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Testing the Impact of Renewable Energy and Institutional Quality on Consumption-Based CO_2 Emissions: Fresh Insights from MMQR Approach

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Abstract: The motivation for this research stems from the United Nations Sustainable Development Goals (UN SDGs), specifically SDGs 7, 11, 12, and 13, which focus on the mitigation of climate change and sustainable economic development. This study examined the impact of renewable energy use, institutional quality, and production expansion on consumption-based carbon dioxide (CCO_2) emissions in BRICS countries (Brazil, Russia, India, China, and South Africa) from 1996 to 2020. To achieve this, we applied advanced econometric techniques, including second-generation cointegration and unit root tests, along with the novel panel method of moments quantile regression (MMQR). The Westerlund cointegration test confirmed the presence of a long-run co-movement among renewable energy usage, economic growth, institutional quality, and environmental quality, suggesting a stable equilibrium relationship between these variables. The results from MMQR reveal that GDP has a positive and statistically significant effect on CCO_2 emissions across all quantiles, indicating that economic expansion contributes to environmental degradation. In contrast, renewable energy consumption and institutional quality show negative and significant impacts on CCO_2 emissions, indicating their mitigating effect on environmental deterioration. As a robustness check, the findings from fixed-effect OLS (FE-OLS), generalized method of moments (GMM), and common correlated effects mean group (CCEMG) estimations broadly confirm the results of MMQR. These findings underscore the importance of renewable energy consumption and strong institutional frameworks in promoting environmental sustainability.

Keywords: institutional quality; BRICS; renewable energy; MMQR; economic growth

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Academic Editor: Grigorios L. Kyriakopoulos

Received: 4 November 2024
Revised: 5 January 2025
Accepted: 12 January 2025
Published: 17 January 2025

Citation: Almulhim, A.A.; Inuwa, N.; Chaouachi, M.; Samour, A. Testing the Impact of Renewable Energy and Institutional Quality on Consumption-Based CO_2 Emissions: Fresh Insights from MMQR Approach. *Sustainability* **2025**, *17*, 704. https://doi.org/10.3390/su17020704

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1. Introduction

The interplay between consumption and production plays a pivotal role in shaping the global economy. However, this dynamic interaction with the natural environment and resources often has detrimental effects on the planet, contributing to climate change and associated environmental challenges. These challenges include air pollution, which is responsible for approximately 5 million deaths annually, increased waste generation, deforestation impacting millions of hectares each year, and water contamination costing the global economy an estimated USD 500 billion annually [1]. While production-based greenhouse gas (GHG) emissions have historically guided climate mitigation policies, consumption-based carbon dioxide (CO_2) emissions have become a top priority for policymakers. The Paris Agreement on climate change underscores this urgency, calling for a

25% reduction in GHG emissions and a commitment to limit the global temperature rise to below 2 °C, with an aspirational goal of 1.5 °C [2].

All BRICS member countries have acceded to the Paris Agreement. Their economies have been identified not only as major contributors to emissions but also as consistent sources of rising CO_2 emissions over the last few decades [3]. By 2025, the economic growth of BRICS nations is projected to account for approximately 50% of the global economy. This growth, even after the global financial crisis of 2009, underscores their dominance among contemporary emerging economies. For instance, Brazil's economy has remained stable, while India and China experienced growth rates of 5.9% and 8.1%, respectively [4].

Although the BRICS nations have committed to decarbonizing the global economy by 2050, this transition is likely to have varied impacts due to their differing economic policies. These economies heavily rely on fossil fuels not only as a primary energy source but also as a significant source of government revenue. Consequently, a one-size-fits-all approach is impractical. Instead, tailored transition strategies are essential to address these differences [5].

In addition to reducing fossil fuel consumption through efficient technologies, transitioning to renewable energy sources offers a viable alternative for mitigating environmental degradation. However, achieving a seamless transition requires sound and efficient institutions capable of enacting and implementing policies that facilitate the adoption of renewable energy technologies. Such institutions also play direct and indirect roles in ensuring environmental sustainability [6].

Recent studies have identified institutional quality as a critical determinant of environmental outcomes. Countries with strong institutions are better positioned to achieve environmental sustainability through effective environmental stewardship. The marked shift toward clean energy consumption and improved energy efficiency observed in recent decades can be attributed to advancements in institutional quality [7].

This research contributes to the existing literature in several ways. First, to the best of our knowledge, it is the first study to examine the dynamic relationships among renewable energy consumption (as a percentage of total energy consumption), institutional quality (six dimensions), GDP per capita, and consumption-based CO_2 emissions in BRICS member countries. Second, this study employed an innovative econometric estimation approach, method of moments quantile regression (MMQR), proposed by Machado and Silva [8]. Many empirical studies in environmental science suffer from two fundamental shortcomings: reliance on OLS mean regression models, which assess only the conditional mean of the endogenous variable [9], and a failure to address heterogeneous data distributions, leading to inaccurate estimates [10]. MMQR addresses these limitations by evaluating the heterogeneous effects of renewable energy consumption and institutional quality on consumption-based CO_2 (CCO_2) emissions across different quantiles (e.g., 0.10, 0.30, 0.50, 0.70, and 0.90). This approach fills a gap in the existing literature, providing nuanced insights into how these factors influence CCO_2 emissions at varying levels. Additionally, MMQR serves as an important planning and resource management tool, offering policymakers actionable insights for targeted interventions.

This study also examined regional differences within BRICS nations using MMQR. Unlike conventional methods that average data, MMQR reveals heterogeneous effects across the entire distribution, enabling a comprehensive understanding of region-specific dynamics [11]. Furthermore, this technique effectively addresses individual, temporal, and spatial effects while correcting for endogeneity issues, as demonstrated by Ghosh et al. [12].

Third, this study enhanced reliability by employing alternative estimation techniques, including fixed-effect OLS (FE-OLS), generalized method of moments (GMM), and common correlated effect mean group (CCEMG) estimators. Finally, the findings provide valuable

insights for policymakers in BRICS nations, emphasizing the importance of adopting eco-friendly technologies to enhance environmental quality.

The research is structured into five sections, beginning with this introduction. Section 2 reviews the relevant literature. Section 3 outlines the data definitions, sources, and estimation strategy. Sections 4 and 5 present the empirical findings and conclude with policy recommendations, respectively.

2. Literature Review

The threat to environmental sustainability remains a significant challenge for policymakers and researchers, particularly as human activities continue to drive air pollution and exacerbate global warming [13]. In response, a growing body of literature has examined the determinants of environmental degradation, which can be categorized into three key strands. The first strand explores the relationship between economic output expansion and carbon emissions, providing a foundational understanding of how economic growth influences environmental quality. The second strand investigates the impact of institutional quality on carbon emissions, highlighting the role of governance and regulatory frameworks in mitigating environmental harm. The third and final strand focuses on the relationship between energy consumption—disaggregated into renewable and non-renewable sources—and CO_2 emissions, offering insights into the potential for clean energy transitions to reduce carbon footprints.

2.1. Economic Growth and Carbon Emissions

A baseline study by Grossman and Krueger [14] highlighted a significant interconnection between output expansion and environmental deterioration, which follows a threshold effect. Beyond this turning point, economies tend to adopt efficient production methods capable of reversing environmental damage. This phenomenon is encapsulated in the environmental Kuznets curve (EKC), which depicts an inverted U-shaped relationship between economic growth and environmental degradation. Over the years, the EKC hypothesis has inspired a wealth of empirical studies examining the nexus between economic growth and CO_2 emissions, yielding diverse and sometimes contradictory results.

Numerous studies validate the presence of the EKC. For instance, Shahbaz et al. [15], in Pakistan, Ali et al. [16], in Malaysia, Apergis and Ozturk [17] in 14 Asian economies, Bilgili et al. [18] across 17 countries, Haseeb et al. [19], and Akadiri et al. [20] for BRICS nations, as well as Destek and Sarkodie [21] in 11 newly industrialized countries, have provided robust empirical evidence. Additional studies by Rahman et al. [22] in 16 Central and Eastern European countries (CEECs), Mert et al. [23] in 26 European economies, Dogan and Inglesi-Lotz [24] in 7 EU countries, Baloch et al. [25] in OECD economies, Sarkodie and Ozturk [26] in Kenya, Murshed et al. [27] in 6 Asian nations, Abbassi et al. [28] in 26 European countries, and Si Mohammed et al. [29] across advanced and emerging economies further support the EKC hypothesis. Other multi-country investigations have also validated the EKC framework [30–34].

