THE FINANCIAL INCLUSION, RENEWABLE ENERGY AND CO_2 EMISSIONS NEXUS IN THE BRICS NATIONS: NEW EVIDENCE BASED ON THE METHOD OF MOMENTS QUANTILE REGRESSION

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Abstract. This paper aims to examine the nexus between financial inclusion, renewable and non-renewable energy consumption, and carbon emissions according to the Environmental Kuznets Curve (EKC) hypothesis in the BRICS nations, employing the Method of Moments Quantile Regression (M.M.Q.R.) approach for 2002-2019. The causal linkages among the tested variables in heterogeneous panel data are investigated by utilising the Dumitrescu and Hurlin test. The empirical outcomes validate the EKC hypothesis for the BRICS nations. Furthermore, the findings from the panel quantile estimations (M.M.Q.R.) showed that the coefficients for the consumption of renewable energy and financial inclusion are negative through all quantiles (1st to 9th quantiles) for the emissions of CO_2. Thus, this suggests CO_2 emission levels are reduced by financial inclusion and renewable energy. In addition, the current analysis indicates that the volume of renewable energy investment in overall energy improves due to economic enlargement in the BRICS economies. Hence, financial inclusion is a catalyst for growth while mitigating carbon emissions. Therefore, financial inclusion should be included in the climate change paradigm strategies of the BRICS countries. To reach sustainable economic growth, we conclude that policy-makers should improve incentives for inclusive green finance.
Keywords: *inclusive green finance, banking, sustainable development, pollution, environment*

Introduction

Financial inclusion, utilisation of renewable energy and reducing carbon intensity are crucial elements of the sustainable development goals (S.D.G.s). A financial inclusion policy that aims to augment a low-carbon economy is defined as inclusive green finance (IGF), as stated by Alliance for Financial Inclusion (A.F.I.) (2020). IGF is the primary mechanism contributing to financial development through financial inclusion by considering environmental health and societal well-being. The Universal Financial Access (U.F.A.) proposes that financial inclusion is the first pillar in the fight against poverty and considering opportunities for economic development (The World Bank, 2020). Its purpose is to provide everybody with affordable access to the financial system. Hence, it leads to the improvement of the monetary framework of the country. Also, it is a holistic aspect of economic development. All countries depend on different types of energies according to their natural resources during their development period. Energy is the primary catalyst of industrial, technological, economic and social development. Some countries have natural resources and use primary energy sources, including those obtained from fossil fuels (natural gas, oil and coal), to obtain a competitive advantage. Both the economic growth of countries and common energy utilisation have a significant effect on

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environmental pollution. Traditional energy utilization leads to the emission of carbon dioxide (CO_2).

CO_2 outflows are the primary ozone harming substances that add to the global increase in temperature. This leads to negative externalities for the environment and directly affects ecology, including natural water sources, natural resources, lands, animals, oxygen in the air, and the overall biodiversity and economy of the country. Thus, it is the main driving force behind implementing new environmentally-friendly power generation for low-carbon economies with sustainable economic growth. Sadorsky (2010) stated that the essential factors of energy demand construct the path for formulating decarbonisation mechanisms in the current economy through financial development. The transition to a renewable energy sector improves every country's economic growth and competitiveness, as stated by Simionescu et al. (2020), Blazejczak et al. (2014), and Wu et al. (2016).

Nevertheless, energy transformation is the most important innovation to mitigate environmental pollution in developed and developing countries (Saleem Jabari et al.,2022). Hence, green finance represents one of the critical factors driving green expansion to mitigate the adverse effects caused by environmental degradation. Since 1972, the United Nations has resolved to find solutions to solve environmental issues. In 2005, the Kyoto protocol came into effect to mitigate greenhouse gas (GHG) emissions, with the target of decreasing emissions by 5% between 2008 and 2012 (Samour et al., 2022a). In 2015, the Paris Agreement accepted and offered climate change mitigation, energy transformation rules and climate finance. It was adopted by 186 parties nationally, and 90 countries are still working on national adaptation plans to address the changing climate. Thus, policy-makers should adopt more incentives to implement renewable energy investments projects to maintain the global warming target level at 2^oC. The U.S. Energy Information Administration, International Energy Outlook 2019 (IEO 2019) proposes that by 2050, energy utilisation will increase by 50%. According to the European Green Deal agreement, the aim is to achieve a 60% reduction in greenhouse gases (GHG) by 2030, maintain global warming below 1.5^oC, and reach a long-term objective of establishing a zero-carbon strategy by 2050.

The BRICS countries are categorised as rapidly growing emerging economies with some of the world's highest greenhouse gas (GHG) emission levels. BRICS is an abbreviation for five countries whose economies are defined as emerging, namely Brazil, Russia, India, China and South Africa. A 2019 report published by the International Renewable Energy Association (I.R.E.N.A.) stated that Brazil meets 42% of its energy needs by using clean energy sources, and 41% of its primary energy supply is generated by oil. According to Nationally Determined Contributions (N.D.C.), Brazil proclaims to decrease its emissions of greenhouse gases (GHG) by 43% by 2030, below the 2005 level. By 2030, Russia intends to lower its emissions of greenhouse gases (GHG) by 25%-30% below the level recorded in 1990. India plans to reduce the emission level by 2030 to 33%-35% below the 2005 level. One of the highest carbon emitters globally with a 28% share, China dominates over 14.84% of the world economy. China's primary energy source is oil, and its share of the energy supply is 64%, whereas the renewable energy supply accounts for only 8%. China intends to reduce its emission levels by 2030 to around 60%-65% below the 2005 level. South Africa proposes to decrease its greenhouse gas (GHG) emissions to 26% by 2030. *Figure 1* shows the carbon emissions from 1990 until 2019 in the BRICS countries.

