce CO₂ emissions. The study proposes increasing financial inclusion for controlling pollution and achieving sustainable environmental goals in light of these findings. Public-sector efforts are needed to integrate financial inclusion goals with continued improvements in energy efficiency and environmental policies.

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1. Introduction

Promoting sustainable economic growth and protecting the environment are two of the most critical issues confronting countries worldwide (Umar, Ji, Kirikkaleli, & Xu, 2020). Since CO₂ is seen as the most severe threat to the ecosystem, nations have made pledges (e.g., the Kyoto Protocol and the Paris Agreement) and set targets, e.g., the U.N. Sustainable Development Goals (S.D.G.s) for 2030 to reduce it (Hasanov et al., 2021; Umar et al., 2022). In the backdrop of increasing carbon emissions across the globe, policymakers and scholars have attempted to notice each determining factor

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or victim of CO₂ emissions. In the 2030 S.D.G.s, financial inclusion is widely regarded as a driver for other economic development (Ielasi et al., 2018; Kaiser & Welters, 2019). In terms of fostering the financial sector and institutions, financial inclusion is a vital component of financial development. It is also believed to be incredibly crucial for promoting economic growth (Le et al., 2020). The concept of financial inclusion first appeared in Chibba (2009) seminal study, in which financial exclusion was identified as a prime root of poverty. Subsequently, other research like (Hussaini & Chibuzo, 2018; Loukoianova et al., 2018) looked into the relationship between financial inclusion and poverty, concluding that financial inclusion plays an important role in reducing poverty. According to the World Bank (2018), financial inclusion is described as persons and enterprises having access to a sort of financial goods and services that satisfy their financial requirements in an accountable, easy, inexpensive, and long-term way. Payment, credit, transaction, saving, insurance, and remittances flow are examples of such products and services. Consequently, a high approach to these services is hoped to speed up economic growth while simultaneously reducing income disparity by providing opportunities to everyone. As a result, a country's high level of financial inclusion can also be regarded as a sign of its financial stability (Sahay et al., 2015). Financial inclusion can be a mitigating mechanism (Renzhi & Baek, 2020; Umar, Mirza et al., 2021). Developing countries are battling to enhance their living standards by increasing financial inclusion levels. If financial inclusion proves to be a viable mitigation strategy, development and climate change policies can be combined to achieve synergy (Umar, Rizvi et al., 2021; Yang et al., 2022). Generally, the financial development process attracts more research and development (R&D) and F.D.I., which reduces environmental damage due to economic development and expansion (Usman et al., 2021). In this regard, industrial units with access to current technology may initiate new sources of energy-efficient, smart, clean, and environmentally friendly manufacturing; as a result, a sustainable environment tends to improve (Ji, Chen, et al., 2021; Ji, Umar, et al., 2021). Furthermore, a strong and well-developed financial sector encourages businesses to invest in environmentally friendly projects and allows for low capital expenditures (Usman et al., 2021).

In the context of the BRICS nations, this study examines the impact of financial inclusion and energy efficiency on the green economic system controlling for the effect of exports, imports, and gross domestic product (G.D.P.) The BRICS countries are chosen as the focus of our research because of the significant importance of this theme in terms of both financial inclusion and environmental change in the region (Hao et al., 2021). We investigate whether providing appropriate financial services to all people of different ages and the most vulnerable cultural communities helps reduce CO₂ emissions in the area (Wang et al., 2021). BRICS is a collection of five great emerging economies at various stages of development and has distinct political forms of government, cultures, and values. One thing common is the share of strong growth rate in recent years among these nations (Arora, 2020; Lobato et al., 2021). The BRICS's share of global output is predicted to jump from 5.8% in 1991–94 to 21.6% in 2018. Meanwhile, in these countries, the financial sector has experienced a major transformation in recent years; however, it differs greatly between countries (Li et al., 2021). Among the BRICS economies, China has seen rapid growth and has a wealth of experience with inclusive financial systems (Shen et al., 2021). More financial services are now

available for individuals and businesses in China, particularly M.S.E.s and low-income groups. According to the People's Bank of China (P.B.C.) and the China Banking and Insurance Regulatory Commission (C.B.I.R.C.), outstanding loans to M.S.E.s and agricultural areas in China reached RMB40.7 trillion and RMB37.8 trillion, respectively by the end of June 2020. This accounts for 24% and 22% of total outstanding loans from financial institutions (Chen et al., 2021). Branchless banking has made significant progress in Brazil to increase financial inclusion. In every municipality in the country, the banks have 149,507 banking correspondent agents (Arora, 2020). Most transaction volumes are made up of bill payments (primarily in urban regions) (Arora, 2020). This banking approach has resulted in enhanced financial inclusion in the country. Besides sustainable financial inclusion, energy efficiency is also an important vehicle for achieving decarbonised economic development and mitigating environmental change (Guo et al., 2022; Yan et al., 2021).

The BRICS economies have substantially contributed to global energy production and consumption. BRICS countries account for about half of the world's population, and their economy's rapid expansion is driving up global energy consumption (Khobai et al., 2017). The demand for world economies to improve energy efficiency has prompted people to look for ways to cut their energy consumption (Shahbaz et al., 2022). To reduce energy waste and pollution and so support long-term sustainability. The BRICS countries have an immense mass of natural resources, significant amounts of energy, and technical advancements for rapid economic development (Camioto et al., 2015). According to the International Partnership for Energy Efficiency Cooperation (I.P.E.E.C.), the BRICS economies are equally committed to improving energy efficiency and conserving resources (Ferrat et al., 2022). In BRICS economies, China achieved the most progress in energy efficiency with an increase of 80% during 2000–2017. Brazil also leads in the index of energy efficiency progress (Camioto et al., 2015).

