

Article

The Role of Energy Consumption, Economic Growth and Globalization in Environmental Degradation: Empirical Evidence from the BRICS Region

Habib Ur Rahman ^{1,2}, Umer Zaman ^{3,*}  and Jarosław Górecki ⁴ 

¹ Holmes Institute, Gold Coast, QLD 4217, Australia; HRahman@holmes.edu.au or HRahman@bond.edu.au

² Bond Business School, Bond University, Gold Coast, QLD 4226, Australia

³ Endicott College of International Studies (ECIS), Woosong University, Daejeon 34606, Korea

⁴ Faculty of Civil and Environmental Engineering and Architecture, UTP University of Science and Technology, Al. Prof. S. Kaliskiego 7, 85-348 Bydgoszcz; Poland; gorecki@utp.edu.pl

* Correspondence: umerzaman@endicott.ac.kr

Abstract: This paper examines the effect of energy consumption, globalization, and economic growth on the CO₂ emission of the BRICS (Brazil, Russian Federation, India, China and South Africa) region. Using annual data from 1989 to 2019, this research applies a panel cointegration approach. In this framework, we use Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods to examine the long-run relationship between the selected variables. This empirical investigation reveals that there is a long-run association between these variables, and energy consumption positively and significantly affects the carbon emission in these countries. These results indicate that energy consumption is the primary source of environmental degradation in the region. In contrast, the globalization (KOF Index of Globalization) negatively and significantly affects the carbon emission, implying the improvement of environmental quality. Further, this research could not find the presence of environmental Kuznets curve in the region. Policy guidelines are suggested in the line of findings.

Keywords: energy consumption; economic growth; globalization; CO₂ emission; FMOLS and DOLS



Citation: Rahman, H.U.; Zaman, U.; Górecki, J. The Role of Energy Consumption, Economic Growth and Globalization in Environmental Degradation: Empirical Evidence from the BRICS Region. *Sustainability* **2021**, *13*, 1924. <https://doi.org/10.3390/su13041924>

Academic Editors: Gyuricza Csaba, Muhammad Asif Khan and Judit Oláh

Received: 23 December 2020

Accepted: 4 February 2021

Published: 10 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Over the last few decades, the challenges of global warming have increased due to couple of factors including (1) growing levels of industrialization, (2) increasing global population, (3) lifestyle changes and (4) rising levels of energy consumption [1]. Almost half of the global greenhouse gas emissions came from the five BRICS (Brazil, Russian Federation, India, China and South Africa) countries and these countries have observed the costly consequences of this massive emission (John Kirton, Co-director, BRICS Research Group reveals these estimates in the paper “BRICS Climate governance in 2020” prepared for presentation at Gaider Forum, RANEP, Moscow at 15th day of January 2020. See section “The Current Climate Crisis” for the details on the country-wise consequences of the climate crisis). Contemporaneously, the BRICS paradigm has become increasingly prevalent in both the public and academic media due to the significant common characteristics such as (1) less-developed yet fast-growing economies, (2) large populations, (3) powerful governments, and (4) readiness to take up global markets [2]. On this vein, different researchers have compared the economic performance of BRICS with the G7 countries (The seven developed countries including, Canada, France, Germany, Italy, Japan, the United States of America and the United Kingdom). Even Pao and Tsai [3] estimated that the GDP of the BRICS region would be higher than the G7 countries by 2050. This rapid growth in the BRICS region can bring positive changes, such as low unemployment and higher per capita income. Hence, the recent and parallel developments in the BRICS economies

cannot be ignored. To keep the pace of this rapid economic growth, the BRICS countries are required to use significant quantities of fossil fuels to produce energy. Resultantly, these emissions are expected to contribute significantly to global warming [1].

Despite the global pledge to address climate change and strive for carbon neutrality, the carbon emission is unavoidable for the BRICS region to maintain its higher economic growth. On this trade-off, many policy makers and researchers are of the view that carbon emission should be reduced to maintain environmental quality [4]. Conversely, another stand of researchers and policy makers are of the view that the immediate implementation of carbon emission-reducing policies will deteriorate the growth and development aspects of the BRICS region [4]. The existing empirical evidence suggests that the aggressive reduction in the level of carbon emission does not help to achieve the objective of sustainable economic growth. Therefore, the effective policies are required for the carbon emission [5,6] (For instance, policy makers should recommend energy-efficient technologies if energy consumption contributes significantly to environmental degradation. Further, the policy makers should devise supportive globalization policies in the region if the globalization deteriorates environmental degradation (Dasgupta, Hamilton, Pandey and Wheeler, 2006)). The global regulative bodies reveal that the developing, emerging, and developed economies should sacrifice economic growth to reduce the carbon emission (This is the message by (1) Kyoto Protocol 1997, (2) Paris Agreement 2015, and (3) Copenhagen Summit 2009). Alternatively, these countries should achieve higher economic growth goals to boost environmental quality. The most recent empirical environmental literature suggests that globalization is the missing determinant of the carbon emission [5,7]. In particular, globalization deteriorates the environmental quality through depletion of the limited natural resources to meet the rising global demand for goods and services. Conversely, some environmentalists argue that globalization helps in improving the environmental quality since the efficient environmental technologies are available to the developing countries. Consequently, the globalization should be included in the carbon emission analysis which has received growing attention [8–10].

Considering these arguments, this study empirically investigates the role of energy consumption, economic growth, and globalization in the carbon emission (a proxy for the environmental degradation) of the BRICS region. This study also checks the validity of the Environmental Kuznets Curve (EKC) hypothesis in the region. Shahbaz and Sinha [11] reveals that the absence of EKC is possible in the developing economies if these countries have not achieved the level of economic growth where the environmental degradation starts. We empirically validate this theoretical justification. Further, this study contributes to the existing literature in different ways. There is substantial lack of empirical literature on the globalization-carbon emission [12,13] which is particularly important for the case of carbon emission analysis of the BRICS region. This inclusion of this variable is expected to contribute to the empirical literature by reducing the omitted variable bias [5]. Further, this study contributes to the existing empirical literature by applying the appropriate methodology that addresses the issue of autocorrelation and endogeneity. We also include the policy discussion in the context of growth-energy-emission nexus, which will provide with the useful insights to the policy makers of the BRICS region.

The rest of the paper is organized as follows. Section 2 presents the relevant literature on the topic. Section 3 elaborates the model, data and empirical strategy. Section 4 presents the empirical results and discussion. This research is concluded in the last section of this paper.

2. Literature Review

For the last few decades, the existing literature has explored the possible determinants of environmental degradation using the bivariate framework and country-specific studies. However, there are a few panel empirical investigations on this exploration in a multivariate system [1,5,14]. The literature on the potential determinants of the environmental degradation can be categorized into four stands, including (1) energy consumption and

economic growth nexus, (2) the linkage between economic growth and carbon emissions, (3) energy consumption, economic growth and carbon emissions, and (4) globalization and carbon emissions. The rest of this section synthesizes these four strands of literature.

2.1. Energy Consumption and Economic Growth Nexus

Kraft and Kraft [15] is the pioneer empirical study on the nexus between energy and growth. After that, there is a plethora of empirical studies on this nexus. However, these evidences are inconclusive based on variable selection, econometric methodology, and the data set [16,17]. To summarize these unconvincing pieces of evidence, some studies provide an excellent review of this nexus [18–20]. Notably, Ozturk [20] provides four types of possible hypotheses on the linkage between energy consumption and economic growth, including (1) growth hypothesis, (2) conservation hypothesis, (3) feedback hypothesis, and (4) neutrality hypothesis.

