



How Do Economic Growth and the Emissions of Carbon Dioxide Relate?

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Abstract

Our work investigated the relationship between carbon dioxide emissions and economic development in 10 different countries from 2010 to 2019, using a panel data technique. The growth of the economy in different countries involves greater use of energy, which leads to more CO₂ emissions; hence pollution is intimately related to the growth of the economy and development. By applying the ECM analysis, we confirmed the long-run correlation between Gross Domestic Product and the emissions of CO₂ is positive, due to the sluggish adoption of new low-carbon policies, which makes it difficult to attain the same output level with lower carbon dioxide emissions in the long run. The short-run relationship between GDP and the emissions of CO₂ is negative, while coherent energy policies are due to help in accomplishing a quick development through more intensive energy consumption, yet our findings show that growth slows as carbon dioxide emissions rise.

Subject Areas

Business Management, Development Economics

Keywords

ECM, GDP, Carbon Dioxide Emissions, Panel Data Approach

1. Introduction

In order to reduce national energy dependence and assure the country's long-term development, in recent years, various countries have shifted their energy policies towards the diversification of sources of supply and the use of renewable energy sources [1]. Several initiatives are currently being implemented, with good outcomes, particularly in the electrical sector. To achieve the goals and the contributions of renewable energies to suitable energy balance that

countries have set themselves, it will be necessary to complete and strengthen current mechanisms for promoting effective energy. There are a lot of studies investigating the relationship between economic growth and CO₂ emissions [2] [3]. Various countries are confronted with a major challenge: ensuring sustained economic growth while also tackling climate change [4]. The issue of the climate crisis is mostly caused by excess CO₂ emissions. Countries' economic boom implies greater use of energy, which leads to more carbonic acid gas emissions, hence carbon emissions are intimately associated with economic growth and development. Economic growth and development, on the other side, involve the introduction of new energy-saving and low-carbon innovations that substitute previous energy and carbon in-depth ones [5]. Generally, energy and GDP are important components of any country's daily life; our work entails talking about everything that is related to them. Studies found that the combustion of fossil fuels in fixed installations, in motor vehicles industries, and other functional pollutions leads to the emission of various pollutants into the atmosphere, including sulfur nitrogen oxide and carbon dioxide (CO₂), etc. [6] [7] [8]. In the publications of the Intergovernmental Panel on Climate Change [9], the urgency of the global climate situation is described in depth. It has also been demonstrated by the recent escalation of catastrophic climate events. **Figure 1** represents the quantity of CO₂ emissions released by our chosen countries, and we see that developed countries play a great role in the urgency of the global climate [10]. Intergovernmental climate change expert group reports have clearly demonstrated the link between fossil fuels, greenhouse gas emissions, and global warming. They've shown that even if CO₂ emissions are frozen at their current levels, CO₂ concentrations in the atmosphere will continue to rise for the next two millennia [11]. The urgency of the global climate situation and the emission reductions to which they have committed the Kyoto Protocol have led