At the same time, the majority of BRICS economies have been identified as leading CO₂ emitters (Qin et al., 2021). China, India, and Brazil are also the main BRICS countries in terms of high CO₂ emissions, just as they are economic dimension. As a result, it is possible that these economies have yet to achieve financial and ecological complementarity in their development strategies. Furthermore, in the next years, the BRICS countries are expected to account for a considerable portion of global output due to their high population, covering almost 40% of the world's population. This mechanism will further worsen CO₂ global emissions levels. At the same time, these developing economies have been identified as potential destinations for international investment. As a result, creating the financial sector, particularly through financial inclusion, is a critical challenge for the BRICS countries, both economically and environmentally. The rest of the study is structured as follows. [Section 2](#) provides literature of review. [Section 3](#) details the theoretical framework. [Section 4](#) presents data and model specification. [Section 5](#) elaborates econometrics techniques. [Section 6](#) presents results and discussion. [Section 7](#) concludes this study and highlights some policy implications.

2. Literature review

This study investigates the role of financial inclusion and energy efficiency to promote a green economic system in BRICS countries. Regarding literature on the role

of financial inclusion and energy efficiency in the case of a sustainable environment is very rare. However, to the best of our knowledge, we include the most recent and relevant literature in our article.

2.1. The literature on financial inclusion and CO₂ emissions

The connection between financial development and CO₂ emissions was studied by numerous scholars, for instance Zhao and Yang (2020) for China; Lv and Li (2021) for 97 countries; Khezri et al. (2021) for 31 Asia Pacific countries; Salahuddin et al. (2018) for Kuwait; Gokmenoglu and Sadeghieh (2019) for Turkey; Charfeddine and Kahia (2019) for 24 Mena countries. While more recently, the diverse impacts of the COVID-19 pandemic and green finance have been analysed in the recent literature from several sets of perspectives like (Mirza et al., 2020; Naqvi et al., 2021; Umar, Ji, Mirza, & Naqvi, 2021; Umar, Ji, Mirza, & Rahat, 2021; Yarovaya et al., 2021; Yu et al., 2022). But only a few research have looked into the impact of financial inclusion on CO₂ emissions. Hypothetically, financial inclusion may have negative and positive effects on carbon emissions. On the one hand, financial inclusion enables businesses and individuals to get easier access to beneficial and inexpensive financial products and services. Furthermore, it makes green technology investments more reasonable. In this aspect, inclusive financial systems positively impact the environment by increasing accessibility, affordability, and the adoption of improved environmental practices that reduce carbon emissions (IPA, 2017). More recently (Renzhi & Baek, 2020) studied the connection between financial inclusion and carbon emissions for a panel of 103 nations. They used system G.M.M. and illustrated that financial inclusion could be used as a better measure for carbon emissions mitigation. The same studies conducted by Usman et al. (2021) analysed financial development as a proxy for financial inclusion for the 15 highest emitting countries from 1990 to 2017. They concluded that financial inclusion overcomes environmental degradation and decreases nature's carbon emissions. Specifically in developing countries, financial inclusion is important for disadvantaged communities, where farmers may lack the funds or credit needed to participate in sustainable energy technology. For instance, solar energy microgrids are not only cost-effective but also produce far fewer CO₂ emissions than coal-fired power plants (IPA, 2017).

On the other hand, better access to financial services boosts industrial and manufacturing activity, potentially increasing CO₂ emissions and, as a result, increased global warming (Le et al., 2020). Furthermore increased financial activities may result in energy poverty, which may be a source of CO₂ emissions (Zhao et al., 2021). The improvement in financial inclusion allows individuals to offer high-energy consumer products such as cars, coolers, and air conditioners, which poses a serious environmental risk due to increased emissions (Tao et al., 2022). Inclusive financial systems boost economic activities, which raise the demand for non-renewable energy sources and emit more carbon emissions to the globe (Frankel & Romer, 1999). Recently (Le et al., 2020) used the Driscoll-Kraay Standard errors method for 31 Asian countries to examine the dynamic associations between financial inclusion and CO₂ emissions over 2004–2014. Their findings found that financial inclusion, F.D.I., income,

industrialisation, urbanisation, and energy consumption have a negative impact on carbon emissions.