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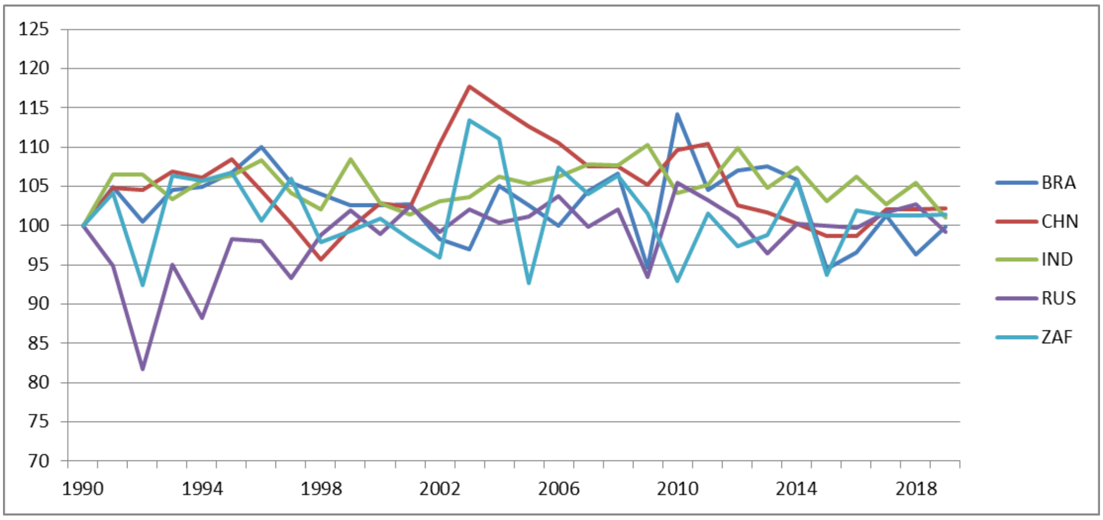

Figure 1. *Carbon emissions for BRICS countries (Million Tons, since 1990=100). (Source: World Bank, 2021)*

Scientific and academic studies have increasingly focused on these negative impacts, and policy-makers have also encouraged studies on technological innovations for low-carbon energy sources like nuclear and renewables. Therefore, to achieve economic sustainability and social development in the long term, energy sources with low carbon emissions should be utilised worldwide. However, this study aims to contribute extant research: The number of studies in the literature about the linkage between economic expansion, financial inclusion, consumption of renewable energy, and emissions of CO_2 for the BRICS nations to achieve sustainable development is limited. First, it provides new insights for the literature regarding financial inclusion and carbon emissions nexus in the light of the Environmental Kuznets Curve hypothesis (EKC) in the context of the BRICS nations. Second, this study considers inclusive green finance for sustainable development. Third, this research employs the newly-developed Method of Moments quantile regression test to analyse the associations. Hence, this research aims to resolve the deficiency in the extant literature by answering the following question: Do financial inclusion, and renewable energy mitigate the emissions of CO_2 in the BRICS nations? Multiple estimation methods are used to investigate the short and long run cause-and-effect relationships to answer the previous question.

The study structure is organised as follows: the second section depicts a review of previous studies on the topic, while the third part presents the model's data and specifications. The fourth presents a discussion of the findings, and finally, the fifth part offers a conclusion.

Literature Review

The relevant scientific studies can be grouped into the following three sub-categories: the affiliation among economic expansion and carbon emissions, the connection among the consumption of renewable energy and non-renewable energy and carbon emissions, and finally, the interrelation between financial inclusion and emissions of carbon.

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Economic growth and CO_2 emissions

Analysing the interconnection between economic growth and carbon emissions has been one of the critical areas of focus in the energy economics domain in recent years. As suggested by the EKC hypothesis, as a country develops, its level of pollution rises, and when the income level increases to a turning point, the carbon emissions reach the highest level and then diminish as a result of economic growth over a specific period. The EKC suggests that an inverse relationship exists between pollution and income. The EKC hypothesis confirmed that industrialised countries become aware of environmental degradation and invest in renewable energy resources through green finance. Many studies have supported the EKC hypothesis. In this field, Apergis and Ozturk (2015) showed that carbon acid gas and income per capita have a reverse U-shape connection and validated the EKC hypothesis. Narayan et al. (2016) investigated the economic enlargement and carbon outflow nexus for 181 nations to validate the EKC hypothesis for 1960 to 2008 using the cross-correlation estimation approach. Haseeb et al. (2018) employed Dynamic Seemingly Unrelated Regression (D.S.U.R.), the Dumitrescu-Hurlin Granger causality test and the FMOLS test, and investigated the interconnection among energy utilisation, monetary expansion, globalisation, economic enhancement, and urbanisation and carbon dioxide outflow, and affirmed the validity of the EKC hypothesis for the BRICS nations. Ike et al. (2020) utilised the new "Method of Moments Quantile Regression" (M.M.Q.R.) approach with fixed effects. The findings showed a significant link between economic development and carbon gas outflow in 15 nations that produced oil from 1980 to 2010. Bibi and Jamil (2021) employed the random effect and fixed effect panel estimations test and validated the EKC among G.D.P. per capita and additional main variables and carbon dioxide emissions in MENA regions from 2000 to 2018. In addition, Sun et al. (2021) examined the linkage among economic expansion, renewable energy technologies, and carbon emissions in the Chinese context for 1990 to 2017 using the V.A.R., V.E.C.M., and Granger causality testing techniques. The outcomes revealed an inverted U-shaped association between economic enlargement and carbon emissions. The results suggested that green technology is the best practice to reduce carbon emissions. Abumunshar et al. (2020) used the A.R.D.L. model to show that G.D.P. has a positive impact on Turkey's level of carbon emissions over the tested period from 1981 to 2015.