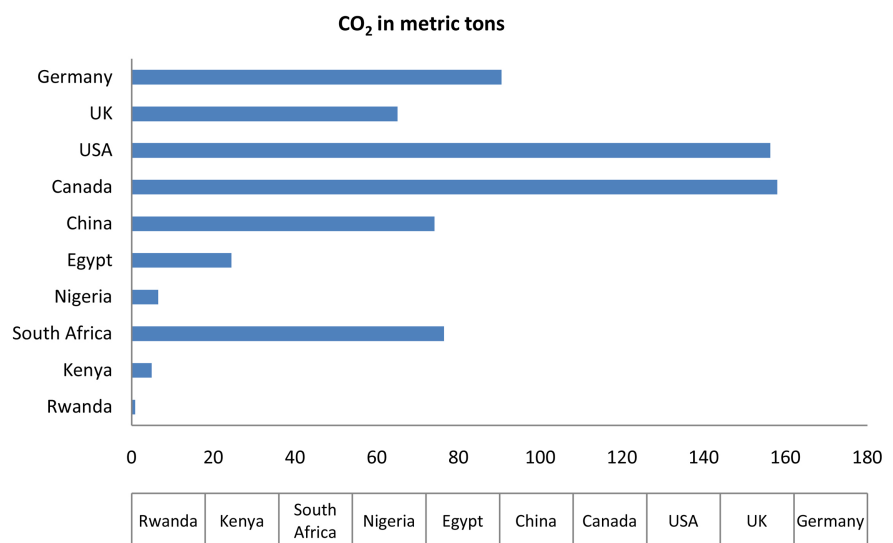


Figure 1. The quantity of the emissions of CO₂ generated by different countries (Source: WDI).

industrialized countries [12], led by European countries, to intensify their countries, especially the European ones, to intensify their investments in renewable energy. These investments concern not only their own territory but also, within the framework of the Clean Development Mechanism (CDM), developing countries [13] [14].

Energy has always been seen as a precious resource in today's society. The reason why the increase in the price of oil can influence the evolution of economic growth either upwards or downwards, depending on the energy profile of each country [15]. Indeed, countries with enough energy resources, in the event of a price increase, can keep the same level of GDP growth and even accelerate it, since the energy sector itself can increase growth. On the other hand, for countries with limited resources and which burdened by the uprising weight of energy imports, an increase in the price of oil will slow down their growth and even reverse it downwards since their national energy resources no longer cover the energy demand, and that it continues to increase at a steady rate and hence the import ratio energy to GDP continues to escalate by affecting the growth of their economies [16] [17]. Regarding developed countries, and as net importers or exporters of (fossils) energy, they are characterized by a strong effective GDP (see Figure 2) which is always ready to face the variability of international energy prices. As a matter of fact, their industries remain the first energy consumer, consequently, this results in high emissions of carbonic acid gas [12] [18]. In addition, the cost of energy in the cost of manufacturing a product becomes a factor determinant of their competitiveness, which is at the same time the cost of environment see Figure 1, for a good management of this problem, countries are called to safeguard their industrial activities, practice the use of renewable

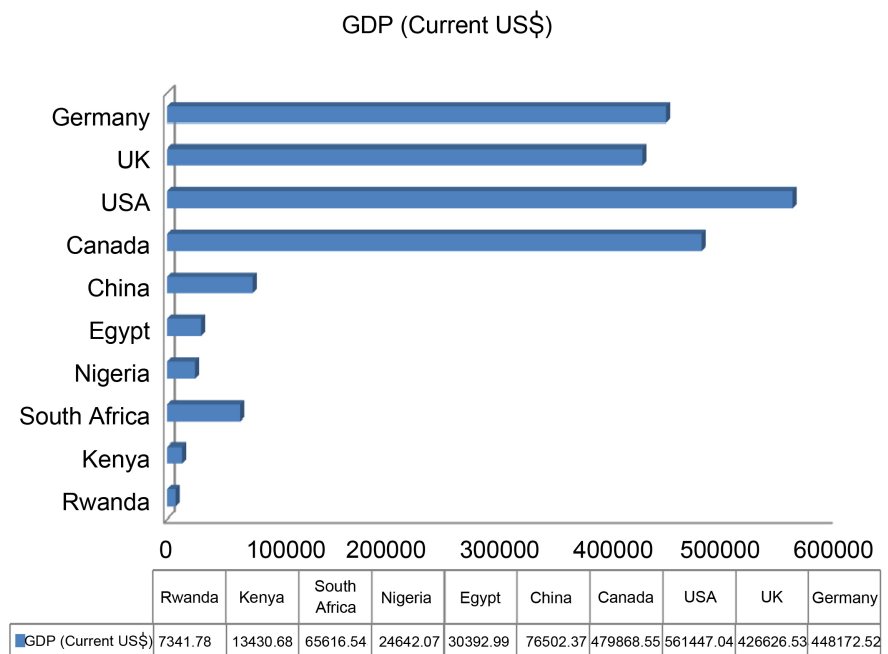


Figure 2. The GDP of our selected countries (Source: WDI).