A wide range of empirical studies favours the growth hypothesis indicating that energy consumption affects the level of economic growth [21–32]. Besides, this line of literature argues that the restriction on energy consumption is likely to affect the process of economic growth. Conversely, the second line of literature argues in favor of the conservation hypothesis, which indicates that economic growth is driving energy use in the economy [29,33–38]. The third strand of literature favors the feedback hypothesis that economic development and energy consumption are mutually conclusive [25,29,39–42]. Interestingly, the last strand of empirical literature could not find any linkage between the energy use and economic growth favoring the neutrality hypothesis. They further reveal that the energy-growing nexus is an over-taxed term [32,43–46].

2.2. Economic Growth and CO₂ Emissions

The existing literature has widely tested the existence of an EKC hypothesis to analyze the nexus between economic growth and carbon emission. The EKC explains the inverted U-shaped relationship between the quality of the environment and economic growth. In particular, this hypothesis reveals that the initial level of economic growth enhances the carbon emission in an economy up to a certain level. However, the further increase in economic growth deteriorates the level of carbon emission since the country can afford efficient technologies. The existing empirical literature is inconclusive on the empirical pieces of evidence of the EKC hypothesis [47–49]. For instance, He and Richard (2010) do not find any association between economic growth and carbon emission for the case of Canada. Similarly, Ozokcu and Ozdemir [48] do not find any association between these variables for the case of 26 OECD economies. Conversely, Tunc et al. [49] report a long-run linear positive association between economic growth and carbon emission for the case of Turkey. For further details, see Arango Miranda et al. [50].

2.3. Energy Consumption, Economic Growth and CO₂ Emissions

Integrating Sections 2.1 and 2.2, the third strand of literature presents the empirical pieces of evidence on the dynamic linkages between energy consumption, economic growth and carbon emission. Interestingly, this literature is also inconsistent. One strand of empirical literature reveals bidirectional causalities in the case of Bangladesh [51], India, [52] and Tunisia [53] between energy consumption and environmental degradation. Conversely, Cowan et al. [1] report the mixed evidence on the causality between electricity consumption and carbon emission for the BRICS region. Some studies reveal the causality from economic growth to (1) energy consumption, and (2) carbon emission for the case of Bangladesh [54], Indonesia [55], Japan [56], six Central American countries [57], and a panel of selected countries [58] (This panel includes the new EU member along with its candidate countries). Second, some empirical studies reveal the unidirectional causality between these variables. Soytaş, Sari, and Ewing [8], for example, reveal a unidirectional causality for the USA from energy consumption to carbon emissions.

Comparably, in the case of five ASEAN countries, Lean and Smyth [59] indicate a unidirectional causality for economic growth from electricity consumption and carbon emissions. For the case of Bangladesh, Alam et al. [51] report unidirectional casualties ranging from carbon emissions to economic growth. In the case of India, however, Alam et al. [52] reported no causality between economic growth and carbon emissions. Similarly, some empirical studies reveal no casual linkage between the income and energy consumption, and income and carbon emission for the case of India [60] and Turkey [45].

2.4. Globalization and CO₂ Emissions

Globalization affects environmental quality through income effect [61], technique effect [62], and composition effect [63]. Income-effect reveals that globalization increases the production and trade level of an economy which reduces the environmental quality through the higher level of carbon emission. The technique effect suggests that countries have better access to energy-efficient technologies due to globalization. The use of energy-efficient technologies enhances environmental quality by reducing carbon emission. The composition effect reveals that globalization affects the ratio between capital and labour, which changes the structure of an economy. Resultantly, it is highly likely that an economy moves from agriculture to industrial and service sectors. Interestingly, the environmental effects of these sectoral shifts are different. The sectoral shift from agriculture to industry deteriorates environmental quality through a higher level of carbon emission. Conversely, the sectoral shift from agriculture to services sector enhances the environmental quality through the lower level of carbon emission. The empirical literature on the nexus between globalization and carbon emission is inconclusive. One strand of the literature reveals that globalization improves the environmental quality for the case of Australia [64], the United States of America [65], and the global economy [66]. Another strand of the literature reveals that globalization deteriorates the environmental quality for the case of 98 economies [67], 63 developed economies [68], and 105 different countries [69].

There can be a couple of reasons for this disagreement between these pieces of evidence, including the omitted variable biases, lack of data, the variable choices, and the econometrics methods. Consequently, the empirical researchers are required to investigate further the role of energy consumption, economic growth and globalization on the environmental degradation by selecting the appropriate variables and using the appropriate data and econometric methods which is expected to provide useful information to the policy makers.

3. Model, Data and Empirical Strategy

3.1. Model and Data

Following the methodologies adopted by the recent empirical studies [5,14,59,70,71], this study analyses the effects of economic growth, energy consumption and the globalization on the environmental degradation for the BRICS counties. In this framework, Equation (1) below specifies the association between the selected variables in the long run.

$$CO_{2,it} = \delta_1 + \delta_2 GDP_{i,t} + \delta_3 GDP_{i,t}^2 + \delta_4 EUS_{i,t} + \delta_5 GLO_{i,t} + \varepsilon_{i,t} \quad (1)$$

where, CO₂, GDP, GDP², EUS and GLO are the per capita carbon dioxide emissions measured in the metric tons, per capita real gross domestic product, the square of GDP, per capita energy use measured in the kg of oil equivalent, and the KOF globalization index, respectively. We use per capita carbon dioxide emission, and the real gross domestic product as the proxies for the environmental quality and economic growth, respectively. The KOF globalization index covers the different dimensions of globalization, consisting of economic, social and political aspects. In this panel setting, the *i* and *t* subscriptions show the country and time. All variables are included after taking their natural logs. In this panel framework, δ_2 , δ_3 , δ_4 , and δ_5 , indicate the long-term elasticity of gross environmental degradation in relation to economic growth, the square of economic growth, energy use and globalization, respectively. We collect annual data from 1989 to 2019 for the BRICS region

from World Development Indicators (WDI, 2020) (The world development indicators are available at <https://databank.worldbank.org/source/world-development-indicators> (accessed on 5 February 2021)) for all variables except the KOF Globalization Index. The index of globalization is the average of the de facto and the de jure index of globalization and is available at [72]. Panel data increases the efficiency of estimation across a wide range of information, variability, and independence.

3.2. Empirical Strategy

Before the estimation, we test the stationarity properties of this panel data by applying the panel unit root tests. The existing empirical literature suggests a range of panel unit root tests. However, almost all the available tests are subject to some statistical shortcoming regarding (1) the power of the test and (2) the properties of sample size [58]. Considering the robustness of the estimated results, we select three-panel unit root tests, including Breitung test [73], Im, Pesaran and Shin test [74], and Hadri [75]. Breitung panel unit root test applies the following equation.

$$Y_{it} = \beta_{it} \sum_{k=1}^{p+1} \delta_{it} X_{it-k} + \varepsilon_{it} \quad (2)$$

The null hypothesis for Breitung [73] panel unit root test is that the variables are non-stationary. Conversely, the alternative hypothesis is that the variables are stationary. Hlouskova and Wagner [76] reveal that the null and alternative hypotheses of Breitung [73] panel unit root test restricts the autoregressive coefficients to be identical across the countries. However, the higher power with the smaller sample size distortion is the main advantage of using Breitung [73]. Im, Pesaran and Shin test [74] uses the same null and alternative hypotheses.

However, Im, Pesaran, and Shin test [74] uses the following t-bar test.

$$t - bar = \frac{\sqrt{N}(t_\alpha - k_t)}{\sqrt{v_t}} \quad (3)$$

The letters and symbols used in Equation (3) are elaborated below. N = the panel size; t_α = the average of ADF t-statistics; k_t = the mean of each test statistics; and v_t = the variance of each test statistics.