However, there are contrary findings related to the EKC hypothesis in the literature. Chakravarty and Mandal (2016) studied the effect of income and carbon emissions for the BRICS nations using the EKC hypothesis between 1997 and 2011, employing the fixed products and G.M.M. testing technique. The findings indicated that the EKC was not valid in the BRICS nations over the tested period. Dogan and Lotz (2020) investigated the linkage between economic systems and carbon emissions according to the EKC hypothesis in several countries in Europe from 1980 to 2014. The author's employed FMOLS and O.L.S. and the S.T.R.I.P.A.T. testing techniques. The empirical analysis revealed that the EKC hypothesis had no validity. Finally, Aydın and Turan (2020) analyzed the importance of economic growth, free trade, and energy intensity on carbon gas outflow for the BRICS countries from 1996 to 2016 using the A.M.G. and C.C.E.M.G. testing models. The empirical findings provided no evidence supporting the presence of the EKC hypothesis in all of the BRICS nations. Recently, several studies confirmed that GDP has powerful impact on the level of carbon emissions in different countries (e.g., Rehman et al., 2021; Pata, 2021;Kirikkaleli et al., 2022; Alola et al., 2022; Adebayo, 2022; Adebayo et al., 2022a,b; Awosusi et al., 2022; Fareed et al., 2022; Miao

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et al., 2022; Akadiri et al., 2022; Pata and Samour, 2022; Yan et al., 2022; Shahzad et a., 2022; Akram et al., 2022; Samour et al., 2022b).

Energy consumption and CO_2 emissions

Various researchers have tested how energy consumption (renewable and non-renewable energy) impacts carbon emission levels. On this subject, Boluk and Mert (2015) investigated the validity of the Environmental Kuznets Curve (EKC) hypothesis by exploring how the consumption of renewable energy impacted decreasing greenhouse gas (GHG) outflow from 1961 to 2010 for Turkey. The findings suggested that the utilisation of renewable energy decreased greenhouse gas (GHG) emissions in Turkey. Using the A.R.D.L. model, Altarhouni et al. (2021) and Qashou et al. (2022) also confirmed that renewable energy decreased greenhouse gas (GHG) emissions in Turkey over the period from 1988-2018 and 1981-2015, respectively. Ummalla and Goyari (2020) validated the EKC hypothesis for the BRICS nations by applying FMOLS and the Dumitrescu–Hurlin panel causality test from 1992 to 2014. The results indicated that the consumption of clean energy significantly decreases carbon emissions. Altinoz and Dogan (2021) employed the quantile regressions estimation method on a panel of 82 countries from 1990 to 2014. The findings revealed that renewable energy consumption negatively influences carbon emission levels. In addition, Aziz et al. (2021) analysed the effects of natural resources, renewable energy and globalisation on carbon emission according to the EKC in the MINT countries by employing the new Method of Moments quantile regression model and Dumitrescu-Hurlin causality test. The outcomes verified the EKC hypothesis among income and carbon outflow except for higher quantiles. At the same time, renewable energy consumption caused a rise in carbon outflow at over half quantiles and reversed in below half quantiles. Thus, the analysis showed that energy supply from renewable sources did not meet the demand for energy consumption from 1995 to 2018.

Dogan and Seker (2016) tested the impact of renewable and non-renewable energy, real income and trade openness on carbon emissions in the European Union according to the EKC hypothesis throughout 1980 to 2012. The findings showed that non-renewable energy positively affects carbon emissions. Zhang et al. (2017) utilised the FMOLS, DOLS and C.C.R. approaches for Pakistan from 1970 to 2012 and validated the EKC hypothesis, reporting that renewable energy significantly and negatively affects carbon emissions. In contrast, the effect of the consumption of non-renewable energy on carbon emissions is significant and positive. Souza et al. (2018) explored the relationship among economic growth, renewable and non-renewable energy and carbon emissions according to the EKC hypothesis for the Southern Common Market (MERCOSUR) from 1990 to 2014. The outcomes indicated that the consumption of clean energy diminished carbon emissions and supported the EKC hypothesis, whereas non-renewable energy usage caused carbon emissions to increase. Chen et al. (2019) analysed the relationship among economic expansion, renewable energy and non-renewable energy consumption and carbon emissions within the EKC hypothesis concerning the regions of China from 1995 to 2012. Using both FMOLS and DOLS approaches, this study indicated that renewable energy negatively impacts carbon emissions in the regions to the east and west of the country, whereas in the central area, the effect is insignificant. However, in all areas, non-renewable energy positively impacts carbon emissions. Zafar et al. (2019) employed the V.E.C.M., CUP-FM, and CUP-BC models to examine the interaction among energy usage, trade openness, and carbon emissions for different emerging economies from 1990

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to 2015. The study showed that the consumption of non-renewable energy positively influences carbon emissions. Anwar et al. (2021) used the FMOLS, DOLS, FE-OLS approaches to test how energy consumption impacts carbon emission levels in the ASEAN countries between 1990 and 2018. The presented evidence verified the presence of the EKC hypothesis based on all approaches. In addition, the results demonstrated that non-renewable energy usage positively affects carbon emission levels.

Financial inclusion and CO_2 emissions

The existing literature highlighted that financial inclusion significantly affects economic variables. Sharma (2015) employed vector auto-regression (V.A.R.) models in this field, and the results indicated that economic growth and financial inclusion variables were positively correlated. Maune et al. (2020) used a regression model and examined how financial inclusion impacts the economic growth of Zimbabwe from 2011 to 2017. The study revealed that financial inclusion causes financial development to improve in Zimbabwe. Ratnawati (2020) examined the nexus between financial inclusion and income inequality, poverty, economic enlargement and financial stability in 10 developing countries in Asia for the period 2009 to 2018 by using G.M.M. methods. The findings showed that financial inclusion creates economic development and improves financial stability, thus diminishing poverty and income inequality. Van et al. (2021) studied financial inclusion and economic improvement in emerging markets using econometric panel techniques and found that economic development and inclusive finance were positively related. Barık and Pradhan (2021) explored how financial inclusion affects financial stability concerning the BRICS nations from 2005 to 2015 by using G.M.M. methods and the Dumitrescu and Hurlin panel Granger causality test. The authors stated that financial inclusion significantly impacts the financial stability of the BRICS nations. Huang et al. (2021) analysed how inclusive finance and trade openness impacted the economic development of 27 members of the European Union (E.U.) from 1995 to 2015 through the use of fully modified least squares (FMOLS). The study revealed that financial inclusion driven policies could be used as a catalyst to improve the financial system, which directly causes economic growth. Conversely, only a few studies have tested the effect of financial inclusion on pollution of the environment. Based on the literature review, financial inclusion policies can mitigate carbon emissions. Samour et al. (2019) used A.R.D.L. and FMOLS to examine how the banking industry impacted Turkish emissions of carbon between 1980 and 2014. The outcomes revealed that banking sector development has a significant positive effect on carbon emissions. Le et al. (2020) analysed how financial inclusion influences carbon emissions from 2004 to 2014 for 31 Asian countries by utilising S.T.I.R.P.A.T. The findings indicated that financial inclusion gradually increased carbon emissions in 31 Asian countries. Renzhi and Baek (2020) explored the presence of the Environment Kuznets curve (EKC) based on financial inclusion in 103 countries between 2004 and 2014. Pooled O.L.S. and fixed effects, G.M.M. and Arellano-Bond and Hansen tests were applied in the analysis. The findings validated the EKC and demonstrated that financial inclusion negatively influences carbon emissions. Also, financial inclusion development, which considers different customer segments, is a significant factor in mitigating environmental degradation. *Table 1* presents a summary of the primary outcomes of the empirical research that have tested the EKC hypothesis.