Conversely, some studies refute the EKC hypothesis. Notably, Acaravci and Ozturk [30] found no evidence for 19 EU countries, Arouri et al. [35] for 12 MENA countries, and Antonakakis et al. [36] for 106 economies segmented by income levels. Similarly, Hu et al. [37] for 25 developing nations, Pata and Aydin [38] in 6 hydropower-dependent countries, Koc and Bulus [39] for SouthKorea, and Pata and Caglar [40] in China failed to corroborate the EKC framework.

Finally, a growing body of research provides mixed evidence regarding the EKC's validity. For example, Ahmed et al. [41] confirmed the EKC hypothesis for 24 European countries only in the long run, while Akadiri et al. [20] observed similar patterns in BRICS

nations. Urban and Nordensvärd [42] analyzed Nordic countries, finding that the EKC hypothesis holds for Denmark, Iceland, and Sweden, but not for Finland. Churchill et al. [43] explored 20 OECD nations and found evidence of an EKC in only 9, with variations including inverted U-shaped and N-shaped relationships. Similarly, Gormus and Aydin [44] identified the EKC in Israel, but not in other top innovative economies.

2.2. Institutional Quality and Carbon Emissions

The assessment of institutional quality often involves various proxy indicators, reflecting its multifaceted influence on environmental outcomes. For instance, Lau et al. [45], using Malaysia as a case study, examined the long-run relationship between the institutional framework and CO_2 emissions over the period 1984–2008. They employed institutional quality indicators such as "law and order" and found that the interaction term between CO_2 emissions and institutional quality indices strengthens the mitigation effect. This suggests that robust institutional quality is crucial for controlling CO_2 emissions while fostering economic development. Consequently, policymakers must ensure institutional efficiency to prevent environmental deterioration. Zhang et al. [46], in their analysis of Asia-Pacific Economic Cooperation (APEC) countries from 1992 to 2012, confirmed that reducing corruption enhances environmental quality. Similarly, Wang et al. [47] examined the nexus of corruption, economic growth, and CO_2 emissions in BRICS nations from 1996 to 2015, concluding that controlling corruption significantly reduces air pollution.

Wawrzyniak and Doryń [48] explored the effect of institutional quality on CO_2 emissions in a sample of 93 developing and emerging economies between 1995 and 2014. Using GMM estimators, they demonstrated that improvements in institutional frameworks, such as controlling corruption and enhancing government effectiveness, mitigate the growth of CO_2 emissions as GDP rises. These findings underscore the need for countries to prioritize institutional reforms to achieve sustainable development. In a more recent study, Le and Ozturk [49] analyzed 47 countries from 1990 to 2014, highlighting how qualitative institutional improvements influence CO_2 emissions. They posited that stronger institutions can promote economic activities and attract investment and trade through economic globalization, inadvertently stimulating CO_2 emissions via the multiplier effect of heightened economic activities. Using a novel quantile autoregressive distributed lag (QARDL) approach, Godil et al. [50] assessed the interplay among institutional quality, ICT, financial development, and CO_2 emissions in Pakistan from 1995Q1 to 2018Q4. Their findings revealed a long-run co-movement between institutional quality and CO_2 emissions.

However, contrasting findings have also emerged in the literature. For instance, Farzanegan and Markwardt [51] analyzed annual data from 1980 to 2015 to explore the income–emissions–democracy nexus in 17 Middle Eastern and North African (MENA) countries. Their results indicated that democratic institutions failed to disrupt CO_2 emissions effectively. Additionally, Arminen and Menegaki [52] investigated the impact of corruption, economic growth, and energy use on CO_2 emissions in 67 countries segmented by income groups between 1985 and 2011. Their findings suggested that the role of corruption in environmental outcomes is not statistically significant.

2.3. Renewable Energy and Carbon Emissions

Renewable energy plays a crucial role in sustainable development, serving as a cornerstone for mitigating environmental damage. Efforts to enhance the quantity and efficiency of renewable energy are embedded in greenhouse gas reduction strategies at local, national, and international levels. A study conducted on Pakistan during the period 1990–2014 demonstrated that renewable energy consumption is a significant factor in reducing carbon emissions [53]. Similarly, Bekun et al. [54], employing the panel PMG version of ARDL,

analyzed data from 16 EU countries and found an inverse relationship between renewable energy usage and air pollution. In a study focusing on nine green countries, Caglar [55] utilized the bootstrap ARDL model and confirmed the mitigating effects of renewable energy on CO_2 emissions.

Sulaiman et al. [56] explored the environmental impact of renewable energy, specifically wood biomass energy, on CO_2 emissions in the EU-27. Their findings indicated that in the long run, wood biomass energy usage adversely affects environmental quality. In contrast, Ikram et al. [57], examining SAARC countries from 2000 to 2014, reported that renewable energy consumption contributes to a decline in CO_2 emissions. Using system GMM and Granger causality tests, Ben Jebli et al. [58] analyzed 120 nations categorized by World Bank income classifications between 1990 and 2015, highlighting the CO_2 emission-reducing effect of renewable energy.

Khattak et al. [59] explored the complex interplay among renewable energy, innovation, and environmental degradation within the EKC framework in BRICS nations. Their results revealed an inverse relationship between renewable energy consumption and CO_2 emissions in BRICS countries, except South Africa. Kuldasheva and Salahodjaev [60] investigated rapidly urbanizing countries, employing system GMM estimators to show that renewable energy usage reduces CO_2 emissions. Similarly, Salahodjaev et al. [61] and Sahoo et al. [62] reinforced these findings, highlighting the strengthened impact of renewable energy in Asian and European contexts.

Focusing on renewable energy and institutional quality as drivers of environmental sustainability offers novel insights. Few studies have explored this interaction, and their findings remain inconclusive. For example, Ding et al. [63] examined G7 economies from 1990 to 2018, demonstrating that renewable energy consumption and productivity improvements enhance environmental sustainability. In Chile, Kirikkaleli et al. [64] documented the positive impact of renewable energy usage on environmental quality from 1990 to 2017.

Balsalobre et al. [65] emphasized the importance of reducing reliance on non-renewable energy sources to achieve sustainable energy strategies. However, non-renewable energy continues to dominate the global energy mix, contributing to environmental degradation. Xie and Liu [66] and Ali et al. [67] found a strong connection between non-renewable energy consumption and environmental deterioration. Similarly, Mahalik et al. [68] demonstrated the positive impact of non-renewable energy usage on CO_2 emissions in BRICS economies from 1990 to 2015. Adebayo et al. [69] confirmed the same for MINT countries between 1990 and 2018, indicating that non-renewable energy drives climate change through higher CCO_2 emissions.

Renewable energy, identified as environmentally friendly, has been widely recognized for its potential to improve environmental quality, as reaffirmed by the recent Paris Agreement. However, many studies examining environmental quality through the lenses of the EKC and institutional quality have limitations. Most studies rely on single governance indicators as proxies for institutional quality, offering an incomplete perspective.

Methodologically, a majority of reviewed studies utilized conditional mean regression, which provides only partial insights into the conditional distribution. Departing from this approach, the current study employs the moment quantile regression method of Machado and Silva [8]. This novel technique accounts for the heterogeneous and conditional distributional effects of renewable energy consumption and institutional quality on consumption-based CO_2 emissions. Moreover, it addresses challenges related to time, location, and individual effects, offering a comprehensive perspective.

3. Data and Methodology

The present study sought to investigate the influence of renewable energy usage and institutional quality on consumption-based CO_2 (CCO_2) emissions in BRICS economies, controlling for output expansion, over the period 1996 to 2020. The data for consumption-based CO_2 emissions were sourced from the Global Carbon Atlas, while data on GDP and renewable energy utilization were obtained from the World Bank Database (2021). Institutional quality was measured using the Institutional Quality Index provided by the World Bank. Table 1 provides a detailed summary of the variable definitions and their respective data sources.

Table 1. Variables and data sources.

Symbol	Variable	Definition	Source
CCO_2	Consumption-Based CO_2 Emissions	Million tons of CO_2 emissions	Global Carbon Atlas (2021)
GDP	Economic Growth	GDP per capita constant/2015	WDI (2021)
REC	Renewable Energy Consumption	Share of renewable energy of total energy consumption	WDI (2021)
IQ	Institutional Quality	Six blocks of institutional quality factors	WDI (2021)

Source: WDI and Global Carbon Atlas.