2.2. The literature on energy efficiency and CO₂ emissions

Energy efficiency is very important to help countries develop a stable energy infrastructure (Akram et al., 2020). Improvements in energy efficiency not only help to keep the environment clean but also provide several economic benefits. Existing research has viewed the effects of energy efficiency on CO₂ emissions in different countries. These scholars believe that whenever there is an increase in energy efficiency, it will positively affect a sustainable environment (Chen et al., 2016). While a decrease in energy efficiency increases emissions to nature (Akbostancı et al., 2011). Studies like Liu et al. (2015) used the logarithmic mean Divisia index (L.M.D.I.) in China to examine the industrial sector through changes in carbon intensity over 1996–2012. Their findings found that improving energy efficiency decreases carbon emissions. In addition, system generalised method of moments (S.Y.S.-G.M.M.) analysis (Ouyang et al., 2020) analysed the factors behind the CO₂ emissions in China. The dynamic findings suggested that advancement in energy efficiency is important for CO₂ emissions reduction. Recent research (Mahapatra & Irfan, 2021) examined the relationship between energy efficiency and CO₂ emissions in 28 industrialised and 34 developing economies. They used a nonlinear panel autoregressive distributed lag model (N.P.A.R.D.L.). Their findings reveal that positive shocks in energy efficiency increase reduces CO₂ emissions to nature. Similarly in the U.S.A. (Ulucak & Khan, 2020) used the Dynamic A.R.D.L. testing method to check the relationship between energy intensity and carbon emissions from 1985 to 2017. Their short-run results indicated that energy efficiency slightly decreases CO₂ emissions while in long run it increases significantly.

2.3. The literature on international trade, G.D.P., and CO₂ emissions

In addition to the above factors (i.e., financial inclusion and energy efficiency), other factors such as Exports, Imports, and Gross Domestic Product can affect a sustainable environment. (Franzen & Mader, 2018; Hasanov et al., 2018; Knight & Schor, 2014; Liddle, 2018) conducted the most recent empirical investigation in this area of research. On the other hand (Peters et al., 2011) and (Steinberger et al., 2012) conducted descriptive research and did not link factors. From 1990 to 2013 (Liddle, 2018) studied the relationship between consumption-based carbon emissions and international commerce for a panel of 117 nations (Dorfleitner & Grebler, 2022). It was discovered that exports have a negative impact on consumption-based carbon emissions, whereas imports had a favourable impact. Furthermore, a positive relationship between G.D.P. and consumption-based carbon emissions is found (Ji, Chen et al., 2021). Similarly, Hasanov et al. (2018) used the same methodology to investigate the effects of exports and imports on consumption-based carbon emissions for nine oil-producing countries from 1995 to 2013 (Karim et al., 2022). The author found that imports and gross domestic product had a favourable impact on

consumption-based carbon emissions, whereas exports negatively impacted. However, Franzen and Mader (2018) compared consumption and production-based CO₂ emissions in 110 O.E.C.D. and non-O.E.C.D. nations from 1997 to 2011, and found no carbon leakage (Xu et al., 2020). However, they did not look at consumption-based CO₂ emissions, and the study was limited to a basic comparison.

2.4. Research gap

There is evidence of sustainable environment nexus with other macroeconomic variables in extant work on different countries. These studies rarely look into consumption-based CO₂ emissions and focus on production-based emissions for a sustainable environment. Moreover, the role of financial inclusion and energy efficiency in consumption-based emissions is missing in the literature of BRICS nations. So finally, engagement of BRICS countries in financial inclusion and efficient energy would result in innovative outcomes. This outcome will help policymakers design and further strengthen the green economic systems in these countries. Moreover, the BRICS countries are linked closely by trade, financial integration, and mega energy projects. In the previous literature concerning the financial inclusion and energy efficiency to the sustainable environment, the potential cross-sectional dependence and slope heterogeneity that may exist within the panel data are often ignored and thus may lead to biased results. That's why this study uses the updated econometric approaches that deal with non-stationarity, heterogeneity, endogeneity, and cross-section dependence.

3. Theoretical framework

Improving financial inclusion might make it easier to get cash to finance an economy's industrialisation, further boosting CO₂ emissions. Furthermore, financial inclusion can increase energy demand. As a result, CO₂ emissions resulting from energy usage are likely to rise (Gill et al., 2019). On the other side, financial inclusion can help reduce CO₂ emissions in a variety of ways. It is claimed that improving access to financial services can aid in the transformation of outdated, environmentally unfriendly manufacturing methods into more contemporary, environmentally friendly alternatives. Due to such transformation CO₂ emissions is successfully presumed in a large amount to nature (Yao & Tang, 2021). In this case, it is expected that financial inclusion shall have a negative or either positive effect on consumption-based CCO₂ emissions, i.e., $FINC_{i,t} < 0$ or $FINC_{i,t} > 0$ respectively.

Due to growing industrialisation, energy security has become a major concern among the BRICS countries (Akram et al., 2020). Furthermore, Increasing R&D expenditure is essential for promoting energy efficiency through technological innovation (He et al., 2021). Without a doubt, expanding R&D to encourage technological advancement and increase energy efficiency is an unavoidable strategy to achieve the objective of a sustainable environment. In short, when energy consumption has a scale impact on the economy, technology trade has a scale, composite, and technique influence on the economy, and capital formation has a composite effect on the economy that covers efficient energy capacity creation (Zafar et al., 2019). Therefore an

improvement in energy efficiency will lead to high production that can be achieved without harming the environment. Therefore it is expected that energy efficiency shall have a negative effect on consumption-based CCO_2 emissions, i.e., $ENEF_{i,t} < 0$.

According to the theory, increasing exports allows recipient countries to consume more products and services while leaving less for local consumption. Locally produced goods and services consumed in the host country are included in exports. As a result, carbon emissions from exports should be emitted in the receiving country (Khan et al., 2020). On the other hand, imports include all those goods and services produced in another country and consumed domestically, raising the emissions locally. It is anticipated that as exports increase, consumption-based carbon emissions will decrease in the host country (Khan et al., 2020). While importing more goods, the recipient country's consumption-based CO_2 emissions will rise. Moreover, the effect of exports on consumption-based carbon emissions is expected to be negative, i.e., $EX_{i,t} < 0$, while in the case of imports positive effect is expected to be $IM_{i,t} > 0$.