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Table 1. *Summary of the review of the literature on economic growth, energy consumption and financial inclusion*

	Authors	Period	Methodology	Country	The Results
1	Apergis and Ozturk (2015)	1990-2011	GMM	Asian Countries	EKC is valid
2	Boluk and Mert (2015)	1961-2010	ARDL	Turkey	EKC is valid
3	Al-Mulali et al. (2016)	1980-2010	DOLS-VECM Granger causality test	7 regions	EKC is valid
4	Chakravarty and Mandal (2016)	1997-2011	GMM	BRICS countries	EKC is not valid
5	Dogan and Seker (2016)	1980-2012	DOLS and Dumitrescu–Hurlin panel causality test	EU	EKC is valid
6	Narayan et al. (2016)	1960-2008	Cross correlation estimation approach	181 countries	EKC is valid
7	Zhang et al. (2017)	1970-2012	FMOLS, DOLS and C.C.R. approach	Pakistan	REC-CO_2 emissions
8	Haseeb et al. (2018)	1995-2014	D.S.U.R., and Dumitrescu-Hurlin Granger causality test	BRICS countries	EKC is valid
9	Souza et al. (2018)	1990-2014	Panel	MERSOCUR	REC-CO_2 emissions
10	Chen et al. (2019)	1995-2012	FMOLS, DOLS	China	REC-CO_2 emissions
11	Samour et al. (2019)	1980-2014	ARDL and FMOLS, CCR	Turkey	Banking sector+CO_2 emissions
12	Zafar et al.(2019)	1990-2015	VECM, CUP-FM, CUP-BC	Emerging economies	NREC+CO_2 emissions
13	Aydin and Turan (2020)	1996-2016	AMG, CCEMG	BRICS countries	EKC is not valid
14	Dogan and Lotz (2020)	1980-2014	FMOLS, OLS, STRIPAT technique	European countries	EKC is not valid
15	Ike et al. (2020)	1980-2010	M.M.Q.R. with fixed effects	15 oil producing countries	EKC is valid
16	Le et al. (2020)	2004-2014	STIRPAT	31 Asian countries	FC+CO_2 emissions
17	Ummalla and Goyari (2020)	1992-2014	FMOLS and Dumitrescu–Hurlin panel causality test	BRICS countries	EKC is valid
18	Renzhi and Baek (2020)	2004-2014	Pooled O.L.S. and fixed effects, G.M.M. and Arellano-Bond and Hansen tests	103 countries	FC-CO_2 emissions
19	Altınoz and Dogan (2021)	1990-2014	M.M.Q.R.	82 countries	REC-CO_2 emissions
20	Anwar et al. (2021)	1990-2018	MMQR	ASEAN countries	NREC+CO_2 emissions
21	Aziz et al.(2021)	1995-2018	M.M.Q.R., FMOLS, DOLS, FE-OLS	MINT countries	REC-CO_2 emissions
22	Bibi and Jamil(2021)	2000-2018	Random effect and fixed effect panel estimations	Different Selected Countries	EKC is valid
23	Sun et al. (2021)	1990-2017	V.A.R., V.E.C.M., Granger causality test	China	EKC is valid
24	Altarhouni et al.,(2021)	1988-2018	ARDL	Turkey	REC-CO_2 emissions
25	Qashou et al.,(2022)	1981-2015	ARDL	Turkey	NREC+CO_2 emissions

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Data Sources and Methodology of the Study

Data

Our data were sourced from the World Bank (W.B.) database and International Monetary Fund (I.M.F.) and consisted of annual observations for the BRICS countries covering 2002 to 2019. Moreover, the obtained data series included gross domestic product (G.D.P.) per capita as a proxy of economic growth, and financial inclusion (F.C.) is an index that is calculated using four sub-indices, including the number of A.T.M.s per 100,000 adults, the number of bank branches per 100,000 adults, the number of credit cards per 1,000 adults, and the number of debit cards per 1,000 adults. In addition, carbon dioxide (CO_2) emissions per capita were used as an indicator of environmental pollution, oil, coal and natural gas power utilisation (N.R.E.C.), and renewable energy consumption (R.E.C.). The details of the data are presented in *Table 2* variables of the study.