energies and so on and so forth [19]. When studying the relationship amidst Growth(GDP) and Carbonic acid gas emissions, we can't ignore the energy consumption issues since they are all interrelated to each other [2] [20] [21]. Historically, a close relationship has existed between economic growth and energy consumption, as economic growth generated inevitably a concomitant increase in energy needs; the energy reflected fairly well the level of the economic development achieved [21]. However, GDP growth and energy consumption growth are more or less proportional, depending on the stages of a country's development. This situation explains the penetration of risk analysis into the study of energy problems [22]. Implications for growth, development and the environment can be apprehended in terms of socio-economic risks and environmental, generated by energy consumption [23].

Because of a high energy demand, the problem of accumulation in the atmosphere, greenhouse gases led to climate change, the consequences of which can be catastrophic within a few decades [24]. The emissions of these gases due to human activities increase their concentration in the atmosphere and the main contribution to the increase in the greenhouse effect comes from carbon dioxide emissions (CO₂) related to energy production and consumption activities. In developing countries like Rwanda, Kenya, South Africa, etc., the recording of a significant increase in consumption of energy results from the improvement of the standard of living of their population while it is also recording a high demand in their oil sources giving rise to the energy balance deficit [5]. The increase in energy consumption is based on the combustion of fossil fuels by causing an increase in greenhouse gas emissions. This increase in the concentration of greenhouse gases consequently generates a rise in the average temperature of the globe from 1.4°C to 5.8°C [13]. As highlighted in **Figure 3**, different

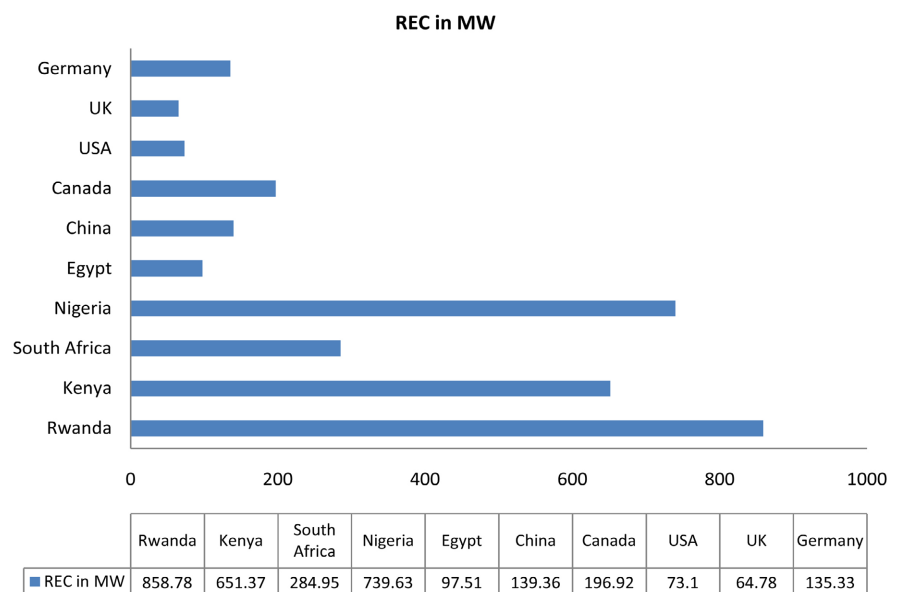


Figure 3. The rate of renewable energy consumption in our chosen countries (Source: WDI).

countries, mostly developing countries are using renewable energies to overcome the problem of global warming, which affects socio-economic development by causing drought and flooding, and also leads to bad impacts on health [23] [25]. Different initiatives are currently being implemented, with good outcomes, particularly the avoidance of the destruction of our mother nature. It will be necessary to complete and strengthen the current mechanisms for promoting clean energies in order to accomplish set goals and meet the future desired energy balance. Recently, to meet the future energy demand, it is necessary to consider problems within energy consumption and production as well as the socio-economic sectors. Fortunately, sustaining the development of the country, and fighting the issues of energy and climate change, different countries have oriented their energy policy towards diversification of supply sources and the use of clean energies [26].