Similarly, gross domestic product (G.D.P.) is a measure of the health of the country's economy that includes different factors: (1) consumption; (2) public expenditures; (3) investment; and (4) net exports. Increased consumption is positively correlated with consumption-based CO_2 emissions since consumption accounts for a large G.D.P. (Seker et al., 2015). Also, when the income increases of the developing countries. Businesses and households may consume more, not just the government, increasing CO_2 emissions (Khan et al., 2020). Therefore it is expected that gross domestic product shall have a positive effect on consumption-based carbon emissions, i.e., $GDP_{i,t} > 0$.

Building upon the above discussion and previous literature, we develop the following hypotheses in the case of BRICS economies.

H1: Financial inclusion control consumption-based carbon emissions.

H2: Energy efficiency promotes a green economic system.

H3: Exports decrease consumption-based carbon emissions.

H4: Imports boost the consumption-based carbon emissions.

4. Data and model specification

Based on the theoretical framework, this study aims to analyse the role of financial inclusion and energy efficiency in a green economic system. The data for the consumption-based carbon emissions is obtained from Global carbon Atlas (2020). Financial inclusion data is obtained from the international monetary fund (I.M.F.). Exports per capita, imports per capita, and G.D.P. are obtained from World Bank and world development indicators (World Bank, 2020). The general specification of the model is given below.

$$CCO_{2,it} = f(EX_{it}, IM_{it}, GDP_{it}, FINC_{it}, ENEF_{it}) \quad (1)$$

In Equation (1) the cross-sections are denoted ' i ', i.e., Brazil, Russia, India, China, and South Africa. ' t ' Is for a time period from 1990 to 2020. The basic regression from Equation (1) is given below.

$$CCO_{2,it} = \pi_i^1 FINC_{i,t} + \pi_i^2 ENEF_{i,t} + \pi_i^3 EX_{i,t} + \pi_i^4 IM_{i,t} + \pi_i^5 GDP_{i,t} + \varepsilon_{i,t} \quad (2)$$

where $CCO_{2,it}$ consumption-based carbon emissions per capita and defined as emissions from fossil fuels subtracting exports and adding imports with a unit of one million tons of carbon emissions (mt CO₂). $FINC_{i,t}$ Indicated financial inclusion in the model. To construct this variable, we computed a financial inclusion index by using different variables such as Institutions of commercial banks, Branches of commercial banks, Outstanding deposits with commercial banks (% of G.D.P.), Numbers of A.T.M.s per 100,000 adults, and outstanding loans from commercial banks (% G.D.P.). Our next important independent variable is energy efficiency ($ENEF_{i,t}$) which is calculated as the real gross domestic product G.D.P. per unit of energy use (denoted in the US\$/million tons of oil equivalent at constant prices 2011). EX_{it} is exports per capita which measure the total exports of goods and services with a unit of constant US\$2010. IM_{it} is imports per capita which measure the total imports of goods and services with a unit of constant US\$2010. GDP_{it} is gross domestic product per capita and defined as the value of all final goods and services within a specified period for a country with a unit of constant US \$2010. The π_i is cross-section error term and $\varepsilon_{i,t}$ is the error term (Table 1).

Table 1. Nomenclature of variables and sources.

Variables	Description	Sources
Consumption-based carbon emissions (CCO ₂)	It is equal to territory-based consumption subtracting carbon emissions embodied in exports plus carbon emissions embodied in imports (measured in mtCO ₂)	Global carbon Atlas (2020)
Financial inclusion (FINC)	The financial inclusion index is calculated using different variables such as Institutions of commercial banks, Branches of commercial banks, Outstanding deposits with commercial banks (% of GDP), Numbers of ATMs per 100,000 adults, and outstanding loans from commercial banks (% GDP).	IMF 2020
Energy Efficiency (ENEF)	GDP per unit of energy usage (\$/kg)	World Bank 2020
Exports (EX)	Exports of goods and services were measured at constant 2010 US dollars (% of GDP).	World Bank 2020
Imports (IM)	Imports of goods and services were measured at constant 2010 US dollars (% of GDP).	World Bank 2020
Gross Domestic Product (GDP)	Gross value added by all resident producers in the economy, plus any product taxes, minus any subsidies not included in the product value (Constant US dollars 2010).	World Bank 2020
Financial Development (FD)	This refers to financial resources delivered to the private sector by financial corporations, such as loans, non-equity securities purchases, trade credits, and other accounts receivable that establish a claim for repayment (% of GDP).	World Bank 2020
Foreign Direct Investment (FDI)	These are the net inflows of funds for long-term management interest. It is the total of reinvested earnings, short and long-term capital provided in the balance of payment, and equity capital (% of GDP).	World Bank 2020
Renewable Energy Consumption (REC)	The proportion of renewable energy in total final energy consumption is called renewable energy consumption (% of total final energy consumption).	World Bank 2020
Renewable Electricity output (RELO)	The percentage of electricity generated by renewable power plants in total electricity generated by all types of plants is known as renewable electricity (% of total electricity output).	World Bank 2020
Electricity Production from Renewable Sources (ELERE)	Electrical power production from sustainable resources, leaving out hydroelectric, consists of geothermal, solar, trends, wind, biomass, as well as biofuels (kwh).	World Bank 2020