Table 2. *Study variables*

Variable	Symbol	Scale Unit	Definition	Source
Renewable energy consumption	R.E.C.	Quad B.T.U.	Consumption of renewable energy per capita	World Bank
Non-renewable energy consumption	N.R.E.C.	Billion B.T.U.s	Oil, coal, natural gas usage	World Bank
GDP	GDP	(constant 2010 US$)	Real GDP per capita (constant 2010US$)	World Bank
Financial Inclusion	F.C.	Calculation index on 4 sub-indices in the banking sector	The calculation of this index is based on 4 sub-indices: the amount of A.T.M.s for every 100,000 adults, the number of banking centres for every 100,000 adults, the number of credit cards for every 100,000 adults, and the number of debit cards for every 100,000 adults.	IMF
Carbon Emissions	CO_2	kiloton (kt)	Carbon emissions in metric tons	World Bank

Empirical methodology

Inspired by the existing literature, the effects of income, renewable energy and non-renewable energy, and financial inclusion on the emissions of CO_2 is formulated as follows (*Eq.1*):

$$CO_{2\,it} = f\,(\text{G.D.}P_{it}, \text{G.D.}P_{it}^2, \text{N.R.E.}C_{it}, \text{RE}C_{it}, \text{F}C_{it}) \qquad \text{(Eq.1)}$$

The investigated variables $CO_{2\,it}$, G.D.P_{it}, G.D.P_{it}^2, N.R.E.C_{it}, REC_{it}, FC_{it} represent CO_2 emissions, G.D.P., and the square of G.D.P., non-renewable energy, consumption of renewable energy and financial inclusion, respectively. The proxy used for REC_{it} is the usage of solar, hydroelectricity, and wind energy (Cui et al., 2022). The proxy used for N.R.E.C_{it} is the consumption of coal, oil, and natural gas—the proxy used for G.D.P_{it} is measured in constant US$. The proxy used for G.D.P_{it}^2 is the square of G.D.P. (Samour and Pata, 2022). The proxy used for FC_{it} is an index, the calculation of which is based on 4 sub-

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indices: the amount of A.T.M.s for every 100,000 adults, the number of banking centres for every 100,000 adults, the number of credit cards for every 100,000 adults, and the number of debit cards for every 100,000 adults. The variables mentioned above were acquired from the World Development Indicators (World Bank, 2021) and I.M.F.

Before assessing the unspecified parameters, various conventional introductory tests are employed to detect the time-series attributes of the factors. From this perspective, this study uses the cross-sectional dependence (CD) test as well as the augmented cross-sectional I.P.S. (C.I.P.S.) test proposed by Pesaran (2007) to measure cross-sectional dependence in the panel data as well as to generate superior outcomes that are probably unmeasured when conducting the first-generation test of Levin, Lin and Chu, Im, Pesaran, and Shin (Aziz et al., 2021).

We simultaneously used three progressive panel estimation approaches for heterogeneous panels called Dynamic O.L.S. (DOLS), Fully Modified O.L.S. (FMOLS), and the Fixed Effects O.L.S. (FE-OLS) testing models to examine the estimation coefficients amongst the investigated variables. The DOLS testing model was developed by Kao and Chiang (2001). Monte Carlo simulations settings form the framework of this test. On the other hand, the FMOLS testing model was developed by Pedroni (2004). The intercepts are unique for each series in the panel. The FE-OLS testing model was created with the standard errors of Driscoll and Kraay, and this test exhibits robustness to standard kinds of cross-sectional dependence.

In this case, models such as O.L.S. built on the assumption of normal distribution may reveal biased estimates. This study utilised a novel estimation approach to overcome this issue, namely the M.M.Q.R. test that was first proposed in the study of Machado and Santos Silva (2019). Unlike earlier regression methods, M.M.Q.R. is used to estimate results through moment conditions that do not assume the presence of the moment function or make distribution assumptions. The M.M.Q.R. approach has superiority as it considers conditional heterogeneous covariance effects of the components of the endogenous explanatory variables. M.M.Q.R. shows the nexus among the variables through different quantiles. Hence, the distributional and heterogeneous effects are ascertained by the panel quantile regression model across quantiles (Aziz et al., 2020). In addition, it reflects factual observations about the linkage between tested variables that consider the fixed effects of distribution heterogeneity. Hence, the testing model shows multiple conditions between tested variables in different conditional distributions that cannot be obtained using conventional regressions based on average factors estimates. However, it is essential to evaluate the tested variables at the conditional distribution within conditional quantiles to delineate the distributive impact of the independent variable on the dependent variable in various quantile ranges (Alhodiry et al., 2021).

To estimate the conditional quantiles $Q_y(\tau|X)$ for the model of the a location-scale variant, the equation (*Eq.2*) below is formulated:

$$Y_{it} = \alpha_{it} + X_{it}^{'}\beta + (\delta_i + Z_{it}\gamma)\mu_{it} \quad \text{(Eq.2)}$$

where the probability, $P\{\delta_i + Z_{it}\gamma > 0\} = 1.$ $(\alpha, \beta', \delta_i, \gamma')$ are estimated parameters. The object *i* fixed is reflected by (α_i, δ_i'). $i = 1, \ldots, n$, and Z is K-vector selected components of X that can be seen in a different format with particular l represented in *Eq.3*:

$$Z_I = Z_I(X),\ I = 1, \ldots, k \quad \text{(Eq.3)}$$

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$X_{it}^{'}$ is identically and independently disposed of for any stabilised *i* and independent through time (t). μ_{it} is identically and independently disposed within time (t), and are orthogonal to $X_{it}^{'}$ and normalised to verify the present status in Machado and Santos Silva (2019) that amongst other variables do not indicate rigid exogeneity. Thus, *equation (2)* designates by *Eq.4* stated below:

$$Q_y(\tau|X_{it}) = \left(\alpha_{it} + \delta_{iq}\,(\tau)\right) + X_{it}^{'}\,\beta + Z_{it}\,\gamma' q\,(\tau) \qquad \text{(Eq.4)}$$

In *Eq.4*, independent variables' vectors are indicated by $X_{it}^{'}$, which in the current study are defined as the natural logarithms of G.D.P_{it}, G.D.P_{it}^{2}, N.R.E.C_{it}, REC_{it}, FC_{it}. $Q_y(\tau|X)$ reflects the quantile distribution of the response variable Y_{it} (the natural log of $CO_{2\,it}$) which is subject to the position of the independent variable $X_{it}^{'}$. $\alpha_{it}(\tau) = \alpha_{it} + \delta_i q\,(\tau)$ is the scalar coefficient, which is significant of the quantile –τ fixed effect for individual *i*.