Our study may then hypothesize that: 1) Hypothesis One, the long-run correlation between GDP and CO₂ emissions is positive, because the slow implementation of new low carbon policies could not allow for the long-run achievement of the same economic output level with the lowest CO₂ emissions. 2) Hypothesis Two, the short-run correlation between GDP and CO₂ emissions is negative because a dramatic rise in economic output can be achieved through more efficient energy use by the latest coherent energy policies, which increase prosperity as the emissions of CO₂ decrease. To test the study's hypothesis, we looked at the relationship between CO₂ emissions and economic growth for 10 different countries from 2010 to 2019. We applied the fundamental ECM (Error Correction Model) estimation as an investigating model, which adheres to the analysis' essence [27] [28]. As the ECM estimation can validate both long-run and short-run relationships between the examined time-series data, thus this approach guarantees that the study's goals are to be met. To establish the order of data integration, we first computed the panel unit root tests. Secondly, we computed the long-run equation and then used the cointegration testing technique to prove that the results were accurate. Then after, researchers assessed the model by using EGLS (Engle-Granger Least Square) approach for sample size, which indicates whether there is a short-run relationship in-between the economic variables we are investigating. With the substantial achievements of [29] and [30], there has been an explosion of literature examining the nexus between environmental quality and economic growth.

Our study is structured as follows. The first section is an introduction. The second section is a brief survey of the literature. The data used in our model is presented in Section 3. The model and econometric approach used in the analysis are described in Section 4. The statistical findings for the order of integration are presented in Section 5. The statistical findings for the model estimation are presented in Section 6. Finally, in Section 7, conclusions are drawn.

2. Literature

The nexus between carbonic acid gas emissions and economic growth has at-

tracted economists' attention in the past few decades. The study on this topic was highlighted by [31]. Using panel data analysis, they looked at the causation link between CO₂ emissions and GDP, consequently, their findings display that for North America, Western and Eastern Europe the causal relation run from emissions to income, for South and Central America, Oceania and Japan causality from income to emissions was found, finally, for Africa and Asia, a bidirectional causality was remarked and their work stated more evidences for the idea of correlation amid economic growth and carbonic acid gas emissions. The analysis of [32] reveals that the largest contribution to the increase in CO₂ emissions is the expansion of the economy, as is typical of generally fast-developing countries. The investigation findings by [33] revealed that total primary energy use, net inflows of foreign direct investment, GDP, and total trade were all significant contributors to rising the emissions of carbonic acid gas in the Middle East countries. Similarly, [34] used time series and panel data from 1968 to 2003 and 1992 to 2001 to investigate the relationship among income and the environment in Turkey. They found a growing correlation between CO₂ emissions and income. [35] findings imply that initiatives to reduce emissions and increased investment in carbonic acid gas abatement efforts will not harm economic growth. It may be a viable useful mechanism for Tunisia to achieve long-term sustainable growth.

The investigation of the nonlinear correlations among the growth of economic and carbonic acid gas emissions in China's eastern, central, and western regions was done by [36]. The impact of economic development on CO₂ emissions varied greatly between regions. They discovered a positive correlation between CO₂ emissions and GDP in the eastern region. In addition, the relationship between CO₂ emissions and GDP is weakly negative in the central and western regions. [20] studied the relationship amidst GDP, carbonic acid gas, and energy consumption in North Africa and Middle East countries. In an interesting way, they show that across that region, real GDP has a quadratic connection with CO₂ emissions. The econometric correlations developed in their research suggest that future CO₂ emissions per capita reductions could be accomplished as the MENA region's GDP per capita continues to grow.