The study estimated the following econometric model, which draws on frameworks proposed by Samour et al. [70], Kirikkaleli and Adebayo [71], Jahanger et al. [72], and Ali and Kirikkaleli [73] with modifications to suit the research objectives:

$$CCO_{2it} = f(GDP_{it}, REC_{it}, IQ_{it}) \quad (1)$$

In Equation (1), CCO_2 represents consumption-based carbon emissions in million tons of CO_2 and stands for environmental degradation [74–76]. The advantage of using CCO_2 lies in the fact that it takes into account the importance of the global supply chain, in addition to identifying where the emissions emanate and the possible place where they are consumed [74]. GDP per capita represents economic growth, consistent with the approach used by Balsalobre-Lorente et al. [65]. Furthermore, REC stands for renewable energy consumption, while IQ demonstrates the Index of Institutional Quality. This index is based on six key factors classified by the World Bank, namely, the rule of law, the efficiency of regulation, control of corruption, voice and accountability, political stability, and regulatory quality. This study proposes the following model for empirical research:

$$\ln CCO_{2,it} = \gamma_0 + \gamma_1 \ln GDP_{it} + \gamma_2 \ln REC_{it} + \gamma_3 \ln IQ_{it} + \epsilon_{it} \quad (2)$$

In Equation (2), $\gamma_1 - \gamma_3$ represent the slope coefficients to be estimated. ϵ_{it} donates the white noise stochastic error terms, which have a mean of zero and unit variance. The subscript i refers to the countries (1, 2, . . ., N), while t indicates the time period (1, 2, . . ., T).

In panel data analysis, testing for cross-sectional dependence (CD) has gained significant attention in recent years, as overlooking it can lead to misleading and unreliable results [77–79]. To assess whether cross-sectional dependence exists among BRICS nations, we employed the cross-sectional CD test [80]. The test is presented as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+j}^{N} \rho_{ij} \right) \quad (3)$$

In Equation (3) above, N represents the number of cross-sectional units, T denotes the time period, and ρ_{ij} is the pairwise correlation of the residuals.

To examine the integration properties of the variables, we applied the second-generation unit root tests CIPS and CADF proposed by Pesaran [80]. First-generation unit root tests, such as the Fisher-type panel unit root test used by Choi [81] and the LLC panel unit root test used by Levin et al. [82], fail to address issues of cross-sectional dependence. In contrast, the more recent CIPS and CADF tests provide efficient and accurate empirical results by accounting for cross-sectional dependence and heterogeneity across the sample. The equations for these tests are as follows:

$$\Delta Y_{it} = \gamma_1 + \alpha_i Y_{it-1} + \beta_i \overline{Y}_{it-1} + \sum_{j=0}^{q} Y_{ij} \Delta \overline{Y}_{it-1} + \sum_{j=0}^{q} \varphi_{ij} Y_{it-1} + \varepsilon_{it} \quad (4)$$

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T) \quad (5)$$

γ_1 indicates a deterministic term, q is the lag order and $\overline{Y}_t$ interprets the cross-sectional mean of time t.

Beyond the potential presence of cross-sectional dependence, the assumption of slope heterogeneity is another important issue that should be examined in panel time-series data. Swamy [83] conducted the pioneering research on the homogeneity test. The equation below illustrates Swamy's test:

$$\widetilde{S} = \sum_{i=1}^{N} \left(\hat{\delta}_i - \widetilde{\delta}_{WFE} \right)' \frac{X_i' M_\tau X_i}{\widetilde{\sigma}_i^2} \left(\hat{\delta}_i - \widetilde{\delta}_{WFE} \right) \quad (6)$$

Therefore, we employed an extension of Swamy's test developed by Pesaran and Yamagata [84] to test the homogeneity of the model's coefficients. In this version, Pesaran and Yamagata [84] introduce two statistics: delta-tilde $\left(\widetilde{\Delta} \right)$ and the deviation-correlated delta-tilde $\left(\widetilde{\Delta}_{adj} \right)$, as shown in the following format:

$$\widetilde{\Delta} = \sqrt{N} \left(\frac{N^{-1} \widetilde{S} - k}{\sqrt{2k}} \right) \sim \chi_k^2 \quad (7)$$

$$\widetilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1} \widetilde{S} - k}{\vartheta(T,k)} \right) \sim N(0,1) \quad (8)$$

where N is the number of cross-sectional units, T represents the time dimension; k is the number of independent variables, and $\widetilde{S}$ is Swamy's test statistic. If the *p*-value of the test exceeds 5%, the H_0 is accepted at the 5% significance level, indicating that the cointegration coefficients are considered homogeneous.

Although conventional first-generation panel cointegration tests, such as those of Johansen, Pedroni, and Kao, have limitations due to their reliance on the assumption of no cross-sectional dependence, much of the literature continues to use these tests to analyze long-term relationships among variables. However, cross-sectional dependence across countries may lead to a loss of power when testing for long-run equilibrium relationships in panel time-series data. To address this issue, we employed the second-generation panel cointegration technique proposed by Westerlund [85] to investigate the presence of long-run connections between the selected variables. Based on the value of the autoregressive parameter under the null hypothesis of no long-run co-movement, Westerlund [85] intro-

duced four statistics that assess the presence of error correction, both for individual panel groups and for the entire panel, in the context of cross-sectional dependence.

$$G_t = N^{-1}\sum_{i=1}^{N} \frac{'\alpha_i}{SE('\alpha_i)} \quad (9)$$

$$G_\alpha = N^{-1}\sum_{i=1}^{N} \frac{T'\alpha_i}{'\alpha_i(1)} \quad (10)$$

$$P_t = \frac{'\alpha}{SE('\alpha_i)} \quad (11)$$

$$P_a = T'\alpha \quad (12)$$

As such, $'\alpha$ depicts the error correction that can be calculated by integrating the values of T and P_a into the above equations.

If Westerlund's [85] test identifies a cointegration relationship among the study variables, the next step is to estimate the relationships among the selected variables. This study employed the recently popularized method of moments quantile regression (MMQR), introduced by Machado and Silva [8]. This method is utilized to uncover not only the heterogeneous influences but also the distributional effects at each of the assessed quantiles in the framework under examination. It is important to note that traditional quantile regressions perform poorly when unobserved heterogeneity exists across panels. In contrast, MMQR accounts for covariance effects, considering conditional heterogeneity, and offers robustness to cross-sectional dependence (CD) [86]. Additionally, endogeneity is a significant issue in traditional quantile regressions, often leading to invalid estimates. MMQR, however, overcomes these limitations, providing both robust and reliable estimates in the presence of endogeneity [70]. Finally, the technique produces more reliable estimates compared to conventional estimators such as FE-OLS, GMM, and CCEMG models. The results from these models will not only serve as a sensitivity test but also provide a basis for a comparative analysis of the conditional mean effects of the explanatory variables on the dependent variables. The following model, when estimated, captures the conditional quantiles along with their location-scale variants, as outlined below:

$$J_{it} = \varphi_{it} + K'_{it}\phi + (\chi_i + L_{it}\lambda')\varepsilon_{it} \quad (13)$$

where $i = 1, 2 \ldots, n$ represents the individual fixed effects, $t = 1, \ldots, T$ stands for time, with probability $P(\chi_i + L_{it}\lambda') \succ 1 = 0$ and $(\varphi, \phi, \chi, \lambda')$ for the estimated parameters. L stands for the K-vector of the unknown explanatory variables, and it is further specified as follows:

$$L_l = L_l(K),\ l = 1, \ldots k \quad (14)$$

where the independent and identical distribution for all fixed i but independent of t is represented by K_{it} and ε_{it} distributed across i and t, but orthogonal to K_{it}, as rightly put by Machado and Silva [8]. Thus, Equation (13) can be respecified in Equation (15) as follows:

$$Q_J(\tau / K_{it}) = (\varphi_i + \lambda_i q(\tau)) + K'_{it}\phi + L_{it}\lambda q(\tau) \quad (15)$$

where (τ / K_{it}) and K'_{it} stand for the quantile distribution of the explained variable and vector of the explanatory variables ($lnIQ_{it}$,$lnREC_{it}$,$lnGDP_{it}$) in the natural logarithms, respectively. Scalar coefficients stand for $L_{it} - \phi_i(\tau) \equiv \phi_i + \lambda_i q(\tau)$, implying the fixed-effect quantile τ for the associated cross section i. However, it is important to emphasize that individual effect does connote intercept shift as obtained in the conventional least squares fixed effects. The coefficients of the parameters do not change over time, and the heteroge-

neous impact can vary along with endogenous variable J of the conditional distribution of the quantiles. $q(\tau)$ stands for the τ-th sample quantile, which is obtained by optimizing the function as follows:

$$\min_q \sum_t \sum_t \theta_\tau (R_{it} - \chi_i + L_{it}\lambda)q) \quad (16)$$

where $\theta_\tau(A) = (\tau - 1)AI[A \leq 0] + TAI[A \succ 0]$ satisfies the check function.