The particular impact indicates no intercept change, unlike the typical fixed least-squares results. These parameters are fixed within time, whose heterogonous degrees are fitted to deviant the conditional distributional quantiles of the selected variables within the model. The τ-the sample quantile is symbolised by q(τ), which is regarded by referencing the issue of optimisation (*Eq.5*):

$$min_q \sum_i \sum_t \rho_\tau\,(R_{it}\; - (\delta_i \;+\; Z_{it}'\,\gamma)\,q) \qquad \text{(Eq.5)}$$

In *Eq.4*, $\rho_\tau\,(A) \;=\; (\tau\;-1)\;AI\;\{A \le 0\} + \tau AI\;\{A > 0\}$ denotes the check function. To confirm the cause-and-effect relationship among the inspected factors, another method of the Dumitrescu and Hurlin (2012) test is utilised to examine the interconnection among the investigated variables in heterogeneous panel information models. In this model, there are two dimensions: the causal link's heterogeneity and the employed regression model's heterogeneity. The hypothesis of non-homogeneous causality H_0 is compared by two subclass options: The first one categorises the cause-and-effect interconnection among two variables, while the second subclass is constructed by two variables that have no relationship.

Empirical Results and Discussion

Unit root test of the second generation and panel co-integration test

The cross-sectional dependence and the C.I.P.S., Im, Pesaran, and Shin tests are presented in *Tables 3. and 4*. The C.I.P.S. test outcomes confirmed that ($CO_{2\,it}$, G.D.P_{it}, G.D.P_{it}^{2}, N.R.E.C_{it}, REC_{it}, FC_{it}) have an order of integration of I(1) at a 1% level of significance. The outcomes of the CD test indicated that the investigated variable series all have significant differences across panels at a significance level of 1%.

Table 5. presents the findings of the Pedroni (2004) and bootstrap Westerlund's (2007) co-integration tests. The test results indicate it is not possible to reject the null hypothesis of "no co-integration". Contrastingly, it is possible to accept the alternative hypothesis. These findings specify and affirm that the tested model variables have a long-run co-integration.

Table 3. *Results of the CD and C.I.P.S. unit root tests*

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Variables	CD test	p-value	C.I.P.S. test	
			Level	1st difference
$CO_{2\ it}$	12.15	0.00	- 1.953	- 5.211***
G.D.P_{it}	13.16	0.00	-1.201	- 6.008***
G.D.P_{it}^2	12.99	0.00	-0.951	- 5.698***
N.R.E.C_{it}	16.18	0.00	- 0.985	- 6.889***
REC_{it}	13.85	0.00	- 0.790	- 6.761***
FC_{it}	19.14	0.00	-1.1985	- 5.448***

Note: ***denotes that the null hypothesis is rejected at the 1% significance level

Table 4. *Stationary analysis outcomes*

	Im, Pesaran, and Shin			
	I(0) Cons	I(0) constant and tend	I(1) constant	I(1) constant and tend
$CO_{2\ it}$	-0.151	-0.250	-5.151***	-6.309***
G.D.P_{it}	-0.131	-0.231	-6.559***	-7.021***
G.D.P_{it}^2	-0.239	-0.320	-5.299***	-6.829***
N.R.E.C_{it}	0.315	0.322	6.315***	5.891***
REC_{it}	-0.589	-0.695	-6.589***	-6.021***
FC_{it}	1.210	1.158	5.210***	7.791***

Note: *** indicates that the null hypothesis is rejected at the 1% significance level

Table 5. *Pedroni co-integration test outcomes*

Test	Statistic	Prob
$CO_{2\ it}$= f(GDP_{it}, G.D.P_{it}^2, N.R.E.C_{it}, REC_{it}, FC_{it})		
Panel v	-0.623	0.650
Panel rho	-0.695	0.350
Panel PP	-3.985***	0.000
Panel ADF	-4.998***	0.000
Panel ADF	0.311	0.573
Group PP	-5.995***	0.000
Group ADF	-4.010***	0.000

Note: *, **, ***means significance of the tested variables at 10%, 5%, 1% levels, respectively

Panel estimation results

After proving that the tested variables are cointegrated, the research employed the DOLS, FMOLS, FE-OLS testing models. The findings of DOLS, FMOLS and FE-OLS presented in *Table 6*. show the influence of G.D.P_{it}, G.D.P_{it}^2, N.R.E.C_{it}, REC_{it}, and FC_{it} on the emissions of CO_2. The results show that at the 5% statistical significance level, G.D.P. positively and significantly influences CO_2 emissions. In contrast, G.D.P^2 negatively and significantly affects CO_2 according to the FMOLS, DOLS and FE-OLS testing models. The model specifications imply that a 1% rise in G.D.P. positively affects emissions by 2.9% according to the DOLS model, 2.3% according to the FMOLS model and 2.5% according to the FE-OLS model.

Table 6. *Results of panel estimation for BRICS nations*

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	DOLS		FMOLS		FE-OLS	
	Coef	**t-stats**	**Coef**	**t-stats**	**Coef**	**t-stats**
GDP_{it}	2.915**	9.795	2.315***	10.980	2.513***	9.889
G.D.P_{it}^2	-0.951**	-5.350	-0.7985***	-5.430	-0.651***	-6.002
REC_{it}	-0.250**	-6.235	-0.557***	-6.005	-0.995***	-5.563
N.R.E.C_{it}	0.884**	7.980	0.7985***	7.980	0.651***	6.851
FC_{it}	-0.410*	-5.621	-0.751	-5.985**	-0.215	3.995*

Note: *, **, ***means significance of the tested variables at 10%, 5%, 1% levels, respectively

Besides, the model specifications imply a 1% increase in G.D.P_{it}^2 negatively affects emissions by 0.95% according to the DOLS model, 0.79% according to the FMOLS model and 0.65% according to the FE-OLS model. The outcomes of this study validate the EKC hypothesis in the context of the BRICS nations. The results of the current research concur with those of empirical research conducted by Boluk and Mert (2015), Al-Mulali et al. (2016), and Narayan et al. (2016).