The work of [37] studied the dynamic correlations between pollutant emissions, energy consumption, and output for Brazil between 1980 and 2007. His analysis states that the link between emissions and income is shaped like an inverted U. Furthermore, the causality findings show that income, energy use, and emissions are all bidirectionally linked. [3] studied the situation between economic growth and the emissions of CO₂ in Malaysia. Their study's results showed that there is a long run bond between the emissions of carbon and the GDP as the CO₂ emissions level is a dependent variable. They also found the inverted-U pattern correlation among the carbon dioxide emissions and the Gross Domestic Product in both short and long term underpinning the EKC hypothesis. The empirical evidences of the research on carbon dioxide, output, energy

consumption, and trade in Tunisia done by [38] has shown two causal long-run correlations between the variables. They added that there are three unidirectional Granger causation correlations running from GDP, squared GDP, and energy consumption to CO₂ emissions in the short run. [39] looked at the long-term Granger causality relationship between economic development, CO₂ emissions, and energy consumption in Turkey. The tangible outcomes imply that Granger causation exists between carbon emissions and energy consumption, but only in one direction. The observations of [40] back up the hypothesis in both the short and long run, with an inverted U-shaped link between CO₂ emissions and growth. Their work discovered that in Pakistan, commerce enhances the environment and that urbanization increases environmental degradation. The important predictor variables that damage the environment in Pakistan are energy use and growth of economy. Based on panel data for 28 provinces of China from 1995 to 2007, [41] looked into the causality among CO₂ emissions, energy consumption, and economic growth. The study's findings show a two-way causality among GDP and CO₂ emissions, as well as crude oil and coal consumption, and between GDP and electricity use. Moreover, higher GDP or energy consumption causes CO₂ emissions to rise. [42] applied the Wavelet technique to study the nexus between the impact of the growth of economy, environmental destruction, and the consumption of energy in the USA. The findings of wavelet coherence reveal that energy consumption and the emissions of carbon dioxide have a positive impact on economic growth in the short run, but that both variables are influenced by economic growth in the long and very long term. Furthermore, in the short run, energy consumption and carbon emissions have a one-way effect on economic growth, however in the long and very long run, there is a strong unidirectional causal relationship between economic growth and energy use, and carbon emissions. It has been discovered that a 1% rise in energy consumption in the transportation sector and GDP growth damage environmental quality by 0.57% and 0.46%, respectively, in Asian countries [43]. For more detail, check **Table 1**.

3. Data

The data used in the computation are gotten from World Development Indicators databases. With the help of World Development indexes, the financial data was adjusted to reflect reality. The data was then converted to a logarithmic form, allowing us to illustrate the relationships between variables in an additive mathematical expression. The study covers 10 different countries (Rwanda, Kenya, South Africa, Nigeria, Ethiopia, Canada, China, Germany, United Kingdom, and United States) from 2010 to 2019. The observations for our panel ensure that our findings are statistically valid and allow us to draw conclusions.

4. The Empirical Model

In this paper, we analyze the long-run nexus between economic growth and CO₂

Table 1. Summary of the literature review.