This test has some advantages over Breitung [73] in terms of restrictions assuming the same speed of convergence towards equilibrium under the alternative hypothesis. The third test applied in our study is the Hadri [75] which applies the following equation.

$$Y_{it} = r_{it} + \beta_{it} + \varepsilon_{it} \quad (4)$$

This test applies the econometrical procedures to test the null hypothesis that there is no unit root in the tested series. Conversely, the alternative hypothesis of Hadri test is that the series has a unit root. Applying the Breitung test [73], Im, Pesaran and Shin test [74], and Hadri [75] panel unit root test for the preliminary data analysis reveals that the variables are non-stationary. Following Rahman [14], we extend our data analysis to examine the degree of integration among the variables used in Equation (1). For this purpose, we apply two cointegration tests, including Pedroni [77,78] and Kao [79].

Pedroni [77,78] residual cointegration test suggests seven Philips-Perron type panel cointegration tests, including the panel and group tests. The panel test and group tests apply within the dimension and between dimension methods, respectively. The panel test applying within dimensions uses four tests, including (1) panel v-Statistics, (2) panel rho-statistics, (3) panel PP-statistics, and (4) panel ADF-statistics. The group test applying between dimension method uses three tests, including (1) group rho-statistics, (2) group pp-statistics, and (3) group ADF-statistics. Pedroni [77,78] and Kao [79] tests are based on

the Engle and Granger [80] two steps residual-based cointegration tests. In particular, the above mentioned seven tests use the following long-run model.

$$Y_{it} = \varphi_i + \gamma_i + \sum_{j=1}^m \beta_{ji} X_{jit} + \varepsilon_i \quad (5)$$

The estimated residuals from Equation (4) are used as the bases for the Pedroni cointegration test statistics where the residuals follow the following structure.

$$\varepsilon_{it} = p_i \varepsilon_{it-1} + \mu_{it} \quad (6)$$

For the panel data, Pedroni cointegration test applies the cointegration structure of $[Y_{it} = \varphi_i + \beta X_{it} + \varepsilon_{it}]$. The null hypothesis for Pedroni [77,78] is that there is no cointegration between the variables. For the hypothesis testing purposes, the seven test statistics are compared with the panel cointegration statistics (These panel cointegration statistics are based on maximum likelihood). Kao [79] proposed the biased corrects panel cointegration tests with the constant variance of innovation in all cross-sections. Kao Augmented Dicky Fuller type test estimates homogenous cointegration relationship between the variables using the following regression.

$$\hat{\varepsilon}_{it} = \rho \hat{\varepsilon}_{it-1} + \sum_{j=1}^p v_j \Delta \hat{\varepsilon}_{it-j} + v_{itp} \quad (7)$$

In this procedure, the Augmented Dicky Fuller test statistics are calculated as follows [79].

$$ADF = \frac{t_{ADF} + \frac{\sqrt{6N} \hat{\sigma}_v}{2\hat{\sigma}_{0v}}}{\sqrt{\frac{\hat{\sigma}_{0v}^2}{2\hat{\sigma}_v^2} + \frac{3\hat{\sigma}_v^2}{10\hat{\sigma}_{0v}^2}}} \quad (8)$$

In Equation (8), t_{ADF} is the test statistics of ρ , and

$$\hat{\sigma}_v^2 = \hat{\Sigma}_{yy} - \hat{\Sigma}_{yx} - \hat{\Sigma}_{xx}^{-1} \quad (9)$$

$$\hat{\sigma}_{0v}^2 = \hat{\Omega}_{yy} - \hat{\Omega}_{yx} - \hat{\Omega}_{xx}^{-1} \quad (10)$$

In Equation (9), Ω is the long-run variance of the residuals? The null hypothesis for Kao [79] residual cointegration test is that there is no cointegration between the variables. The above-mentioned residual-based cointegration tests enable us to establish the panel cointegration between the carbon emission, economic growth, energy consumption and globalization. We further explore the long-run association between these variables by applying FMOLS proposed by Pedroni [81] and Phillips and Moon [82]. The OLS estimator is corrected for the endogeneity and serial correlation. As a robustness test, we apply DOLS. Kao and Chiang [83] reveal that DOLS has comparatively better sampling properties and is less biased than FMOLS.

4. Empirical Results and Analysis

Table 1 presents the descriptive statistics of the variables used in the study. A critical analysis of Table 1 reveals that Brazil and India have the highest and the lowest mean values of GDP per capita of 9680.93 and 1018.80, respectively. Further, Table 1 indicates that the Russian Federation has the highest mean values of carbon emission, energy consumption and globalization index of 12.43, 4712.69 and 63.96, respectively. The highest variation in carbon emission and economic growth is also observed for the case of the Russian Federation. Conversely, India has the lowest mean values of carbon emission, energy consumption and globalization index of 1.12, 464.42 and 49.45, respectively. Table 1 further reveals the highest level of variation in the economic growth and globalization index for

the case of China and South Africa, respectively. Further analysis of Table 1 reveals that all the data series are approximately normally distributed. The results of three-panel unit root tests, including the Breitung test [73], the Im, Pesaran, and Shin test [74], and the Hadri test [75] are presented in Table 2. In particular, columns 1 to 3 and Column 4 to 5 present the results of three-panel root test units at the level and the first difference, respectively. For the Breitung and Im, Pesaran and Shin measures, null assumptions suggest that the variables are non-stationary. Conversely, the null hypothesis for the Hadri panel unit test indicates that there is no root unit in the variables. Breitung and Im, Pesaran and Shin unit root test results show that we are unable to fail null unit root hypotheses at one percent significance level (see column one and two). Additionally, the Hadri panel root test results indicate sufficient evidence to reject the null non-stationarity hypothesis. In short, a root unit panel analysis reveals that there is a root unit in the variables.

Table 1. Summary statistics.

	Mean	Maximum	Minimum	SD	Skew	Kurt	JB (Prob)
CO ₂ _B	1.91	2.63	1.40	0.34	0.34	2.39	0.60
EUS_B	1162.71	1495.54	935.75	181.28	0.49	1.92	0.29
GDP_B	9680.93	11,993.48	7791.76	1390.20	0.32	1.60	0.23
KOF_B	53.73	60.88	42.81	6.13	−0.39	1.76	0.27
CO ₂ _R	12.43	24.40	10.13	3.43	2.91	10.23	0.00
EUS_R	4712.69	5928.66	3981.50	497.85	0.79	3.23	0.24
GDP_R	8703.75	11,731.38	5505.70	2215.08	−0.04	1.47	0.27
KOF_R	63.96	72.60	44.82	7.57	−0.97	3.04	0.12
CO ₂ _I	1.12	1.82	0.68	0.35	0.68	2.20	0.24
EUS_I	464.42	670.93	342.70	101.08	0.70	2.16	0.21
GDP_I	1018.80	1875.73	562.30	390.79	0.65	2.26	0.28
KOF_I	49.45	62.24	32.14	11.06	−0.28	1.59	0.26
CO ₂ _C	4.30	7.56	2.15	2.03	0.53	1.66	0.18
EUS_C	1276.62	2244.25	720.34	554.06	0.65	1.84	0.17
GDP_C	2861.53	6907.96	712.12	1943.18	0.71	2.18	0.21
KOF_C	53.80	64.87	32.62	10.27	−0.53	1.89	0.25
CO ₂ _S	8.77	9.98	7.73	0.57	0.40	2.78	0.66
EUS_S	2576.57	2950.15	2290.67	152.79	0.49	2.83	0.56
GDP_S	6517.09	7582.70	5517.53	778.44	0.20	1.36	0.19
KOF_S	58.02	70.64	37.11	12.55	−0.61	1.74	0.17

Note. _B, _R, _I, _C, and _S indicate Brazil, Russia, India, China and South Africa. For instance, CO₂_B indicates the carbon emission for the case of Brazil. All the variables are defined in the Section 3.1 Model and Data.