Across the model specifications, the findings for renewable energy consumption show that at the 5% statistical significance level, a 1% increase in REC_{it} causes CO_2 emissions to be negatively and significantly affected by 0.25% in the DOLS model, 0.55% in FMOLS and 0.99% in the FE-OLS testing models. This is aligned with the findings of existing empirical studies conducted by Zafar et al. (2019), Anwar et al. (2021), and Aziz et al. (2021). The energy transformation paradigm represents an important challenge for the sustainability of human well-being and economic growth. Clean energy utilisation is the primary driver in efforts to mitigate carbon emissions. Our outcomes are consistent with existing empirical studies, which confirm that environmental sustainability can be reached by producing clean energy.

In contrast, the findings for non-renewable energy consumption imply a 1% expansion in N.R.E.C_{it} consumption escalates the carbon emissions by 0.88% according to the DOLS model, 0.79% according to the FMOLS model and 0.65% according to the FE-OLS model. Hence, non-renewable energy consumption positively and significantly affects carbon emissions. The BRICS countries are therefore heavily dependent upon coal-based conventional energy supply. Thus, this indicates that the BRICS countries emit carbon dioxide. In this line, the BRICS nations should promote green finance to mitigate carbon emissions. The findings of the current research are consistent with the empirical studies conducted by Zhang et al. (2017), Souza et al. (2018), and Chen et al. (2019).

Conversely, the financial inclusion outcomes suggest that at the 5% level of statistical significance, the impact of FC_{it} on CO_2 emissions is negative and significant according to the FMOLS, DOLS and FE-OLS testing models. The results imply that as financial inclusion increases, this causes CO_2 to decrease by 0.41%, 0.75%, 0.21% in FMOLS, DOLS and FE-OLS, respectively. The outcomes of the current research are consistent with the empirical studies conducted by Renzhi and Baek (2020), who explored the existence of the Environment Kuznets curve (EKC) based on financial inclusion in 103 countries for the period between 2004 and 2014, using Pooled O.L.S. and fixed effects, G.M.M. and Arellano-Bond and Hansen tests.

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Method of moments of quantile regression results

This paper investigates the effects of G.D.P., consumption of non-renewable energy, renewable energy usage, and financial inclusion on the emissions of carbon for the BRICS Panel by employing the M.M.Q.R. model. In *Table 7*, the findings of panel quantile estimations (M.M.Q.R.). The outcomes show that the effect of G.D.P_{it} on CO_2 emissions is positive across all quantiles (1st to 9th quantiles). G.D.P_{it} causes CO_2 emissions to increase from the lower to middle quantiles, decreasing from 219% to 165%. Thus, the findings show that the emissions of CO_2 rise from the lower to middle quantiles, and the emission intensity decreases throughout the middle and upper quantiles. While G.D.P_{it}^2 negatively affects the level of carbon emissions across each of the quantiles (1st to 9th quantiles). Hence, the testing model outcome provides empirical findings that validate the EKC hypothesis in the BRICS countries. The outcomes of the quantile regression confirm the conclusions of the FMOLS, DOLS, FE-OLS tested models. The empirical findings demonstrate that as economic growth occurs, this initially accelerates carbon emissions but decreases carbon emissions.

Table 7. *Panel quantile estimations (M.M.Q.R.) results*

Variables	Location	Scale	Quantiles								
			0.10	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
G.D.P_{it}	0.711**	0.322***	1.889***	2.210***	2.235***	2.791***	2.191***	2.099***	1.981***	1.881***	1.651***
G.D.P_{it}^2	-0.631*	-0.299**	-0.890**	-0.931**	-0.860**	-0.880**	-0.832**	-0.795***	-0.733**	-0.652**	-0.611**
REC_{it}	-0.251**	-0.195**	-0.250**	-0.281**	-0.290***	-0.325**	-0.350***	-0.315***	-0.299**	-0.290**	-0.271**
N.R.E.C_{it}	0.650**	0.351***	0.291***	0.298***	0.396***	0.321***	0.299***	0.250***	0.248***	0.232***	0.202***
FC_{it}	-0.391**	-0.298*	-0.315*	-0.395*	-0.441**	-0.488**	-0.480**	-0.431**	-0.401	-0.388	-0.381

Note: *, **, ***means significance of the tested variables at 10%, 5%, 1% levels, respectively

The findings from the panel quantile estimations (M.M.Q.R.) show that the coefficient of $\mathrm{REC_{it}}$ for CO_2 emissions is significant and negative through all quantiles (1st to 9th quantiles), implying that renewable energy causes CO_2 emissions to decrease. The quantile regression finding confirms the conclusions of the FMOLS, DOLS, FE-OLS tested models. However, the BRICS economies are growing, which has caused a dramatic transformation in demand for energy due to pressure on the environmentally-friendly power generations. From medium to upper quantiles, there are sustainable levels on the effect of carbon emissions; thus, the incentives for a low carbon economy should be increased.

However, the findings show that N.R.E.C_{it} is significant and positive for the emissions of CO_2 throughout all quantiles (1st to 9th quantiles), and it is evident that more non-renewable energy consumption causes pollution to rise. The findings of the quantile regression confirm the findings of the F.M.L.O.S., DOLS, FE-OLS tested models. Moreover, the (M.M.Q.R.) findings show a significant and negative coefficient of FC_{it} impact emissions of CO_2 across quantiles (1st to 9th quantiles), which demonstrates that financial inclusion causes CO_2 emissions to decrease. However, our study provides new empirical evidence that financial inclusion negatively affects carbon emissions in the BRICS nations using the new M.M.Q.R. technique.