5. Econometrics techniques

5.1. Slope heterogeneity and cross-section dependence test

Mostly in panel data analysis, homogeneous slope coefficient without testing for slope heterogeneous coefficient would lead to erroneous estimator findings (Jalil, 2014). As a result, a modified version of Swamy (1970) created by Pesaran and Yamagata is used to estimate cross-section slope heterogeneity (Pesaran & Yamagata, 2008). Similarly, Cross-section dependence is most likely to appear in panel data econometrics in the present era due to increased economic integration, falling trade barriers, or in the era of globalisation (Tufail et al., 2021). Ignoring the issue of cross-section dependence and presuming cross-section independence may result in biased, inconsistent, and misleading information (Westerlund & Edgerton, 2007). In this study (Pesaran, 2015), a test for weakly exogenous cross-section dependence in large panel data econometrics is used to check for cross-section dependence. To use relevant panel data econometric unit root tests, it is necessary to first examine for the presence of slope homogeneity and cross-section dependence. The general Equation for C.S.D. tests is given below.

$$CSD = \sqrt{\frac{2T}{N(N-1)N} \left(\sum_{i=1}^{N-1} \sum_{k=i+1}^N \widehat{Corr}_{i,t} \right)} \quad (3)$$

The pairwise correlation is obtained in Equation (1) via O.L.S. and indicated $\widehat{Corr}_{i,t}$. The cross-section dependence test's null hypothesis suggests independence among units and vice-versa. It must be noted that slope parameters are likely to be heterogeneous. This is due to socio-economic, different economies, and demographic differences.

5.2. Panel unit root test

The use of first-generation panel unit root tests, like Fisher-augmented Dickey-Fuller (Fisher-A.D.F.), Levin-Lin and Chu (L.L.C.), Im, Pesaran & Shin (I.P.S.), and Fisher Phillips-Perronis not logical due to the presence of heterogeneous cross-sectional slopes for coefficients and cross-section dependence. Since cross-section, dependence is not allowed by first-generation panel unit root testing, and even Levin-Lin and Chu test does not allow for a heterogenous cross-sectional slope coefficient. Hence this article applies (Pesaran, 2007) cross-sectionally augmented Dickey-Fuller (C.A.D.F.) panel unit root tests, which properly solve the problem of slope heterogeneity coefficient in cross-section dependence. The general form of C.I.P.S. is given as

$$\Delta Y_{i,t} = \gamma_i + \gamma_i Y_{i,t-1} + \gamma_i \bar{X}_{t-1} \sum_{l=0}^P \gamma_{il} \Delta \bar{Y}_{t-1} + \sum_{l=1}^P \gamma_{il} \Delta Y_{i,t-1} + \varepsilon_{it} \quad (4)$$

In Equation (4) \bar{Y}_{t-1} and $\Delta \bar{Y}_{t-1}$ represents lagged and first differences averages. The statistics for the C.I.P.S. test is given as:

$$CIPS = \frac{1}{N} \sum_{i=1}^n CADF_i \quad (5)$$

In Equation (5) the C.A.D.F. represents cross-sectionally augmented Dickey-Fuller and is used with Equation (4). The null hypothesis support non-stationarity while the alternative for stationarity.

5.3. Panel cointegration test

This study used the second-generation (Westerlund & Edgerton, 2007) panel cointegration approach to determine the cointegration connections between the variables of concern. This technique accurately predicts the cointegration properties in cross-sectionally dependent heterogeneous panel data sets. It also calculates four-panel non-cointegration test statistics based on error correction. This test is generally defined as follows:

$$G_\alpha = \frac{1}{N} \sum_{i=1}^N \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (6)$$

$$G_t = \frac{1}{N} \sum_{i=1}^N \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (7)$$

$$P_T = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad (8)$$

$$P_\alpha = T\hat{\alpha} \quad (9)$$

The G^t and G^a stand for group means statistics, while P^t and P^a stand for cointegration. These test statistics are anticipated when the null hypothesis is that there is no cointegrating link between the variables in a model and the alternative hypothesis is that there are cointegrating relationships.

5.4. Cross-sectional autoregressive distributed lags regression test

It is very important to use such panel regression estimators to deal with both C.S.D. and slope heterogeneity issues in the data. Most commonly used panel regression techniques fail to address these issues throughout the estimation process. Therefore this article uses Chudik and Pesaran's recently proposed Cross-sectional Autoregressive Distributed Lags (C.S.-A.R.D.L.) regression approach to correct for these issues (Chudik & Pesaran, 2015). The C.S.-A.R.D.L. model has many advantages: (1) The problem of heterogeneous slope coefficients and endogeneity; (2) it provides robust results even with a problem of cross-section dependence; (3) it works when there is a problem of serial correlation in the panel series; (4) solves the problem of common-correlation bias; (5) corrects model misspecification bias; and (6)

handles non-stationary panel series issues. The C.S.-A.R.D.L. model predicted the Short-run parameters, long-run parameters, and an Error Correction Term (E.C.T.).