Table 2. Panel unit root tests.

	Breitung	IPS	Hardi	Breitung	IPS	Hardi
	(1)	(2)	(3)	(4)	(5)	(6)
	At Level			At First Difference		
lnCO ₂	0.2894 (0.6139)	−0.2564 (0.3988)	4.8211 *** (0.0000)	−3.3935 *** (0.0003)	−2.4553 *** (0.0070)	0.1524 (0.4394)
lnEUS	1.0122 (0.8443)	−0.3300 (0.3707)	4.0421 *** (0.0000)	−3.8821 *** (0.0001)	−5.9932 *** (0.0000)	1.4452 * (0.0742)
lnGDP	1.6275 (0.9482)	1.8822 (0.9701)	6.8425 *** (0.0000)	−2.1546 ** (0.0156)	−3.1946 *** (0.0007)	1.1991 (0.1152)
lnGDP ²	1.3024 (0.9036)	−0.8573 (0.1957)	2.9652 *** (0.0015)	−2.3230 ** (0.0101)	−2.1205 ** (0.0170)	1.2084 (0.1135)
lnKOF	1.8476 (0.9677)	2.0845 (0.9814)	22.3601 *** (0.0000)	−2.5619 *** (0.0052)	−4.2866 *** (0.0000)	1.9803 ** (0.0238)

Note. The null hypothesis for the case of Hardi is “Stationarity”. And the Heteroscedastic Consistent Z-stat are reported against Hardi panel unit root test. ***, **, and * denote significance level at 1%, 5% and 10% respectively. *p*-values are given in the parentheses.

Then we extend our analysis to analyze the panel cointegration between the variables. For this purpose, we apply Pedroni [77,78] and Kao [79] panel cointegration tests. Table 3 presents the results of these panel cointegration tests. The null hypothesis for Pedroni [77,78] test indicates that there is no cointegration between the variables. The column 1 and 2 reveals that the test statistics of three-panel tests (first, third and fourth) and two group panel tests (second and third) falls in the rejection region at 1 percent level of significance except for the panel v-statistics (The test statistics of panel v-statistics falls in the rejection region at 10 percent level of significance). Column 3 and 4 presents the weighted statistics for four-panel statistics tests. These results indicate that the weighted statistics for the third and fourth-panel statistics fall in the rejection region at one percent level of significance. Overall, these results of Pedroni [77,78] residual cointegration tests reveal that there is cointegration between the variables. Column 5 and 6 present the results of Kao [79] residual cointegration tests where the null hypothesis is that there is no cointegration between the variables. The test statistics of Kao Augmented Dicky Fuller type test falls in the rejection region at 1 percent level of significance indicating that there is the long-run association between the energy consumption, economic growth, globalization, and carbon emission.

Table 3. The results of panel cointegration tests.

	(1)	(2)	(3)	(4)	(5)	(6)
	Pedroni [77,78] Residual Co-Integration Test				Kao [79] Residual Cointegration Test	
	Within-Dimension					
	Statistics	p-Value	Weighted Statistics	p-Value	Statistics	p-Value
PS (v)	1.3357 *	0.0908	0.4367	0.3312		
PS (rho)	−0.4915	0.3115	−0.3822	0.3512		
PS (PP)	−2.4188 ***	0.0078	−3.1331 ***	0.0009		
PS (ADF)	−3.3542 ***	0.0004	−2.6501 ***	0.0040		
	Between-dimension					
	Statistics	p-value				
GS (rho)	0.5193	0.6982				
GS (PP)	−3.3358 ***	0.0004				
GS (ADF)	−3.3593 ***	0.0004				
ADF					−6.358 ***	0.000

Note: Each test uses the null hypotheses of no co-integration between the variables. Trend assumption: No deterministic trend. The above estimate uses the SIC criterion along with the maximum lags of five and six for the Pedroni and Kar tests, respectively. Further, these tests use the automatic bandwidth selection of Newey-West and Bartlett kernel. PS indicates panel statistics and GS indicates group statistics. ***, **, and * denote significant level at 1%, 5%, and 10%, respectively.

In the presence of cointegration, we extend our analysis to explore the long-run association between the variables by applying FMOLS [81,83]. One of the main advantages of FMOLS method is that the OLS estimator under this method is corrected for the endogeneity and serial correlation. Column 1 of Table 4 presents the results of panel FOMLS. Column 1 reveals that there is a positive and significant relationship between energy consumption and carbon emission. These results indicate that a higher level of energy consumption leads to a higher level of carbon emission. These results further reveal that one percent increase in energy consumption enhances the per capita carbon emission 0.36 percent on average. These results are consistent with the existing literature [8,14,51–53]. Therefore, the energy consumption is the primary source of carbon emissions in the regions.

Table 4. Panel FMOLS and DOLS estimates.

	(1)	(2)
	Panel FMO	Panel DOLS
lnEUS	0.3675 *** (4.1797)	1.2588 *** (9.2487)
lnGDP	−0.4311 (−0.2149)	−2.8087 (−0.1357)
lnGDP ²	0.3471 (0.3462)	1.1063 (0.1069)
lnKOF	−0.7182 *** (−8.1071)	−0.6211 * (−1.8032)

Note: ***, **, and * denote significance level at 1%, 5% and 10% respectively. The values given in the parentheses are *t*-statistics.

The first distinct part of the analysis reveals the presence of cointegration between the variables. Therefore, we extend our analysis to explore the long-run association between the variables by applying FMOLS. One of the main advantages of the FMOLS method is the correction of the endogeneity and serial correlation of the OLS estimator under this method. Therefore, we use FMOLS method to explore the long-run association between these variables. The results of Panel FOMLS are presented in Column 1 of Table 4. Column 1 reveals that the relationship between energy consumption and carbon emissions is positive and significant. These findings show that higher energy consumption results in higher levels of carbon emissions. These results further show that an increase of one percent in energy consumption increases per capita carbon emissions by an average of 0.36 percent. These findings are consistent with the current literature [8,13,14,51–53]. Energy consumption is, therefore, the primary source of environmental degradation in this region.

Turning now towards economic growth, the results indicate that the relationship between the per capita GDP and carbon emissions is negative and insignificant. Conversely, the relationship between the square of per capita GDP and carbon emissions is positive and significant (see Column 1). Interestingly, each association is insignificant. Contrary to expectations, we could not find any evidence in the BRICS region of the Environmental Kuznets Curve. These findings are consistent with the He and Richard [47], Ozokcu and Ozdemir [48] and Shahbaz and Sinha [11]. These nations are more concerned about achieving the economic growth rather than environmental quality due to the low levels of income elasticity of environmental demand and environmental awareness [11]. These findings are expected to support the neutrality hypothesis [32,43–46,84–90]. However, these findings contrast with Tunc et al. [49] and Haseeb et al. [12] (For further details, see Arango Miranda et al. (2020)). Further analysis reveals that there is a negative and significant relationship between globalization and the carbon emission indicating that the region with the higher level of globalization experience the less environmental pollution. In particular, one percent increase in the level of globalization reduces the carbon emission by 0.71 percent on average. These results are consistent with one strand of the empirical literature [64–66]. However, these results are in contrast with another strand of the empirical literature [67–69]. These findings are in support of the technique effects [58]. The possible reason is the fact that the BRICS countries have better access to energy-efficient technologies due to the globalization. The use of energy-efficient technologies enhances environmental quality by reducing carbon emission.