To ensure the robustness of the estimated parameters, we initially applied three related techniques: OLS (FE-OLS), GMM, and CCEMG. Figure 1 illustrates the methodological framework of the current study.

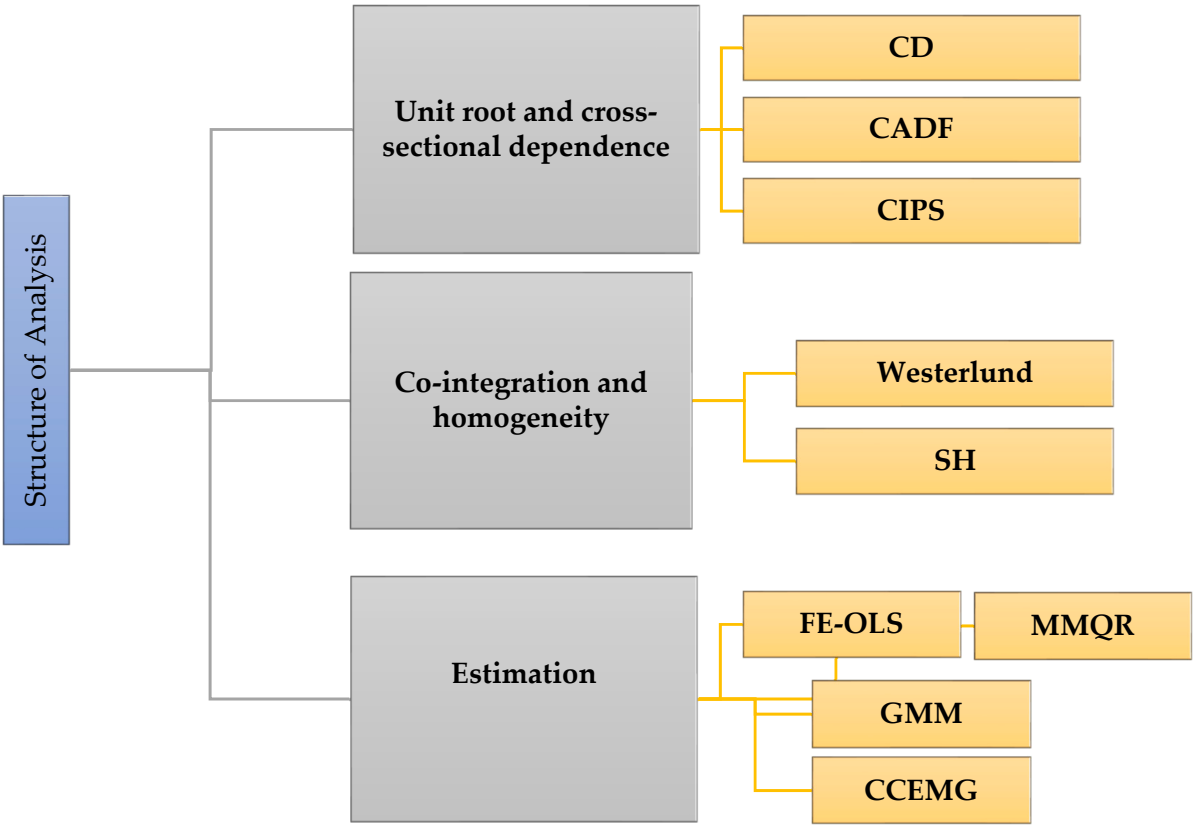


Figure 1. Structure of analysis.

4. Empirical Findings

4.1. CD and Unit Root Test Results

The study presents both cross-sectional dependence (CD) and cross-sectional-based unit root tests in Table 2. The results from the CD test indicate that CCO_2, GDP, REC, and IQ exhibit cross-sectional dependence at the 1% significance level. This leads to the rejection of the null hypothesis (*H*0) that posits that the variables are cross-sectionally independent, suggesting that all the study variables are cross-sectionally dependent. Additionally, the CD test serves as a criterion for choosing between first- and second-generation methodologies. Therefore, the CD test supports the use of second-generation unit root tests, such as CADF and CIPS, which are designed to account for cross-sectional dependence. The results of these tests, shown in Table 2, indicate that the variables, at their level values, contain unit roots. However, the variables become stationary after differencing, confirming that all tested variables are integrated of order I (1) at the 1% significance level.

Table 2. Outcomes of CD, CIPS, and CADF tests.

Variables	CD		CIPS		CADF	
	I(0)	*p*-Value	I(0)	I(I)	I(0)	I(I)
CCO_2	8.00 ***	0.000	−2.400	−4.283 ***	−0.830	−2.855 ***
GDP	13.92 ***	0.000	−2.441	−4.117 ***	−1.681	−2.940 ***
REC	6.02 ***	0.000	−0.785	−5.441 ***	−1.311	−3.779 ***
IQ	3.21 ***	0.000	−1.658	−4.107 ***	−2.07	−4.843 ***

Note: Authors' computation. *** 1% level of significance.

4.2. Slope Heterogeneity Test Results

Next, we conducted the slope heterogeneity (SH) test proposed by Pesaran and Yamagata [84]. Table 3 presents the results of the SH test, with both delta ($\hat{\Delta}$) and adjusted delta ($\hat{\Delta}_{\text{Adj}}$) being statistically significant at the 1% level. This leads to the rejection of the null hypothesis that the slopes of the coefficients are homogeneous, thereby confirming the presence of slope heterogeneity. The findings suggest that slope heterogeneity is valid in the BRICS economies, which can be attributed to the diverse economic structures within these nations.

Table 3. Outcomes of slope heterogeneity test.

$\hat{\Delta}$	*p*-Value	$\hat{\Delta}_{\text{Adj}}$	*p*-Value
8.469 ***	0.000	9.469 ***	0.000

Note: Authors' computation. *** 1% level of significance.

4.3. Cointegration Test Results

The results from both the CADF and CIPS tests suggest the use of the Westerlund cointegration test, and the findings are reported in Table 4. This test is specifically employed to examine the long-run co-movement of variables. The outcomes from the tests confirm the presence of cointegration among the variables, with the exception of the statistics. These results indicate the existence of a long-run equilibrium relationship and co-movement among the variables (CCO_2, REC, GDP, and IQ).

Table 4. Results of Westerlund cointegration test.

Statistics	Value	Z-Value	*p*-Value
Gt_t	−2.403 **	−2.180	0.015
Ga_t	−8.872	−1.246	0.106
Pt_t	−5.096 **	−2.258	0.012
Pa_t	−8.175 ***	−2.590	0.005

Note: Authors' computation. ***, ** 1% and 5% levels of significance, respectively.

4.4. Quantile Regression

After establishing the cointegration relationship among the examined variables, we applied the MMQR to capture the quantile associations between CCO_2 and the variables REC, GDP, and IQ. The results of the MMQR approach are presented in Table 5**.**

The results show that GDP has a positive and statistically significant impact on CCO_2 emissions across all quantiles. This relationship is likely linked to the collective and comprehensive efforts of BRICS nations to boost their economic output. Given the importance of BRICS in the global economy, with their combined output representing over 20% of global production, the connection between output expansion and fossil fuel consumption—the dominant conventional energy source in these countries—is evident. These findings are consistent with those of Akadiri et al. [20] for BRICS nations, Murshed et al. [27] for six

selected Asian economies, Abbasi et al. [28] for 26 European countries, Ghosh et al. [12] for BRICS economies, Samour et al. [87] for Belgium, and Inuwa et al. [88] for India, all of which confirm that an increase in GDP leads to a rise in environmental degradation.

Table 5. Outcomes of MMQR.

Variables	Quantiles				
	0.10	**0.30**	**0.50**	**0.70**	**0.90**
GDP	0.764 ***	0.748 ***	0.728 ***	0.712 ***	0.679 ***
REC	−0.067 ***	−0.052 ***	−0.035 *	−0.022 *	−0.03 *
IQ	−0.035 ***	−0.039 ***	−0.044 ***	−0.048 ***	−0.057 **
Alternative measures					
GDP	0.772 ***	0.752 ***	0.73 ***	0.711 ***	0.675 ***
REC	−0.072	−0.055 ***	−0.03 ***	−0.022 *	−0.008
IQ	−0.036 ***	−0.04 ***	−0.045 ***	−0.049 ***	−0.057 *

Note: Authors' computation. ***, **, and * 1%, 5%, and 10% levels of significance, respectively.