The following is the baseline regression model for cross-sectionally augmented A.R.D.L. (C.S.-A.R.D.L.):

$$\Delta Y_{i,t} = \alpha_i + \sum_{l=1}^P \alpha_{i,t} \Delta Y_{i,t-l} + \gamma_i \bar{X}_{t-1} \sum_{l=0}^P \alpha_{i,t} EXV_{s,i,t-l} + \sum_{l=0}^1 \alpha_{i,t} \overline{CSA}_{i,t-l} + \varepsilon_{it} \quad (10)$$

Where $\overline{CSA}_t = (\Delta Y_t, EXV_{s,t})$ and $EXV_{s,t} = (FINC_{i,t}, ENEF_{i,t}, EX_{i,t}, IM_{i,t}, GDP_{i,t})$ that is, $EXV_{s,t}$ is the set of explanatory variables, financial inclusion index, Energy Efficiency, Exports, Imports, and Real Gross Domestic Product.

6. Results and discussion

This section starts by reporting and examining the outcomes from slope homogeneity and C.S.D. tests, followed by the analysis and outcome from the unit root test, cointegration, and regression.

Table 2 shows the results of the (Pesaran & Yamagata, 2008) slope homogeneity test and (Pesaran, 2015) cross-section dependence test. The results of the statistical significance of the (Pesaran & Yamagata, 2008) test reject the null hypothesis of slope homogeneity, which proves the existence of heterogeneous slope coefficients in the panel. In this study, the outcomes are consistent across the model. The majority of (Pesaran, 2015) C.S.D. test statistics have statistical significance at the 1% level, which rejects the null hypothesis and affirms cross-sectional dependence among data. This is expected because BRICS members comprise six big economies of the world. Furthermore, these countries have a number of similarities in terms of trade and macroeconomics policies and projects. To avoid biased and misleading outcomes, it is mandatory to resolve the C.S.D. and slope heterogeneity issues. After the slope homogeneity and C.S.D. test, the second-generation tests like panel unit root and cointegration are carried out.

The results of the unit root test are shown in Table 3. The results show that all of the variables are stationary at the first difference, i.e., 1(1). After taking their differences, all of the variables, such as CCO₂, F.I.N.C., E.N.E.F., E.X., I.M., and G.D.P. become stationary.

Table 2. Slope heterogeneity and cross-section dependence.

Homogenous/Heterogeneous Slope Coefficient Testing			
	$\tilde{\Delta}$		$\tilde{\Delta}^{Adjusted}$
	10.464***		11.893***
Pesaran (2004) Cross-Section Dependence Test			
CCO ₂	EX	IM	GDP
11.744***	8.084***	6.803***	16.08***
FINC	ENEF	-	-
6.169***	17.015***	-	-

Note: The levels of significance are *** 1%, ** 5% and * 10%.

Source: Authors.

Table 3. Unit root testing.

Variable(s)	Trend and Intercept		Order of Integration
	I(0)	I(1)	
CCO ₂	-2.417	-4.880***	I(1)
EX	-2.892**	-	I(0)
IM	-3.102***	-	I(0)
GDP	-1.438	-2.743*	I(1)
FINC	-2.076	-3.777***	I(1)
ENEf	-2.741*	-	I(0)

Note: The levels of significance are *** 1%, ** 5% and * 10%.
Source: Authors.

Table 4. Cointegration test.

Statistic	G ^t	G ^a	p ^t	p ^a
Values	-8.659***	-16.421***	-27.803***	-17.318***
p-values	0.000	0.000	0.000	0.005

Note: The levels of significance are *** 1%, ** 5% and * 10%.
Source: Authors.

Table 5. Outcomes of CS-ARDL.

Variables	Short – Run Coefficients			
	Coefficients	Standard Errors	Z – Statistics	Signs
Δ EX	-0.451***	0.096	-4.69	< 0
Δ IM	0.349***	0.092	3.76	> 0
Δ GDP	0.356***	0.112	3.17	> 0
Δ ENEf	-0.211***	0.041	-5.08	< 0
Δ FINC	0.0431*	0.025	1.68	> 0
ECM(-1)	-0.743***	0.115	-6.43	< 0
	Long – Run Coefficients			
EX	-0.634***	0.155	-4.08	< 0
IM	0.362***	0.125	2.89	> 0
GDP	0.464***	0.164	2.82	> 0
ENEf	-0.360***	0.038	-9.47	< 0
FINC	0.0651*	0.035	1.81	> 0

Note: The levels of significance are *** 1%, ** 5% and * 10%.
Source: Authors.

Furthermore, [Table 4](#) represents the results of the cointegration analysis. In this study, the statistical significance of the four test statistics at the 1% and 5% levels indicates that the desired variable in the model is cointegrated. Therefore it can be claimed that in the context of the BRICS nations, there exist long-run associations between CCO₂ emissions, financial inclusion, energy efficiency, exports, imports, and G.D.P. The affirmation of long-run cointegrating relationships meets the need of forecasting long-run coefficients using the proper panel regression method.

[Table 5](#) shows the C.S.-A.R.D.L. regression analysis outcome for the short-run and long-run, respectively. The C.S.-A.R.D.L. short-run findings show that financial inclusion degrades sustainable environmental quality in BRICS countries by discharging higher volumes of CCO₂ emissions into the atmosphere. A 1% increase in financial inclusion is connected with a 0.04% increase in CCO₂ emissions on average, *ceteris paribus*. Hence in line with these findings, it can be said that BRICS countries have failed to achieve a sustainable environment through their financial inclusion process.