Further, we apply DOLS to test the robustness of our results. Kao and Chiang [83] reveal that DOLS has comparatively better sampling properties and is less biased than FMOLS. The results of the DOLS panel are presented in Table 4, Column 2. These results from DOLS also show that the energy consumption per capita increases the carbon emission rate per capita. Per capita economic growth has a negative and insignificant relationship with per capita carbon emissions. On the other hand, the per capita economic growth square has a positive and insignificant relationship to per capita carbon emissions. The

DOLS results do not support the existence of the EKC in the BRICS region. These results are consistent with the findings of the FMOLS. Finally, the results of DOLS on globalization reveal a negative and significant link between globalization and carbon emissions. Overall, the DOLS findings are consistent with our FMOLS results.

In the presence of heterogeneity of parameters, the existing empirical literature [14,91] recommend estimating the separate FMOLS for each country. Therefore, this study estimates the long-run parameters for each country applying FMOLS. Table 5 presents the country-wise results of FMOLS. Looking at the long-term estimates of energy consumption, column 1, 2 and 5 indicates that there is a positive and significant relationship between the per capita energy consumption and the per capita carbon emission for the case of Brazil, Russian Federation, and South Africa. These results are consistent with the panel estimates of FMOLS and DOLS (See the discussion on the panel FMOLS above for the detailed comparison of these results with the existing empirical literature). These results indicate that energy consumption is the primary source of carbon emissions in Brazil, the Russian Federation and South Africa. Looking at the Brazil energy-emission nexus, this analysis reveals that per capita energy consumption is the higher source of carbon emissions in Brazil where one percent increase in the per capita energy consumption enhances the per capita carbon emission by 2.88 percent, on average. The results of the Russian Federation and South Africa contrast with the Cowan et al. [1] and this might be due to the use of fossil fuel and non-renewable energy. For the case of South Africa, most sources depend upon the coal-burning, which enhance the level of carbon emission [92].

Table 5. The results of FMOLS estimation (country wise).

	(1)	(2)	(3)	(4)	(5)
	Brazil	Russia	India	China	South Africa
lnEUS	2.8805 *** (8.1376)	0.5811 *** (11.1702)	−2.2004 *** (−41.1480)	0.0636 (0.4050)	0.4784 ** (2.2731)
lnGDP	4.7398 (1.2269)	5.0421 (1.6595)	−9.9627 *** (−5.7727)	1.1450 (0.1555)	−0.7636 (−0.2595)
lnGDP ²	−3.5028 * (−1.7920)	−2.3580 (−1.5489)	6.0510 *** (7.0659)	−0.0768 (−0.0209)	0.2713 (0.1829)
lnKOF	0.2726 (0.9278)	−1.2935 *** (−13.0279)	−0.2884 *** (18.5564)	−3.2171 *** (−8.1342)	0.0038 (1.1034)

Note. ***, **, and * denote significance level at 1%, 5% and 10% respectively. The values given in the parentheses are t-statistics.

However, the coefficient estimates of column 3 reveal that there is a negative and significant relationship between the per capita energy consumption and the per capita carbon emission for the case of India. These findings are consistent with the Ghosh [60] (Gosh (2010) reveals no causal linkage between income and energy consumption, and income and carbon emission for the case of India). However, these results contrast with the panel FMOLS and panel DOLS results. The estimates in column 3 of Table 5 further reveals that one percent increase in the per capita energy consumption deteriorates the per capita carbon emission by 2.20 percent, on average. One of the possible reasons for this association can be the efforts of the Indian government to generate the electricity from the non-fossil fuel sources. One these lines, the Indian government has promised to ensure that 40 percent of the electricity generation capacity comes from the non-fossil fuel sources. It is somewhat surprising that there is a positive but insignificant relationship between the per capita energy consumption and the per capita carbon emission for the case of China. These findings are inconsistent with the Cowan et al. [1]. This might be due to the tremendous progress China is making in terms of using alternative and clean energy sources. China has Three Gorges Dam (a hydroelectric gravity dam) which has the largest installed capacity. Further, China holds over half of the world wind turbine industry and nuclear capacity being built (For further details, see [93]).

The next section of Table 5 reveals the long-run association between the per capita economic growth and the per capita carbon emission. The coefficients for the case of Brazil, the Russian Federation and China indicate the inverted U-shaped EKC. However, these relationships are insignificant since the test-statistics falls in the non-rejection regions. For the case of Brazil, the square of per capita economic growth is negative and significant which might be since Brazil has the second and the third largest hydropower plants in the world on the Panama River and the Belo Monte projects in the Amazon Basin [93]. Looking at the Russian results, the policy makers of Russian federation should focus on the infrastructure spending to boost their energy efficiency to reduce the level of carbon emission in the country ultimately. Turning now towards China, the insignificant relationship between the per capita economic growth and per capita carbon emission is consistent with the Cowan et al. [1]. The possible reason for these results is the fact that the total energy intensity of China has reduced significantly. Further, China is on track to meet the targets set by the Twelfth Five Year Plan [94] (Also see China, Energy Efficiency Report available on the www.abb.com).

Turning now towards India and South Africa, column 3 of Table 5 reveals that there is a presence of U-shaped EKC for the case of India. These results are in line with Ozcan [91] and Wang et al. [6]. However, these results are in contrast to many studies [59,94–96]. On these lines, Ozcan [91] reveals that one of the possible reasons of U-shaped EKC for the developing countries can be fact that these economies might ignore using eco-friendly technologies in their growth processes. Another possible reasons can be the fact Indian economy shift to the industrial sector. Therefore, carbon emission starts to increase. These findings suggest that India still needs efficient technologies to keep the pace of its existing economic growth since the current level of economic growth is enhancing the carbon emission. The coefficients for the case of South Africa indicate the U-shaped EKC. However, these relationships are insignificant since the test-statistics falls in the non-rejection regions. These findings can be elaborated through the composition effect. One of the possible reasons can be the fact the South African economy relies on the energy sector; therefore, the carbon emission starts to increase [1]. Overall, the results validate the existence of U-shaped EKC for the case of India.

The last section of Table 5 presents the results on the long-run association between the KOF globalization index and the per capita carbon emission. Column 2, 3 and 4 of Table 5 reveal that there is a negative and significant association between the globalization index and the per capita carbon emission for the case of the Russian Federation, India and China. It is encouraging to compare these results with the panel FMOLS and DOLS. Furthermore, interestingly, these results are consistent with each other. The country-wise results further indicate that one percent increase in the globalization index deteriorates the per capita carbon emission by 1.29 percent, 0.29 percent and 3.22 percent for the case of Russian Federation, India and China, respectively. These results are consistent with Shahbaz, Bhattacharya and Ahmed [64], Dogan and Turkekul [65], Lee and Min [66], Ahmed et al. [97] and other establishing that globalization deteriorates the carbon emissions via income, scale and technology effect. On these lines, Shahbaz, Bhattacharya and Ahmed [64] reveals that globalization is one the main sources of economic growth and environmental quality through reducing the carbon emission. They further indicate that the intermediate effects of technology are more evident when an economy has achieved a higher level of globalization. The transmission mechanism of globalization to reduce carbon emission is the availability of technology. India and China observed the fast annual growth in the globalization index during last couple of decades. This higher level of globalization along with the investment opportunities are expected to bring attract foreign direct investment by multinational enterprises (MNE). Resultantly, these MNEs will bring the latest and energy-efficient technologies in these emerging economies [66].

Column 1 and 5 reveals that there is a positive and insignificant relationship between the globalization index and the per capita carbon emission for the case of Brazil and South Africa. Overall, our results indicate that higher level of globalization improves

the quality of environment through reducing the level of carbon emission. And these results are consistent with one strand of the empirical literature [12,64–66]. However, these results are in contrast with another strand of the empirical literature [67–69]. Looking at the transmission mechanisms, these findings for the case of the Russian Federation, India and China are supported by the technique effect where countries have better access to the energy-efficient technologies due to the globalization. The use of energy-efficient technologies enhances environmental quality by reducing carbon emission.