Additionally, the MMQR revealed a significant mitigating effect of renewable energy consumption (REC) on CCO_2 emissions across all quantiles. The inverse relationship between renewable energy usage and consumption-based CO_2 emissions indicates the positive impact of renewable energy utilization on environmental quality among BRICS member countries. This aligns with the planned actions to achieve the Paris Agreement, as reflected in the nationally determined contributions (NDCs). Over the last five years, the continuous efforts of BRICS countries have led to an increase in the proportion of renewable energy in total primary energy consumption. These findings are consistent with those of Ding et al. [63] for G7 countries, Kirikkaleli et al. [64] for Chile, Adeleye et al. [89] for selected South Asian economies, Samour et al. [87] for Belgium, Ghosh et al. [12] for BRICS economies, and Inuwa et al. [88] for India, all of which show that higher use of renewable energy leads to reduced environmental degradation.

On the other hand, the MMQR results demonstrate that institutional quality has a negative and statistically significant impact on CCO_2 emissions across all quantiles. This suggests that improved institutional quality plays a crucial role in enhancing environmental sustainability in BRICS countries. High-quality institutions, with their constitutional and political authority, can effectively regulate energy consumption by all users. This regulation is achieved through the development and implementation of sound energy policies that promote energy efficiency. These findings are supported by studies such as those by Wang et al. [47] for BRICS, Zhang et al. [46] for APEC countries, Hussain and Dogan [90] for BRICS, Wang et al. [91] for 24 African countries, Jahanger et al. [72] for 69 developing countries, and Wahab et al. [92] for OECD countries, all of which confirm that institutional quality—through effective environmental laws and enforcement—helps mitigate environmental degradation.

To further validate the findings from MMQR, we used an alternative measure of renewable energy, specifically renewable energy per capita. The results show that renewable energy per capita negatively affects CCO_2 emissions. Moreover, the MMQR results using this alternative measure confirm that the impact of economic growth and institutional quality on environmental sustainability remains consistent.

4.5. Robustness and Additional Analysis

To assess the robustness of the results, we employed fixed-effect OLS, GMM, and CCEMG methods. The findings are presented in Table 6.

Table 6. Outcomes of FE-OLS, GMM, and CCEMG.

Variables	FE-OLS			GMM			CCEMG		
	Coeff.	**t.stats**	**Prob**	**Coeff.**	**t.stats**	**Prob**	**Coeff.**	**t.stats**	**Prob**
GDP	0.727 ***	25.322	0.000	0.701 ***	13.967	0.000	0.852 ***	6.910	0.000
REC	−0.034 *	−1.839	0.068	−0.075 ***	−7.824	0.000	−0.031 **	−2.140	0.032
IQ	−0.045 ***	−3.438	0.000	−0.048 ***	−2.636	0.009	−0.011 ***	−5.510	0.000

Note: Authors' computation. ***, **, and * 1%, 5%, and 10% levels of significance, respectively.

The results from FE-OLS, GMM, and CCEMG indicate a detrimental effect of output expansion on CCO_2 emissions. Specifically, a 1% increase in GDP is associated with a 0.701–0.852% deterioration in environmental quality. This finding is consistent with the studies of Adeleye et al. [89] for selected South Asian economies, Abbasi et al. [28] for 26 European countries, and Ali et al. [93] for the USA. Similarly, the results from FE-OLS, GMM, and CCEMG show that renewable energy consumption (REC) positively impacts environmental quality. This suggests that higher renewable energy usage leads to less environmental degradation. Specifically, a 1% increase in renewable energy usage would reduce environmental degradation by 0.031–0.075%. These findings align with those of Samour et al. [87] for Belgium, Zhang et al. [94] for the USA, and Samour et al. [70] for the UAE, all of which indicate that renewable energy significantly enhances environmental quality. Furthermore, the results from FE-OLS, GMM, and CCEMG reveal a positive effect of institutional quality (IQ) on environmental quality in BRICS economies. This means that a 1% increase in IQ would improve environmental quality by 0.011–0.048%. These results corroborate the findings from MMQR. However, the study prioritizes the MMQR outcomes over FE-OLS, GMM, and CCEMG due to its ability to capture the impact of renewable energy use, economic expansion, and institutional quality on environmental quality across various quantiles. This allows for a better understanding of their heterogeneous effects on the explained variable.

5. Conclusions

This study explored the relationships between renewable energy usage, institutional quality, economic growth, and consumption-based CO_2 (CCO_2) emissions in BRICS nations. It contributes to the existing literature by investigating the dynamic links between institutional quality and CCO_2 emissions using the innovative method of moments quantile regression (MMQR). This approach was selected for its ability to assess the heterogeneous effects of renewable energy consumption and institutional quality on CCO_2 emissions across various quantiles. As a result, the study provides new insights into the symmetric impact of institutional quality on CCO_2 emissions within the context of BRICS nations. The findings from the MMQR and robust models revealed that renewable energy consumption positively impacts environmental quality across all quantiles. Similarly, institutional quality (IQ) demonstrated a mitigating effect on environmental degradation in all quantiles. However, the results also indicated that GDP expansion negatively affects environmental quality within BRICS countries. These findings have several policy implications.

First, given that renewable energy consumption enhances environmental quality, it is recommended that BRICS governments prioritize and promote the regular use of renewable energy sources, such as solar and wind power. Collaboration and knowledge-sharing on energy-efficient technologies can support this goal. Additionally, efforts should focus on developing new and clean fuels to further increase the share of renewable energy in their energy mix.

Second, the study highlights the role of institutional quality in reducing environmental degradation. Therefore, it is recommended that BRICS nations improve institutional

quality by establishing and strengthening institutions capable of enforcing environmental regulations. Policymakers must align environmental sustainability goals with institutional quality to promote economic growth without compromising environmental health. This can be achieved by enhancing existing environmental monitoring and enforcement laws.

The study also has global implications, as BRICS nations accounted for over 40% of global CO_2 emissions in 2019. Understanding the drivers of environmental degradation in these countries and the measures to mitigate it will not only inform local policy but also contribute significantly to global sustainability efforts.

While this study provides valuable insights, it has two limitations. First, the data used cover the period from 1996 to 2020, with some variables lacking data beyond 2020. Second, while the MMQR effectively captures the heterogeneous and distributional effects of the variables, future research could explore alternative panel techniques to assess the dynamic, disaggregated influence of institutional quality on environmental sustainability, incorporating a broader mix of both developed and developing nations.

Author Contributions: Methodology, N.I. and M.C.; formal analysis, A.A.A. and A.S.; data curation, A.S. and A.A.A.; writing—original draft, M.C. and N.I.; writing—review and editing, N.I., M.C., A.S., and A.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant No: KFU250095].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

APEC	Asia-Pacific Economic Cooperation
ARDL	autoregressive distributed lag
BRICS	Brazil, Russia, India, China, and South Africa
CADF	cross-sectionally augmented Dickey–Fuller
CCEMG	common correlated effect mean group
CCO_2	consumption-based carbon dioxide emissions
CD	cross-sectional dependence
CIPS	cross-sectionally augmented Im–Pesaran–Shin
CO_2	carbon dioxide
EKC	environmental Kuznets curve
FE-OLS	fixed effect
FM-OLS	fully modified ordinary least square
GDP	gross domestic product
GHG	greenhouse gas
GMM	generalized method of moments
ICT	information and communication technology
LLC	Levin, Lin, and Chu
MENA	Middle East and Northern Africa
MINT	Mexico, Indonesia, Nigeria, and Turkey
MMQR	method of moments quantile regression
NDC	nationally determined contributions
OECD	Organisation for Economic Co-operation and Development

PMG	pooled mean group
QARDL	quantile autoregressive distributed lag
SAARC	South Asian Association for Regional Cooperation