This can be justified from the perspective that most of these countries are at the lower stage of financial development.

On the other hand, energy efficiency (Δ ENEF) with CCO_2 emissions is also examined. A 1% rise in efficient energy figures reduces CCO_2 emissions by -0.21% *ceteris paribus*. In the case of BRICS economies, private and public sector participation in clean coal, wind, solar, and hydro projects has considerably increased in the past few decades. These initiatives become a constant source of environment-related invitation for these countries, improving energy efficiency and reducing consumption-based carbon emissions. Furthermore, exports effectively mitigate the CCO_2 in the BRICS countries. A 1% rise in exports figures mitigates CCO_2 emissions by -0.45% , *ceteris paribus*. This is because items produced in the BRICS countries are exported and consumed in other countries, reducing consumption-based carbon emissions. In the case of imports, it is found that the increase of imports degrades the sustainable environment. A 1% increase in imports is observed to rise CCO_2 emissions by 0.349, *ceteris paribus*. It means that commodities produced in various countries and imported for use in BRICS countries boost carbon emissions from consumption. Similarly, a 1% increase in G.D.P. increases 0.35% consumption-based carbon emissions in these selected countries. Rising economic activity imposes great pressure on the environment due to increased demand for fossil fuels, causing environmental degradation (Khan et al., 2021). In Table 4 for C.S.-A.R.D.L. the speed of adjustment to equilibrium E.C.M. (-1) is -0.743 , which is highly statistically significant. According to the outcomes for E.C.M. (-1), nearly 74.3% of disequilibrium is corrected each year. This means the cointegration relationship between the variables is stable.

Table 5 also shows the C.S.-A.R.D.L. analyses long-run coefficients estimates. The long-run effects of financial inclusion and energy efficiency and other control variables on the green economic system are consistent with the short-run effects, as seen by the identical signs of the short- and long-run coefficient estimates. Financial inclusion, our core variable of interest, appears to have resulted in higher consumption-based CO_2 emissions in BRICS economies. The F.I.N.C. coefficients are positive with 0.065, which means that a 1% rise in F.I.N.C. can positively raise the CCO_2 emissions in the long term by 0.065%. These findings suggest that the BRICS countries' financial development programs have yet to be aligned with their respective environmental welfare goals. As a result, these countries' pollution-intensive businesses are likely to have developed due to increased access to financial services. Furthermore, such unfriendly environmental practices in these countries compel their residents to buy more products such as automobiles, refrigerators, air conditioners, television sets, etc. As BRICS economies cover almost 42% population of the world. This huge population further accelerates the national use of fossil fuel energy. Finally, the consumption of such items in huge amounts boosts consumption base carbon emissions in the region. Similar results were found by Le et al. (2020) and Qin et al. (2021), but they have only focused on carbon emissions rather than consumption-based carbon emissions.

On the other hand, the long-run estimates also imply that persistent use of efficient energy reduces consumption-based CO_2 emissions in BRICS countries. Particularly the E.N.E.F. coefficients are negative with -0.360 , which means that a

1% rise in E.N.E.F. can positively reduce the CCO₂ emissions in the long term by -0.360% . Energy efficiency is just one of the BRICS countries' adopted plans. We suggest putting even more effort into developing more energy-efficient modern technologies and persuading them to less-developed nations. Furthermore, the responsibility of the BRICS nation is to assist policies enforcement in these countries to alleviate climate change concerns. As a result, they may ensure current generation power security by reducing fossil fuel consumption and improving their lifestyle by improving environmental quality. Our findings are consistent with the findings of Hassan et al. (2022) and He et al. (2021).

In the case of exports, a 1% rise in exports reduces -0.63% CCO₂ emissions in BRICS economies in the long run. These economies exports a massive amount of goods and services to the world. As we discussed earlier in our theoretical section, when a country exports a lot to another country, it consumes less domestically, and finally, it reduces consumption-based emissions. For instance, according to 2017 estimates, China leads the world in exports with US\$2.41 trillion, followed by Russia with US\$341 billion, India with US\$292 billion, Brazil with US\$219 billion and South Africa with US\$108 billion (Hasanov et al., 2021; Simoes & Hidalgo, 2011). Similar findings in the case of exports were found by Hasanov et al. (2018; 2021). Furthermore, a 1% rise in imports produces a 0.36% increase in CCO₂ in the long run. BRICS countries imports many intermediate and final goods and services as developing economies. A high level of imports triggers domestic consumption, which further boosts CCO₂. Imports provide a significant contribution to national consumption. China, for instance, imports US\$1.54 trillion, Brazil US\$140 billion, India US\$417 billion, Russia US\$221 billion, and South Africa US\$81.9 billion from the rest of the globe (Hasanov et al., 2021; Simoes & Hidalgo, 2011).

According to the long-run estimates, a 1% rise in G.D.P. accelerates to a 0.46% increase in CCO₂. This result corresponds to the theoretical framework in the previous section. Furthermore, environmental theories such as the S.T.I.R.P.A.T. and the E.K.C. predict that increased G.D.P. will result in increased CO₂ emissions: an increase in economic activity or income is linked to increased consumption of final and intermediate goods. Similar findings were obtained by Hasanov et al. (2021), Hassan et al. (2021) and Wahab et al. (2020).