5. Conclusions

Applying a panel cointegration approach on the annual data from 1989 to 2019, this paper examines the effect of energy consumption, globalization, and economic growth on the CO₂ emission of the BRICS region. The results of panel unit root tests reveal that there is a unit root in the variables. We, therefore, broaden our research to evaluate the inter-variables panel cointegration. For this purpose, we apply Pedroni [77,78] and Kao [79] panel cointegration tests. The results of tests of panel cointegration demonstrate that the variables are co-integrated. We extend our analysis in the presence of cointegration to investigate the long-term interaction of variables by applying FMOLS. The results of the FMOLS panel showed a positive and significant association between energy consumption and carbon emissions, indicating energy consumption as the fundamental cause of carbon emissions. The policy makers of BRICS economies should design the policies to improve energy efficiency through: (1) subsidizing new and well-developed raw material; (2) developing energy infrastructure; (3) supporting energy-saving projects; and (4) implementing energy-conservative policies. We could not find any evidence of the Environmental Kuznets Curve during the panel analysis of BRICS region. Further, research shows that the relationship between globalization and carbon emissions is negative and significant and that the region with the highest level of globalization is experiencing the lowest pollution of the atmosphere. When we look at the transmission pathways, these results confirm the technical effects [62]. The explanation is possible because the BRICS countries have greater access to energy-efficient technologies due to the globalization. By reducing carbon emissions, the use of energy-efficient technology increases environmental efficiency. These results indicate that government of these countries should pay attention to improve globalization.

The country-specific study has shown that energy consumption is the fundamental cause of environmental degradation in Brazil, the Russian Federation and South Africa. However, the per capita energy consumption and per capita carbon emissions in India are negatively and significantly related. Looking at the economic growth, the square of per capita economic growth is negative and significant for the case of Brazil which might be since Brazil has the second and the third largest hydropower plants in the world on the Panama River and the Belo Monte projects in the Amazon Basin [93]. For the case of India, there is a U-shaped EKC presence. The fact that Indian economies shift from agriculture to the industrial sector can be one of the possible factors. The carbon emission is, therefore beginning to increase. These results indicate that India needs effective technology to keep pace with its current economic development, as current growth raises carbon emissions. The globalization index and the per capita carbon dioxide emissions for the Russian Federation, India, and China have been significantly and negatively related.

Author Contributions: Conceptualization, H.U.R. and U.Z.; methodology, H.U.R.; software, H.U.R.; validation, H.U.R.; formal analysis, H.U.R.; investigation, U.Z.; resources, U.Z.; data curation, H.U.R.; writing—original draft preparation H.U.R.; writing—review and editing, U.Z. and J.G.; visualization, H.U.R.; supervision, U.Z. and J.G.; project administration, U.Z.; funding acquisition, U.Z. and J.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the UTP University of Science and Technology, Bydgoszcz, Poland.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All relevant study data is contained within the article. Additional request for panel data source materials can be made directly to the corresponding author.

Acknowledgments: We thank the UTP University of Science and Technology, Bydgoszcz (Poland) and its Faculty of Civil and Environmental Engineering and Architecture for proving funds for the publication of the manuscript.

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

References

1. Pao, H.T.; Tsai, C.M. CO₂ emissions, energy consumption and economic growth in BRIC countries. *Energy Policy* **2010**, *38*, 7850–7860. [\[CrossRef\]](#)
2. Cowan, W.N.; Chang, T.; Inglesi-Lotz, R.; Gupta, R. The nexus of electricity consumption, economic growth and CO₂ emissions in the BRICS countries. *Energy Policy* **2014**, *66*, 359–368. [\[CrossRef\]](#)
3. Azevedo, V.G.; Sartori, S.; Campos, L.M. CO₂ emissions: A quantitative analysis among the BRICS nations. *Renew. Sustain. Energy Rev.* **2018**, *81*, 107–115. [\[CrossRef\]](#)
4. Nain, M.Z.; Ahmad, W.; Kamaiah, B. Economic growth, energy consumption and CO₂ emissions in India: A disaggregated causal analysis. *Int. J. Sustain. Energy* **2017**, *36*, 807–824. [\[CrossRef\]](#)
5. Rahman, M.M. Environmental degradation: The role of electricity consumption, economic growth and globalisation. *J. Environ. Manag.* **2020**, *253*, 109742. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Wang, S.S.; Zhou, D.Q.; Zhou, P.; Wang, Q.W. CO₂ emissions, energy consumption and economic growth in China: A panel data analysis. *Energy Policy* **2011**, *39*, 4870–4875. [\[CrossRef\]](#)
7. Shahbaz, M.; Khan, S.; Ali, A.; Bhattacharya, M. The impact of globalization on CO₂ emissions in China. *Singap. Econ. Rev.* **2017**, *62*, 929–957. [\[CrossRef\]](#)
8. Soytaş, U.; Sari, R.; Ewing, B.T. Energy consumption, income, and carbon emissions in the United States. *Ecol. Econ.* **2007**, *62*, 482–489. [\[CrossRef\]](#)
9. Apergis, N.; Payne, J.E.; Menyah, K.; Wolde-Rufael, Y. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecol. Econ.* **2010**, *69*, 2255–2260. [\[CrossRef\]](#)
10. Khan, M.K.; Teng, J.Z.; Khan, M.I.; Khan, M.O. Impact of globalization, economic factors and energy consumption on CO₂ emissions in Pakistan. *Sci. Total Environ.* **2019**, *688*, 424–436. [\[CrossRef\]](#)
11. Shahbaz, M.; Sinha, A. Environmental Kuznets curve for CO₂ emissions: A literature survey. *J. Econ. Stud.* **2019**, *46*, 106–168. [\[CrossRef\]](#)
12. Haseeb, A.; Xia, E.; Baloch, M.A.; Abbas, K. Financial development, globalization, and CO₂ emission in the presence of EKC: Evidence from BRICS countries. *Environ. Sci. Pollut. Res.* **2018**, *25*, 31283–31296. [\[CrossRef\]](#)
13. Salahuddin, M.; Gow, J.; Ali, M.I.; Hossain, M.R.; Al-Azami, K.S.; Akbar, D.; Gedikli, A. Urbanization-globalization-CO₂ emissions nexus revisited: Empirical evidence from South Africa. *Heliyon* **2019**, *5*, e01974. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Rahman, M.M. Do population density, economic growth, energy use and exports adversely affect environmental quality in Asian populous countries? *Renew. Sustain. Energy Rev.* **2017**, *77*, 506–514. [\[CrossRef\]](#)
15. Kraft, J.; Kraft, A. On the relationship between energy and GNP. *J. Energy Dev.* **1978**, *3*, 401–403.
16. Liu, Y.; Hao, Y. The dynamic links between CO₂ emissions, energy consumption and economic development in the countries along “the Belt and Road”. *Sci. Total Environ.* **2018**, *645*, 674–683. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Karanfil, F. How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools? *Energy Policy* **2009**, *37*, 1191–1194. [\[CrossRef\]](#)
18. Lee, C.C. Energy consumption and GDP in developing countries: A cointegrated panel analysis. *Energy Econ.* **2005**, *27*, 415–427. [\[CrossRef\]](#)
19. Zachariadis, T.; Pashourtidou, N. An empirical analysis of electricity consumption in Cyprus. *Energy Econ.* **2007**, *29*, 183–198. [\[CrossRef\]](#)
20. Ozturk, I. A literature survey on energy–growth nexus. *Energy Policy* **2010**, *38*, 340–349. [\[CrossRef\]](#)
21. Altinay, G.; Karagol, E. Electricity consumption and economic growth: Evidence from Turkey. *Energy Econ.* **2005**, *27*, 849–856. [\[CrossRef\]](#)
22. Asafu-Adjaye, J. The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Econ.* **2000**, *22*, 615–625. [\[CrossRef\]](#)
23. Belloumi, M. Energy consumption and GDP in Tunisia: Cointegration and causality analysis. *Energy Policy* **2009**, *37*, 2745–2753. [\[CrossRef\]](#)
24. Ho, C.Y.; Siu, K.W. A dynamic equilibrium of electricity consumption and GDP in Hong Kong: An empirical investigation. *Energy Policy* **2007**, *35*, 2507–2513. [\[CrossRef\]](#)
25. Masih, A.M.; Masih, R. Energy consumption, real income and temporal causality: Results from a multi-country study based on cointegration and error-correction modelling techniques. *Energy Econ.* **1996**, *18*, 165–183. [\[CrossRef\]](#)