References

1. Sadoff, C.W. *Securing Water, Sustaining Growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth*; University of Oxford: Oxford, UK, 2015; ISBN 978-1-874370-54-3.
2. *Global Warming of 1.5 °C*; IPCC: Geneva, Switzerland, 2018.
3. Chapungu, L.; Nhamo, G.; Chikodzi, D.; Maoela, M.A. BRICS and the Race to Net-Zero Emissions by 2050: Is COVID-19 a Barrier or an Opportunity? *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 172. [CrossRef]
4. Zakarya, G.Y.; Mostefa, B.; Abbes, S.M.; Seghir, G.M. Factors Affecting CO_2 Emissions in the BRICS Countries: A Panel Data Analysis. *Procedia Econ. Financ.* **2015**, *26*, 114–125. [CrossRef]
5. International Labour Organization. Employment and Just Transition to Sustainability in BRICS Countries. In Proceedings of the 1st BRICS Employment Working Group Meeting Under China's Presidency, Geneva, Switzerland, 5–16 June 2022.
6. Maji, I.K.; Saari, M.Y.; Habibullah, M.S.; Mohd Saudi, N.S. Clean Energy, Institutional Quality and Environmental Sustainability in Sub-Saharan Africa. *Clean. Mater.* **2022**, *6*, 100135. [CrossRef]
7. Bond, D.; Kim, A.B. How Economic Freedom Creates a Healthy Environment. The Energy and Resources Institute, BRICS Energy Reports. 2021. Available online: https://brics2021.gov.in/brics/public/uploads/docpdf/getdocu-41.pdf (accessed on 10 March 2022).
8. Machado, J.A.F.; Santos Silva, J.M.C. Quantiles via Moments. *J. Econom.* **2019**, *213*, 145–173. [CrossRef]
9. Isa, Z.; Alsayed, A.R.; Kun, S.S. Review Paper on Economic Growth–Aggregate Energy Consumption Nexus. *Int. J. Energy Econ. Policy* **2015**, *5*, 385–401.
10. Zaidi, I. Examining the Relationship Between Economic Growth, Energy Consumption and CO_2 Emission Using Inverse Function Regression. *Appl. Ecol. Environ. Res.* **2017**, *15*, 473–484. [CrossRef]
11. Ike, G.N.; Usman, O.; Sarkodie, S.A. Testing the Role of Oil Production in the Environmental Kuznets Curve of Oil Producing Countries: New Insights from Method of Moments Quantile Regression. *Sci. Total Environ.* **2020**, *711*, 135208. [CrossRef]
12. Ghosh, S.; Hossain, M.S.; Voumik, L.C.; Raihan, A.; Ridzuan, A.R.; Esquivias, M.A. Unveiling the Spillover Effects of Democracy and Renewable Energy Consumption on the Environmental Quality of BRICS Countries: A New Insight from Different Quantile Regression Approaches. *Renew. Energy Focus* **2023**, *46*, 222–235. [CrossRef]
13. Rani, M.; Keshu; Shanker, U. Sunlight-Induced Photocatalytic Degradation of Organic Pollutants by Biosynthesized Hetrometallic Oxides Nanoparticles. *Environ. Sci. Pollut. Res.* **2021**, *28*, 61760–61780. [CrossRef]
14. Grossman, G.; Krueger, A. *Environmental Impacts of a North American Free Trade Agreement*; National Bureau of Economic Research: Cambridge, MA, USA, 1991; p. w3914.
15. Shahbaz, M.; Lean, H.H.; Shabbir, M.S. Environmental Kuznets Curve Hypothesis in Pakistan: Cointegration and Granger Causality. *Renew. Sustain. Energy Rev.* **2012**, *16*, 2947–2953. [CrossRef]
16. Ali, W.; Abdullah, A.; Azam, M. Re-Visiting the Environmental Kuznets Curve Hypothesis for Malaysia: Fresh Evidence from ARDL Bounds Testing Approach. *Renew. Sustain. Energy Rev.* **2017**, *77*, 990–1000. [CrossRef]
17. Apergis, N.; Ozturk, I. Testing Environmental Kuznets Curve Hypothesis in Asian Countries. *Ecol. Indic.* **2015**, *52*, 16–22. [CrossRef]
18. Bilgili, F.; Koçak, E.; Bulut, Ü. The Dynamic Impact of Renewable Energy Consumption on CO_2 Emissions: A Revisited Environmental Kuznets Curve Approach. *Renew. Sustain. Energy Rev.* **2016**, *54*, 838–845. [CrossRef]
19. Haseeb, A.; Xia, E.; Danish; Baloch, M.A.; Abbas, K. Financial Development, Globalization, and CO_2 Emission in the Presence of EKC: Evidence from BRICS Countries. *Environ. Sci. Pollut. Res.* **2018**, *25*, 31283–31296. [CrossRef] [PubMed]
20. Akadırı, S.S.; Alola, A.A.; Usman, O. Energy Mix Outlook and the EKC Hypothesis in BRICS Countries: A Perspective of Economic Freedom vs. Economic Growth. *Environ. Sci. Pollut. Res.* **2021**, *28*, 8922–8926. [CrossRef] [PubMed]
21. Destek, M.A.; Sarkodie, S.A. Investigation of Environmental Kuznets Curve for Ecological Footprint: The Role of Energy and Financial Development. *Sci. Total Environ.* **2019**, *650*, 2483–2489. [CrossRef] [PubMed]
22. Shujah-ur-Rahman; Chen, S.; Saud, S.; Saleem, N.; Bari, M.W. Nexus between Financial Development, Energy Consumption, Income Level, and Ecological Footprint in CEE Countries: Do Human Capital and Biocapacity Matter? *Environ. Sci. Pollut. Res.* **2019**, *26*, 31856–31872. [CrossRef]
23. Mert, M.; Bölük, G.; Çağlar, A.E. Interrelationships among Foreign Direct Investments, Renewable Energy, and CO_2 Emissions for Different European Country Groups: A Panel ARDL Approach. *Environ. Sci. Pollut. Res.* **2019**, *26*, 21495–21510. [CrossRef] [PubMed]
24. Dogan, E.; Inglesi-Lotz, R. The Impact of Economic Structure to the Environmental Kuznets Curve (EKC) Hypothesis: Evidence from European Countries. *Environ. Sci. Pollut. Res.* **2020**, *27*, 12717–12724. [CrossRef] [PubMed]