Furthermore, the heterogeneous causality technique for panel data (Dumitrescu and Hurlin, 2012) is employed for verifying the causality among the tested variables. The

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causality test results are shown in *Table 8*. A uni-directional cause-and-effect relationship is ascertained among G.D.P., G.D.P_{it}^2 , N.R.E.C_{it}, REC_{it} , FC_{it} and the levels of carbon emissions. Hence, G.D.P., G.D.P_{it}^2 , N.R.E.C_{it}, REC_{it}, FC_{it} cause $CO_{2\,it}$ in the BRICS economies.

Table 8. *Granger heterogeneous causality*

Null hypotheses	Z-bar	P-Value
G.D.P_{it} does not homogenously cause $CO_{2\,it}$	8.511***	0.000
$CO_{2\,it}$ does not homogenously cause G.D.P_{it}	1.511	0.211
G.D.P_{it}^2 does not homogenously cause $CO_{2\,it}$	7.511***	0.000
$CO_{2\,it}$ does not homogenously cause G.D.P_{it}^2	0.211	0.293
N.R.E.C_{it} does not homogenously cause $CO_{2\,it}$	8.511***	0.000
$CO_{2\,it}$ does not homogenously cause N.R.E.C_{it}	1.850	0.251
REC_{it} does not homogenously cause $CO_{2\,it}$	4.1251*	0.051
$CO_{2\,it}$ does not homogenously cause REC_{it}	0.151	0.399
FC_{it} does not homogenously cause $CO_{2\,it}$	7.150***	0.000
$CO_{2\,it}$ does not homogenously cause FC_{it}	1.991	0.319

Note: **, ***means the significance of the tested variables at 10%, 5% levels, respectively

However, the findings show that the EKC is valid in the BRICS countries. Furthermore, the results show that non-renewable energy consumption positively affects the levels of carbon emissions. In contrast, the findings from these tests show that renewable energy consumption negatively affects the levels of carbon emissions. Financial inclusion mitigates CO_2 emissions. The BRICS countries have extensive resources for renewable energy. In this context, China has extensive resources of wind and biomass, which have been assuming a significant share of the total capacity over the last years; the total generation capacity in the country experienced six-fold growth, reaching 91,400 MW. However, the renewable energy supply accounts for only 8%. China intends to reduce its emission levels by 2030 to around 60%-65%.

Brazil has extensive resources in wind energy sources; with the help of increased funding and technology, wind energy will provide around 10% of total electricity in 2023. A 2019 report published by the International Renewable Energy Association (I.R.E.N.A.) stated that Brazil meets 42% of its energy needs by using clean energy sources, and 41% of its primary energy supply is generated by oil. According to Nationally Determined Contributions (N.D.C.), Brazil proclaims to decrease its emissions of greenhouse gases (GHG) by 43% by 2030.

South Africa and India also have extensive resources for solar energy. South Africa became the first country with installed P.V. capacity approaching 1000 MW. The wind energy program in this country contributed much to this success. In this context, large-scale wind generators were constructed in the Darling Wind Farm in the country over the last few years. On the other hand, India is a tropical country with an average annual temperature of between 25 °C and 27 °C; the country receives around 5000 trillion kW h equivalents in the source of solar energy; this condition is suitable for the development of solar energy in India.

Despite the BRICS countries having extensive resources in renewable energy, they should promote the consumption and production of renewable energy. Therefore, one primary requirement is investment and financing in these sources to develop and promote

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renewable energy. Hence, the study suggests that policy-makers should develop energy strategies to reduce non-clean energy use through efficient energy use channels, and they should design systems to support projects and investments that use renewable energy resources. In this line, the policy-makers need to formulate conducive and investment-friendly environment policies to boost more green investment. Furthermore, the Policies should enhance new consumer influxes to accelerate financial inclusion and investment in renewable energies to implement zero-carbon production processes to mitigate pollution in the BRICS countries. Thus, this will lead to sustainable development in these countries.

Conclusion and Policy Implications

In this empirical study, the effects of financial inclusion, as well as the consumption of renewable and non-renewable energy on the emissions of carbon are examined according to the EKC hypothesis in the BRICS for 2002 and 2019, using multivariate structure techniques including DOLS and FMOLS FE-OLS and D-H panel causality estimation and M.M.Q.R. approaches. It is the first study to use the Method of Moments quantile regression technique to explore the connection among the selected variables according to the EKC hypothesis in the BRICS nations. The outcomes of the M.M.Q.R. model exhibit more sensitivity than the DOLS, FMOLS, FE-OLS approaches.

The findings of the DOLS, FMOLS, FE-OLS, M.M.Q.R. tests show that G.D.P. positively affects the levels of carbon emissions, while the impacts of GDP^2 on carbon emissions are adverse. However, the G.D.P. and GDP^2 results confirm that the EKC is valid for the BRICS nations. Furthermore, the DOLS, FMOLS, FE-OLS, and M.M.Q.R. test findings reveal that non-renewable energy consumption positively influences the levels of carbon emissions. In contrast, the conclusions of these tests reveal that renewable energy usage negatively affects the levels of carbon emissions. Therefore, based on the research findings, it is recommended that policy-makers develop energy strategies to reduce non-clean energy use through efficient energy use channels, and they should design systems to support projects and investments that use green energy resources. In this line, the policy-makers need to formulate conducive and investment-friendly environment policies to boost more green investment.

On the other hand, the findings of the DOLS, FMOLS, FE-OLS, and M.M.Q.R. tests show that financial inclusion mitigates carbon emissions. Renewable energy coefficients are significant and negative, which indicates that FC_{it} decreases the CO_2 emissions. THE RESULTS OF the D-H panel approach show that a uni-directional association exists among all variables and CO_2 emissions. According to the research findings, the BRICS must incentivise green investment for the sustainability of economic growth. This indicates that the BRICS countries should offer environmental and financial initiatives associated with CO_2 reduction, particularly by considering financial inclusion and renewable energies. Policies should promote the willingness of people to accelerate financial inclusion and investment in renewable energies to implement zero-carbon production processes to mitigate pollution in the BRICS countries. Thus, this will lead to sustainable development in these countries. Furthermore, further studies could also incorporate the digital financial inclusion variables for particular countries, and a similar study may also apply identical indicators for developing nations.

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