26. Narayan, P.K.; Smyth, R. Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Econ.* **2008**, *30*, 2331–2341. [\[CrossRef\]](#)
27. Oh, W.; Lee, K. Causal relationship between energy consumption and GDP revisited: The case of Korea 1970–1999. *Energy Econ.* **2004**, *26*, 51–59. [\[CrossRef\]](#)
28. Shiu, A.; Lam, P.L. Electricity consumption and economic growth in China. *Energy Policy* **2004**, *32*, 47–54. [\[CrossRef\]](#)
29. Soytas, U.; Sari, R. Energy consumption and GDP: Causality relationship in G-7 countries and emerging markets. *Energy Econ.* **2003**, *25*, 33–37. [\[CrossRef\]](#)
30. Squalli, J. Electricity consumption and economic growth: Bounds and causality analyses of OPEC members. *Energy Econ.* **2007**, *29*, 1192–1205. [\[CrossRef\]](#)
31. Yang, H.Y. A note on the causal relationship between energy and GDP in Taiwan. *Energy Econ.* **2000**, *22*, 309–317. [\[CrossRef\]](#)
32. Yu, E.S.; Choi, J.Y. The causal relationship between energy and GNP: An international comparison. *J. Energy Dev.* **1985**, *10*, 249–272.
33. Ang, J.B. Economic development, pollutant emissions and energy consumption in Malaysia. *J. Policy Model.* **2008**, *30*, 271–278. [\[CrossRef\]](#)
34. Cheng, B.S. Energy consumption, employment and causality in Japan: A multivariate approach. *Indian Econ. Rev.* **1998**, *33*, 19–29.
35. Cheng, B.S. Causality between energy consumption and economic growth in India: An application of cointegration and error-correction modeling. *Indian Econ. Rev.* **1999**, *34*, 39–49.
36. Narayan, P.K.; Smyth, R. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. *Energy Policy* **2005**, *33*, 1109–1116. [\[CrossRef\]](#)
37. Zamani, M. Energy consumption and economic activities in Iran. *Energy Econ.* **2007**, *29*, 1135–1140. [\[CrossRef\]](#)
38. Zhang, X.P.; Cheng, X.M. Energy consumption, carbon emissions, and economic growth in China. *Ecol. Econ.* **2009**, *68*, 2706–2712. [\[CrossRef\]](#)
39. Erdal, G.; Erdal, H.; Esengun, K. The causality between energy consumption and economic growth in Turkey. *Energy Policy* **2008**, *36*, 3838–3842. [\[CrossRef\]](#)
40. Glasure, Y.U. Energy and national income in Korea: Further evidence on the role of omitted variables. *Energy Econ.* **2002**, *24*, 355–365. [\[CrossRef\]](#)
41. Hondroyannis, G.; Lolos, S.; Papapetrou, E. Energy consumption and economic growth: Assessing the evidence from Greece. *Energy Econ.* **2002**, *24*, 319–336. [\[CrossRef\]](#)
42. Hwang, D.B.; Gum, B. The causal relationship between energy and GNP: The case of Taiwan. *J. Energy Dev.* **1991**, *16*, 219–226.
43. Akarca, A.T.; Long, T.V. On the relationship between energy and GNP: A reexamination. *J. Energy Dev.* **1980**, *5*, 326–331.
44. Altinay, G.; Karagol, E. Structural break, unit root, and the causality between energy consumption and GDP in Turkey. *Energy Econ.* **2004**, *26*, 985–994. [\[CrossRef\]](#)
45. Soytas, U.; Sari, R. Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecol. Econ.* **2009**, *68*, 1667–1675. [\[CrossRef\]](#)
46. Stern, D.I. Energy and economic growth in the USA: A multivariate approach. *Energy Econ.* **1993**, *15*, 137–150. [\[CrossRef\]](#)
47. He, J.; Richard, P. Environmental Kuznets curve for CO₂ in Canada. *Ecol. Econ.* **2010**, *69*, 1083–1093. [\[CrossRef\]](#)
48. Ozokcu, S.; Ozdemir, O. Economic growth, energy, and environmental Kuznets curve. *Renew. Sustain. Energy Rev.* **2017**, *72*, 639–647. [\[CrossRef\]](#)
49. Tunc, G.I.; Turut-Aşık, S.; Akbostancı, E. A decomposition analysis of CO₂ emissions from energy use: Turkish case. *Energy Policy* **2009**, *37*, 4689–4699. [\[CrossRef\]](#)
50. Arango Miranda, R.; Hausler, R.; Romero Lopez, R.; Glaus, M.; Pasillas-Diaz, J.R. Testing the environmental kuznets curve hypothesis in North America's free trade agreement (NAFTA) countries. *Energies* **2010**, *13*, 3104. [\[CrossRef\]](#)
51. Alam, M.J.; Begum, I.A.; Buysse, J.; Van Huylenbroeck, G. Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. *Energy Policy* **2012**, *45*, 217–225. [\[CrossRef\]](#)
52. Alam, M.J.; Begum, I.A.; Buysse, J.; Rahman, S.; Van Huylenbroeck, G. Dynamic modeling of causal relationship between energy consumption, CO₂ emissions and economic growth in India. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3243–3251. [\[CrossRef\]](#)
53. Mbarek, M.B.; Saidi, K.; Rahman, M.M. Renewable and non-renewable energy consumption, environmental degradation and economic growth in Tunisia. *Qual. Quant.* **2018**, *52*, 1105–1119. [\[CrossRef\]](#)
54. Rahman, M.M.; Kashem, M.A. Carbon emissions, energy consumption and industrial growth in Bangladesh: Empirical evidence from ARDL cointegration and Granger causality analysis. *Energy Policy* **2017**, *110*, 600–608. [\[CrossRef\]](#)
55. Shahbaz, M.; Hye, Q.M.A.; Tiwari, A.K.; Leita, N.C. Economic growth, energy consumption, financial development, international trade and CO₂ emissions in Indonesia. *Renew. Sustain. Energy Rev.* **2013**, *25*, 109–121. [\[CrossRef\]](#)
56. Hossain, S. An econometric analysis for CO₂ emissions, energy consumption, economic growth, foreign trade, and urbanization of Japan. *Low Carbon Econ.* **2012**, *3*, 92–105. [\[CrossRef\]](#)
57. Apergis, N.; Payne, J.E. A dynamic panel study of economic development and the electricity consumption-growth nexus. *Energy Econ.* **2011**, *33*, 770–781. [\[CrossRef\]](#)
58. Kasman, A.; Duman, Y.S. CO₂ emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. *Econ. Model.* **2015**, *44*, 97–103. [\[CrossRef\]](#)
59. Lean, H.H.; Smyth, R. CO₂ emissions, electricity consumption and output in ASEAN. *Appl. Energy* **2010**, *87*, 1858–1864. [\[CrossRef\]](#)