25. Baloch, M.A.; Ozturk, I.; Bekun, F.V.; Khan, D. Modeling the Dynamic Linkage between Financial Development, Energy Innovation, and Environmental Quality: Does Globalization Matter? *Bus. Strategy Environ.* **2021**, *30*, 176–184. [CrossRef]
26. Sarkodie, S.A.; Ozturk, I. Investigating the Environmental Kuznets Curve Hypothesis in Kenya: A Multivariate Analysis. *Renew. Sustain. Energy Rev.* **2020**, *117*, 109481. [CrossRef]
27. Murshed, M.; Ali, S.R.; Banerjee, S. Consumption of Liquefied Petroleum Gas and the EKC Hypothesis in South Asia: Evidence from Cross-Sectionally Dependent Heterogeneous Panel Data with Structural Breaks. *Energy Ecol. Environ.* **2021**, *6*, 353–377. [CrossRef]
28. Abbasi, K.R.; Lv, K.; Radulescu, M.; Shaikh, P.A. Economic Complexity, Tourism, Energy Prices, and Environmental Degradation in the Top Economic Complexity Countries: Fresh Panel Evidence. *Environ. Sci. Pollut. Res.* **2021**, *28*, 68717–68731. [CrossRef] [PubMed]
29. Mohammed, K.S.; Tiwari, S.; Ferraz, D.; Shahzadi, I. Assessing the EKC Hypothesis by Considering the Supply Chain Disruption and Greener Energy: Findings in the Lens of Sustainable Development Goals. *Environ. Sci. Pollut. Res.* **2022**, *30*, 18168–18180. [CrossRef]
30. Acaravci, A.; Ozturk, I. On the Relationship between Energy Consumption, CO_2 Emissions and Economic Growth in Europe. *Energy* **2010**, *35*, 5412–5420. [CrossRef]
31. Dong, K.; Sun, R.; Hochman, G.; Zeng, X.; Li, H.; Jiang, H. Impact of Natural Gas Consumption on CO_2 Emissions: Panel Data Evidence from China's Provinces. *J. Clean. Prod.* **2017**, *162*, 400–410. [CrossRef]
32. Jardon, A.; Kuik, O.; Tol, R.S.J. Economic Growth and Carbon Dioxide Emissions: An Analysis of Latin America and the Caribbean. *Atmósfera* **2017**, *30*, 87–100. [CrossRef]
33. Kang, H. Impacts of Income Inequality and Economic Growth on CO_2 Emissions: Comparing the Gini Coefficient and the Top Income Share in OECD Countries. *Energies* **2022**, *15*, 6954. [CrossRef]
34. Abbasi, K.R.; Awan, A.; Bandyopadhyay, A.; Rej, S.; Banday, T.P. Investigating the Inverted N-Shape EKC in the Presence of Renewable and Nuclear Energy in a Global Sample. *Clean Technol. Environ. Policy* **2023**, *25*, 1179–1194. [CrossRef]
35. Arouri, M.E.H.; Ben Youssef, A.; M'henni, H.; Rault, C. Energy Consumption, Economic Growth and CO_2 Emissions in Middle East and North African Countries. *Energy Policy* **2012**, *45*, 342–349. [CrossRef]
36. Antonakakis, N.; Chatziantoniou, I.; Filis, G. Energy Consumption, CO_2 Emissions, and Economic Growth: An Ethical Dilemma. *Renew. Sustain. Energy Rev.* **2017**, *68*, 808–824. [CrossRef]
37. Hu, H.; Xie, N.; Fang, D.; Zhang, X. The Role of Renewable Energy Consumption and Commercial Services Trade in Carbon Dioxide Reduction: Evidence from 25 Developing Countries. *Appl. Energy* **2018**, *211*, 1229–1244. [CrossRef]
38. Pata, U.K.; Aydin, M. Testing the EKC Hypothesis for the Top Six Hydropower Energy-Consuming Countries: Evidence from Fourier Bootstrap ARDL Procedure. *J. Clean. Prod.* **2020**, *264*, 121699. [CrossRef]
39. Koc, S.; Bulus, G.C. Testing Validity of the EKC Hypothesis in South Korea: Role of Renewable Energy and Trade Openness. *Environ. Sci. Pollut. Res.* **2020**, *27*, 29043–29054. [CrossRef] [PubMed]
40. Pata, U.K.; Caglar, A.E. Investigating the EKC Hypothesis with Renewable Energy Consumption, Human Capital, Globalization and Trade Openness for China: Evidence from Augmented ARDL Approach with a Structural Break. *Energy* **2021**, *216*, 119220. [CrossRef]
41. Ahmed, A.; Uddin, G.S.; Sohag, K. Biomass Energy, Technological Progress and the Environmental Kuznets Curve: Evidence from Selected European Countries. *Biomass Bioenergy* **2016**, *90*, 202–208. [CrossRef]
42. Urban, F.; Nordensvärd, J. Low Carbon Energy Transitions in the Nordic Countries: Evidence from the Environmental Kuznets Curve. *Energies* **2018**, *11*, 2209. [CrossRef]
43. Awaworyi Churchill, S.; Inekwe, J.; Ivanovski, K.; Smyth, R. The Environmental Kuznets Curve in the OECD: 1870–2014. *Energy Econ.* **2018**, *75*, 389–399. [CrossRef]
44. Gormus, S.; Aydin, M. Revisiting the Environmental Kuznets Curve Hypothesis Using Innovation: New Evidence from the Top 10 Innovative Economies. *Environ. Sci. Pollut. Res.* **2020**, *27*, 27904–27913. [CrossRef] [PubMed]
45. Lau, L.-S.; Choong, C.-K.; Eng, Y.-K. Carbon Dioxide Emission, Institutional Quality, and Economic Growth: Empirical Evidence in Malaysia. *Renew. Energy* **2014**, *68*, 276–281. [CrossRef]
46. Zhang, Y.-J.; Jin, Y.-L.; Chevallier, J.; Shen, B. The Effect of Corruption on Carbon Dioxide Emissions in APEC Countries: A Panel Quantile Regression Analysis. *Technol. Forecast. Soc. Change* **2016**, *112*, 220–227. [CrossRef]
47. Wang, Z.; Danish; Zhang, B.; Wang, B. The Moderating Role of Corruption between Economic Growth and CO_2 Emissions: Evidence from BRICS Economies. *Energy* **2018**, *148*, 506–513. [CrossRef]
48. Wawrzyniak, D.; Doryń, W. Does the Quality of Institutions Modify the Economic Growth-Carbon Dioxide Emissions Nexus? Evidence from a Group of Emerging and Developing Countries. *Econ. Res.-Ekon. Istraživanja* **2020**, *33*, 124–144. [CrossRef]
49. Le, H.P.; Ozturk, I. The Impacts of Globalization, Financial Development, Government Expenditures, and Institutional Quality on CO_2 Emissions in the Presence of Environmental Kuznets Curve. *Environ. Sci. Pollut. Res.* **2020**, *27*, 22680–22697. [CrossRef] [PubMed]

50. Godil, D.I.; Sharif, A.; Agha, H.; Jermsittiparsert, K. The Dynamic Nonlinear Influence of ICT, Financial Development, and Institutional Quality on CO_2 Emission in Pakistan: New Insights from QARDL Approach. *Environ. Sci. Pollut. Res.* **2020**, *27*, 24190–24200. [CrossRef] [PubMed]
51. Farzanegan, M.R.; Markwardt, G. Development and Pollution in the Middle East and North Africa: Democracy Matters. *J. Policy Model.* **2018**, *40*, 350–374. [CrossRef]
52. Arminen, H.; Menegaki, A.N. Corruption, Climate and the Energy-Environment-Growth Nexus. *Energy Econ.* **2019**, *80*, 621–634. [CrossRef]
53. Waheed, R.; Chang, D.; Sarwar, S.; Chen, W. Forest, Agriculture, Renewable Energy, and CO_2 Emission. *J. Clean. Prod.* **2018**, *172*, 4231–4238. [CrossRef]
54. Bekun, F.V.; Alola, A.A.; Sarkodie, S.A. Toward a Sustainable Environment: Nexus between CO_2 Emissions, Resource Rent, Renewable and Nonrenewable Energy in 16-EU Countries. *Sci. Total Environ.* **2019**, *657*, 1023–1029. [CrossRef] [PubMed]
55. Emre Caglar, A. The Importance of Renewable Energy Consumption and FDI Inflows in Reducing Environmental Degradation: Bootstrap ARDL Bound Test in Selected 9 Countries. *J. Clean. Prod.* **2020**, *264*, 121663. [CrossRef]
56. Sulaiman, C.; Abdul-Rahim, A.S. Can Clean Biomass Energy Use Lower CO_2 Emissions in African Economies? Empirical Evidence from Dynamic Long-Run Panel Framework. *Environ. Sci. Pollut. Res.* **2020**, *27*, 37699–37708. [CrossRef] [PubMed]
57. Ikram, M.; Zhang, Q.; Sroufe, R.; Shah, S.Z.A. Towards a Sustainable Environment: The Nexus between ISO 14001, Renewable Energy Consumption, Access to Electricity, Agriculture and CO_2 Emissions in SAARC Countries. *Sustain. Prod. Consum.* **2020**, *22*, 218–230. [CrossRef]
58. Ben Jebli, M.; Farhani, S.; Guesmi, K. Renewable Energy, CO_2 Emissions and Value Added: Empirical Evidence from Countries with Different Income Levels. *Struct. Change Econ. Dyn.* **2020**, *53*, 402–410. [CrossRef]
59. Khattak, S.I.; Ahmad, M.; Khan, Z.U.; Khan, A. Exploring the Impact of Innovation, Renewable Energy Consumption, and Income on CO_2 Emissions: New Evidence from the BRICS Economies. *Environ. Sci. Pollut. Res.* **2020**, *27*, 13866–13881. [CrossRef]
60. Kuldasheva, Z.; Salahodjaev, R. Renewable Energy and CO_2 Emissions: Evidence from Rapidly Urbanizing Countries. *J. Knowl. Econ.* **2023**, *14*, 1077–1090. [CrossRef]
61. Salahodjaev, R.; Sharipov, K.; Rakhmanov, N.; Khabirov, D. Tourism, Renewable Energy and CO_2 Emissions: Evidence from Europe and Central Asia. *Environ. Dev. Sustain.* **2022**, *24*, 13282–13293. [CrossRef]
62. Sahoo, B.; Behera, D.K.; Rahut, D. Decarbonization: Examining the Role of Environmental Innovation versus Renewable Energy Use. *Environ. Sci. Pollut. Res.* **2022**, *29*, 48704–48719. [CrossRef] [PubMed]
63. Ding, Q.; Khattak, S.I.; Ahmad, M. Towards Sustainable Production and Consumption: Assessing the Impact of Energy Productivity and Eco-Innovation on Consumption-Based Carbon Dioxide Emissions (CCO_2) in G-7 Nations. *Sustain. Prod. Consum.* **2021**, *27*, 254–268. [CrossRef]
64. Kirikkaleli, D.; Güngör, H.; Adebayo, T.S. Consumption-based Carbon Emissions, Renewable Energy Consumption, Financial Development and Economic Growth in Chile. *Bus. Strategy Environ.* **2022**, *31*, 1123–1137. [CrossRef]
65. Balsalobre-Lorente, D.; Shahbaz, M.; Roubaud, D.; Farhani, S. How Economic Growth, Renewable Electricity and Natural Resources Contribute to CO_2 Emissions? *Energy Policy* **2018**, *113*, 356–367. [CrossRef]
66. Xie, Q.; Liu, J. Combined Nonlinear Effects of Economic Growth and Urbanization on CO_2 Emissions in China: Evidence from a Panel Data Partially Linear Additive Model. *Energy* **2019**, *186*, 115868. [CrossRef]
67. Isiksal, A.Z.; Samour, A.; Resatoglu, N.G. Testing the Impact of Real Interest Rate, Income, and Energy Consumption on Turkey's CO_2 Emissions. *Environ. Sci. Pollut. Res.* **2019**, *26*, 20219–20231. [CrossRef] [PubMed]
68. Mahalik, M.K.; Mallick, H.; Padhan, H. Do Educational Levels Influence the Environmental Quality? The Role of Renewable and Non-Renewable Energy Demand in Selected BRICS Countries with a New Policy Perspective. *Renew. Energy* **2021**, *164*, 419–432. [CrossRef]
69. Adebayo, T.S.; Oladipupo, S.D.; Adeshola, I.; Rjoub, H. Wavelet Analysis of Impact of Renewable Energy Consumption and Technological Innovation on CO_2 Emissions: Evidence from Portugal. *Environ. Sci. Pollut. Res.* **2022**, *29*, 23887–23904. [CrossRef]
70. Samour, A.; Onwe, J.C.; Inuwa, N.; Imran, M. Insurance Market Development, Renewable Energy, and Environmental Quality in the UAE: Novel Findings from a Bootstrap ARDL Test. *Energy Environ.* **2024**, *35*, 610–627. [CrossRef]
71. Kirikkaleli, D.; Adebayo, T.S. Do Renewable Energy Consumption and Financial Development Matter for Environmental Sustainability? New Global Evidence. *Sustain. Dev.* **2021**, *29*, 583–594. [CrossRef]
72. Jahanger, A.; Usman, M.; Balsalobre-Lorente, D. Linking Institutional Quality to Environmental Sustainability. *Sustain. Dev.* **2022**, *30*, 1749–1765. [CrossRef]
73. Ali, M.; Kirikkaleli, D. The Asymmetric Effect of Renewable Energy and Trade on Consumption-based CO_2 Emissions: The Case of Italy. *Integr. Environ. Assess. Manag.* **2022**, *18*, 784–795. [CrossRef]
74. Adebayo, T.S.; Udemba, E.N.; Ahmed, Z.; Kirikkaleli, D. Determinants of Consumption-Based Carbon Emissions in Chile: An Application of Non-Linear ARDL. *Environ. Sci. Pollut. Res.* **2021**, *28*, 43908–43922. [CrossRef] [PubMed]