Table 6 shows robustness outcomes obtained from the augmented mean group (A.M.G.) and common correlated mean group (C.C.E.M.G.). A.M.G. and C.C.E.M.G. confirm a positive relationship between financial inclusion and consumption-based carbon emissions with coefficients values of 0.0212 and 0.055%, respectively. On the other hand, energy efficiency and consumption-based carbon emissions have a

Table 6. Robustness results.

Variable(s)	Coefficients _{AMG}	Coefficients _{CCMG}
EX	-0.331^{***}	-0.339^{***}
IM	0.221^{***}	0.164^{***}
GDP	0.592^{***}	0.761^{***}
ENEFF	-0.327^{***}	-0.395^{***}
FINC	0.0212^{***}	0.055^{***}
Constant	-1.013^{***}	-1.074^{***}

Note: The levels of significance are *** 1%, ** 5% and * 10%.

Source: Authors.

Table 7. What if analysis using various variables.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
EX	−0.37***	−0.31***	−0.33***	−0.27***	−0.29***
IM	0.18***	0.13***	0.11***	0.14***	0.12***
GDP	0.70***	0.62***	0.51***	0.55***	0.57***
FD	−0.15***	–	–	–	–
FDI	–	−0.01***	–	–	–
REC	–	–	−0.40***	–	–
RELO	–	–	–	−0.11***	–
ELERE	–	–	–	–	0.01***

Note: The levels of significance are *** 1%, ** 5% and * 10%.

Source: Authors.

negative association, with values of -0.327% and -0.395% for A.M.G. and C.C.E.M.G., respectively. Similarly, G.D.P. and consumption-based carbon emissions are positively correlated, with correlations of 0.592% and 0.761% , respectively. In the case of exports, it shows negative relationships with CCO_2 with coefficients values of -0.331 and -0.339 . In contrast, the imports show a positive relationship with CCO_2 , for A.M.G. and C.C.E.M.G. with coefficients values 0.221 and 0.164 , respectively. The robustness check results back up our findings from the cross-sectionally augmented autoregressive distributed lags model (C.S.-A.R.D.L.).

We further examined the robustness Mean Group test for other important control variables such as Financial Development (F.D.), Foreign Direct Investment (F.D.I.), Renewable Energy Consumption (R.E.C.), Renewable Electricity output (R.E.L.O.), and Electricity Production from Renewable Sources (E.L.E.R.E.). The robustness' results indicate a positive relationship between F.D. and CCO_2 emissions with a coefficient value of -0.15% . On the other hand, F.D.I. and CCO_2 emissions have a negative association, with values of -0.01% . Similarly, R.E.L.O. and CCO_2 emissions are negatively associated with a value of -0.11% , respectively. While the case of E.L.E.R.E. shows positive relationships with CCO_2 with coefficients values of 0.01 . Our results show that these control variables are important factors explaining the CCO_2 emissions (Table 7).

7. Conclusion

In light of the ongoing debate over the causes of a sustainable environment, this study adds to the limited existing body of knowledge by examining the role of financial inclusion and energy efficiency on consumption-based CO_2 emissions in the context of exports, imports, and G.D.P. in BRICS economies from 1990 to 2020. For the integration, cointegration, cross-country interdependence, and slope heterogeneity properties in the panel data set, this study used 2nd generation econometrics methodologies. As a result, our findings are reliable, and our policy recommendations are credible. We observed that the aforementioned variables have a significant role in a sustainable environment for BRICS economies in the long run and short run. We calculated that financial inclusion, imports, and G.D.P. increases CCO_2 emissions, whereas energy efficiency and exports decrease CCO_2 .

7.1. Policy implications

Financial inclusion has negative effects on the environment does not mean that it should be reduced. Instead, policymakers should enhance the precision of financial inclusion. For example, China, one of the main pillars in BRICS economies, has introduced green financing, which has mandatory policy implications (Zhang et al., 2019). In 2012 the 'Green Credit Guidelines' were described as a turning point in China's green credit policy. Chinese financial institutions must support the development of a green, low-carbon economy and improve their green credit standards due to this process (Liu et al., 2019). Therefore it is recommended that other economies of BRICS countries should also introduce such policies with coordination of China and enhance their capacity towards green credit standards. Second, policymakers must increase access to and inclusion of climate finance to assist underprivileged and economically marginalised groups in society cope with rising CO₂ emissions. Individuals, micro-, small-, and medium-sized firms should have adequate access to financial products and services to enable them to engage in local, small-scale mitigation and adaptation activities to reduce CO₂ emissions. In this regard, Sachs et al. (2019) emphasise the significance of massive public and private investment, among other S.D.G.s, for the transition to a low-carbon, green economy.

7.2. Limitations' and future guidelines

Finally, we want to talk about the limitations of our research study and how they could motivate future research. Due to the lack of information, our evaluation will be completed in 2020. A future study that includes one of the most recent modifications, such as oil rate reductions and the COVID-19 economic crisis, would undoubtedly be worth considering. Another factor is that we limited our research to the BRICS countries. The findings of this research study can be applied to other groups of countries in the future, such as the G7, G8, and G20. Furthermore, more research might be conducted to examine the complementarities between financial inclusion and several other indicators in impacting the green economics system.

Conflict of interest

The authors declare that they have no conflict of interest.

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