60. Ghosh, S. Examining carbon emissions economic growth nexus for India: A multivariate cointegration approach. *Energy Policy* **2010**, *38*, 3008–3014. [\[CrossRef\]](#)
61. Jena, P.R.; Grote, U. Growth-trade-environment nexus in India. *Econ. Bull.* **2008**, *17*, 1–11.
62. Dasgupta, S.; Hamilton, K.; Pandey, K.D.; Wheeler, D. Environment during growth: Accounting for governance and vulnerability. *World Dev.* **2006**, *34*, 1597–1611. [\[CrossRef\]](#)
63. Shahbaz, M.; Shahzad, S.J.H.; Mahalik, M.K. Is globalization detrimental to CO₂ emissions in Japan? New threshold analysis. *Environ. Model. Assess.* **2018**, *23*, 557–568. [\[CrossRef\]](#)
64. Shahbaz, M.; Bhattacharya, M.; Ahmed, K. CO₂ emissions in Australia: Economic and non-economic drivers in the long-run. *Appl. Econ.* **2017**, *49*, 1273–1286. [\[CrossRef\]](#)
65. Dogan, E.; Turkekul, B. CO₂ emissions, real output, energy consumption, trade, urbanization and financial development: Testing the EKC hypothesis for the USA. *Environ. Sci. Pollut. Res.* **2016**, *23*, 1203–1213. [\[CrossRef\]](#)
66. Lee, K.H.; Min, B. Globalization and carbon constrained global economy: A fad or a trend? *J. Asia-Pac. Bus.* **2014**, *15*, 105–121. [\[CrossRef\]](#)
67. Le, T.H.; Chang, Y.; Park, D. Trade openness and environmental quality: International evidence. *Energy Policy* **2016**, *92*, 45–55. [\[CrossRef\]](#)
68. Managi, S. Trade liberalization and the environment: Carbon dioxide for 1960–1999. *Econ. Bull.* **2004**, *17*, 1–5.
69. Shahbaz, M.; Nasreen, S.; Ahmed, K.; Hammoudeh, S. Trade openness–carbon emissions nexus: The importance of turning points of trade openness for country panels. *Energy Econ.* **2017**, *61*, 221–232. [\[CrossRef\]](#)
70. Dogan, E.; Aslan, A. Exploring the relationship among CO₂ emissions, real GDP, energy consumption and tourism in the EU and candidate countries: Evidence from panel models robust to heterogeneity and cross-sectional dependence. *Renew. Sustain. Energy Rev.* **2017**, *77*, 239–245. [\[CrossRef\]](#)
71. Inglesi-Lotz, R.; Dogan, E. The role of renewable versus non-renewable energy to the level of CO₂ emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators. *Renew. Energy* **2018**, *123*, 36–43. [\[CrossRef\]](#)
72. Gygli, S.; Haelg, F.; Potrafke, N.; Sturm, J.-E. The KOF globalisation index–revisited. *Rev. Int. Organ.* **2019**, *14*, 543–574. [\[CrossRef\]](#)
73. Breitung, J. *The Local Power of Some Unit Root Tests for Panel Data, Discussion Paper*; Humboldt University: Berlin, Germany, 1999.
74. Im, K.S.; Pesaran, M.H.; Shin, Y. Testing for unit roots in heterogeneous panels. *J. Econom.* **2003**, *115*, 53–74. [\[CrossRef\]](#)
75. Hadri, K. Testing for stationarity in heterogeneous panel data. *Econom. J.* **2000**, *3*, 148–161. [\[CrossRef\]](#)
76. Hlouskova, J.; Wagner, M. The performance of panel unit root and stationarity tests: Results from a large scale simulation study. *Econom. Rev.* **2006**, *25*, 85–116. [\[CrossRef\]](#)
77. Pedroni, P. Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxf. Bull. Econ. Stat.* **1999**, *61* (Suppl. 1), 653–670. [\[CrossRef\]](#)
78. Pedroni, P. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econom. Theory* **2004**, *20*, 597–625. [\[CrossRef\]](#)
79. Kao, C. Spurious regression and residual-based tests for cointegration in panel data. *J. Econom.* **1999**, *90*, 1–44. [\[CrossRef\]](#)
80. Engle, R.F.; Granger, C.W. Co-integration and error correction: Representation, estimation, and testing. *Econom. J. Econom. Soc.* **1987**, *55*, 251–276. [\[CrossRef\]](#)
81. Pedroni, P. Fully Modified OLS for Heterogeneous Cointegrated Panels. *Nonstationary Panels Panel Cointegr. Dyn. Panels* **2000**, *15*, 93–130.
82. Phillips, P.C.; Moon, H.R. Linear regression limit theory for nonstationary panel data. *Econometrica* **1999**, *67*, 1057–1111. [\[CrossRef\]](#)
83. Kao, C.; Chiang, M.H. On the estimation and inference of a cointegrated regression in panel data. In *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*; Emerald Group Publishing: Somerville, MA, USA, 2001.
84. Cheng, B.S. An investigation of cointegration and causality between energy consumption and economic growth. *J. Energy Dev.* **1995**, *21*, 73–84.
85. Eden, S.H.; Hwang, B.K. The relationship between energy and GNP: Further results. *Energy Econ.* **1984**, *6*, 186–190.
86. Eden, S.H.; Jin, J.C. Cointegration tests of energy consumption, income, and employment. *Resour. Energy* **1992**, *14*, 259–266.
87. Fatai, K.; Oxley, L.; Scrimgeour, F. Energy consumption and employment in New Zealand: Searching for causality. In *Proceedings of the NZAE Conference, Wellington, New Zealand, 26–28 June 2002; Volume 2*.
88. Halicioglu, F. An econometric study of CO₂ emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy* **2009**, *37*, 1156–1164. [\[CrossRef\]](#)
89. Jobert, T.; Karanfil, F. Sectoral energy consumption by source and economic growth in Turkey. *Energy Policy* **2007**, *35*, 5447–5456. [\[CrossRef\]](#)
90. Payne, J.E. On the dynamics of energy consumption and output in the US. *Appl. Energy* **2009**, *86*, 575–577. [\[CrossRef\]](#)
91. Ozcan, B. The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. *Energy Policy* **2013**, *62*, 1138–1147. [\[CrossRef\]](#)
92. EIA. *U.S. Energy Information Administration, Country Analysis 2013*. Available online: <http://www.eia.gov/countries> (accessed on 5 February 2021).
93. EIA. *U.S. Energy Information Administration, Country Analysis 2012*. Available online: <http://www.eia.gov/countries> (accessed on 5 February 2021).

-
94. Hallding, K. *Together Alone: BASIC Countries and the Climate Change Conundrum*; Nordic Council of Ministers: Copenhagen, Denmark, 2011.
 95. Apergis, N.; Payne, J.E. CO₂ emissions, energy usage, and output in Central America. *Energy Policy* **2009**, *37*, 3282–3286. [[CrossRef](#)]
 96. Apergis, N.; Payne, J.E. The emissions, energy consumption, and growth nexus: Evidence from the commonwealth of independent states. *Energy Policy* **2010**, *38*, 650–655. [[CrossRef](#)]
 97. Ahmed, K.; Bhattacharya, M.; Qazi, A.Q.; Long, W. Energy consumption in China and underlying factors in a changing landscape: Empirical evidence since the reform period. *Renew. Sustain. Energy Rev.* **2016**, *58*, 224–234. [[CrossRef](#)]