75. Hasanov, F.J.; Khan, Z.; Hussain, M.; Tufail, M. Theoretical Framework for the Carbon Emissions Effects of Technological Progress and Renewable Energy Consumption. *Sustain. Dev.* **2021**, *29*, 810–822. [CrossRef]
76. Jiang, Q.; Rahman, Z.U.; Zhang, X.; Islam, M.S. An Assessment of the Effect of Green Innovation, Income, and Energy Use on Consumption-Based CO_2 Emissions: Empirical Evidence from Emerging Nations BRICS. *J. Clean. Prod.* **2022**, *365*, 132636. [CrossRef]
77. Alsamara, M.; Mrabet, Z.; Dombrecht, M. Asymmetric Import Cost Pass-through in GCC Countries: Evidence from Nonlinear Panel Analysis. *Econ. Model.* **2018**, *75*, 432–440. [CrossRef]
78. Shahbaz, M.; Shahzad, S.J.H.; Mahalik, M.K.; Sadorsky, P. How Strong Is the Causal Relationship between Globalization and Energy Consumption in Developed Economies? A Country-Specific Time-Series and Panel Analysis. *Appl. Econ.* **2018**, *50*, 1479–1494. [CrossRef]
79. Musah, M.; Kong, Y.; Mensah, I.A.; Antwi, S.K.; Osei, A.A.; Donkor, M. Modelling the Connection between Energy Consumption and Carbon Emissions in North Africa: Evidence from Panel Models Robust to Cross-Sectional Dependence and Slope Heterogeneity. *Environ. Dev. Sustain.* **2021**, *23*, 15225–15239. [CrossRef]
80. Pesaran, M.H. A Simple Panel Unit Root Test in the Presence of Cross-section Dependence. *J. Appl. Econom.* **2007**, *22*, 265–312. [CrossRef]
81. Choi, I. Unit Root Tests for Panel Data. *J. Int. Money Financ.* **2001**, *20*, 249–272. [CrossRef]
82. Levin, A.; Lin, C.-F.; James Chu, C.-S. Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. *J. Econom.* **2002**, *108*, 1–24. [CrossRef]
83. Swamy, P.A.V.B. Efficient Inference in a Random Coefficient Regression Model. *Econometrica* **1970**, *38*, 311. [CrossRef]
84. Hashem Pesaran, M.; Yamagata, T. Testing Slope Homogeneity in Large Panels. *J. Econom.* **2008**, *142*, 50–93. [CrossRef]
85. Westerlund, J. Testing for Error Correction in Panel Data. *Oxf. Bull. Econ. Stat.* **2007**, *69*, 709–748. [CrossRef]
86. Zhang, Y.; Britton, T.; Zhou, X. Monitoring Real-Time Transmission Heterogeneity from Incidence Data. *PLOS Comput. Biol.* **2022**, *18*, e1010078. [CrossRef]
87. Samour, A.; Onwe, J.C.; Inuwa, N.; Imran, M.; Ifelunini, I.A.; Fulu, O. Assessing the Effect of Real Estate Market and Renewable Energy on Environmental Quality in Belgium. *OPEC Energy Rev.* **2023**, *47*, 148–159. [CrossRef]
88. Inuwa, N.; Rej, S.; Onwe, J.C.; Hossain, M.E. Do Clean Energy and Dependence on Natural Resources Stimulate Environmental Sustainability? A New Approach with Load Capacity Factor and Temperature. *Nat. Resour. Forum* **2024**. [CrossRef]
89. Adeleye, B.N.; Akam, D.; Inuwa, N.; Olarinde, M.; Okafor, V. Investigating Growth-Energy-Emissions Trilemma in South Asia. *Int. J. Energy Econ. Policy* **2021**, *11*, 112–120. [CrossRef]
90. Hussain, M.; Dogan, E. The Role of Institutional Quality and Environment-Related Technologies in Environmental Degradation for BRICS. *J. Clean. Prod.* **2021**, *304*, 127059. [CrossRef]
91. Wang, M.L.; Ntim, V.S.; Yang, J.; Zheng, Q.; Geng, L. Effect of Institutional Quality and Foreign Direct Investment on Economic Growth and Environmental Quality: Evidence from African Countries. *Econ. Res.-Ekon. Istraživanja* **2022**, *35*, 4065–4091. [CrossRef]
92. Wahab, S.; Imran, M.; Ahmed, B.; Rahim, S.; Hassan, T. Navigating Environmental Concerns: Unveiling the Role of Economic Growth, Trade, Resources and Institutional Quality on Greenhouse Gas Emissions in OECD Countries. *J. Clean. Prod.* **2024**, *434*, 139851. [CrossRef]
93. Joof, F.; Samour, A.; Ali, M.; Rehman, M.A.; Tursoy, T. Economic complexity, renewable energy and ecological footprint: The role of the housing market in the USA. *Energy Build.* **2024**, *311*, 114131. [CrossRef]
94. Zhang, M.; Abbasi, K.R.; Inuwa, N.; Sinisi, C.I.; Alvarado, R.; Ozturk, I. Does Economic Policy Uncertainty, Energy Transition and Ecological Innovation Affect Environmental Degradation in the United States? *Econ. Res.-Ekon. Istraživanja* **2023**, *36*, 2177698. [CrossRef]

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