Reference	Study region	Study Time	Results of the study	Method
Lise [32]	Turkey	1980-2003	CO ₂ ←GDP	Complete decomposition analysis
Coondoo <i>et al.</i> [31]	All parts of the World	1990-2009	CO ₂ →GDP: For America, Western and Eastern Europe, GDP→CO ₂ : for South and Central America, Oceania and Japan, and GDP↔CO ₂ : for Africa and Asia	Granger causality test
Al-Mulali <i>et al.</i> [33]	Middle East	1968-2003	GDP→CO ₂	Panel data analysis
Akbostanci <i>et al.</i> [34]	Turkey	1991-2002	CO ₂ ↔GDP	Environment Kuznets Curve
Fodha <i>et al.</i> [35]	Tunisia	1961-2004	CO ₂ ←GDP	EKC
Nie <i>et al.</i> [36]	China	1995-2014	Positive relationship between (GDP & CO ₂) in Eastern region. Negative relationship between(GDP & CO ₂) in Western region	PSTR model
Arouri <i>et al.</i> [20]	North Africa and Middle East Countries	1981-2005	GDP has a quadratic connection with CO ₂	EKC hypothesis
Pao <i>et al.</i> [37]	Brazil	1980-2007	Relationship between CO ₂ & GDP is an inverted-U. GDP↔CO ₂ ↔REC	GMs and ARIMA
Saboori <i>et al.</i> [3]	Malaysia	1980-2009	Long-run relation between CO ₂ & GDP CO ₂ & GDP have an inverted-U shape in short & long term.	EKC and ECM
Farhani <i>et al.</i> [38]	Tunisia	1971-2008		ARDL
Ahmed <i>et al.</i> [40]	Pakistan	1978-2008	Inverted-U relationship between CO ₂ & GDP	EKC and ARDL
Chang [41]	China	1995-2007	GDP↔CO ₂	Multivariate Granger Causality Tests
Raza <i>et al.</i> [42]	USA	1973-2015	CO ₂ has a positive impact on GDP in short-run, but GDP→CO ₂ in long-run	Wavelet technique
Nasreen <i>et al.</i> [43]	Asian Countries	1980-2017	A 1% rise in GDP results in 0.46% rise in CO ₂	Common correlated effects mean group (CMG)
Yang <i>et al.</i> [44]	USA	1990-2017	GDP→CO ₂	Maki Co-integration, DOLS and Robust Regression
Saidi <i>et al.</i> [45]	Sub-Saharan Africa, North Africa, Middle East, Europe, North Asia, Latin America and Caribbean	1990-2012	CO ₂ →REC, GDP→REC	Generalized Method of Moments (GMM)

emissions using a panel data technique. We prefer a framework based on the fundamental Error Correction Model (ECM) developed by [17], in which the nexus between the GDP and CO₂ emissions is treated as a long-run dependence, with renewable energy consumption (REC), renewable energy output (REO), and government final consumption expenditure (GFC) being treated as exogenous inputs in the short-run GDP equation.

Our study assumes that: $GDP \sim I(1)$, $CO_2 \sim I(1)$

$$GDP_{m,n} = \theta_0 + \theta_1 CO_{2m,n} + \mu_{m,n}$$

Let $\mu_{m,n} = W$. As a result, W is transformed as $W \sim I(1)$ when CO₂ and GDP are considered to be cointegrated variables. Therefore, a short-run GDP mathematical formula is estimated:

$$\begin{aligned} \Delta \ln GDP_{m,n} = & \theta_0 + \theta_1 \Delta \ln GDP_{m,n-1} + \theta_2 \Delta \ln CO_{2m,n-1} + \theta_3 \Delta \ln REC_{m,n} \\ & + \theta_4 \Delta \ln REO_{m,n} + \theta_5 \Delta \ln GFC_{m,n} + \theta_6 \Delta \ln W_{m,n-1} \end{aligned}$$

where: $\Delta \ln GDP \sim I(0)$, $\Delta \ln CO_2 \sim I(0)$, $\Delta \ln REC \sim I(0)$, $\Delta \ln REO \sim I(0)$, $\Delta \ln GFC \sim I(0)$, here W appears to be a significant variable with coefficient θ_6 of negative value $(-1,0)$, which denotes that our the estimated statement turn-back to the long run sustainability. In this work, the panel analysis is estimated following 3 steps. We firstly estimated the panel unit root analysis to test the level of integration of the variables. Second, we carried out the panel unit root tests suggested by [46] and [47]. Lastly, Fisher-ADF and Fisher-PP as suggested by [48] and [49]. After determining the order of integration, the concern of whether the two examined variables GDP and CO₂ have a long-run equilibrium correlation arises. The short-run equation was approximated using panel EGLS once the long-run dependence was established.

5. Testing for the Level of Integration

Unit root tests were used to determine the level of integration of the estimated time series. **Table 2** presents the results of testing for unit roots in the level and difference variables.

The null hypothesis that variables assumed a common and individual unit root operation cannot be rejected in the case of the level of variables since, after adopting the first difference, all of the variables match the EGLS estimation conditions. As a result, we may admit that the variables at the level are integrated of a level one operation $\sim I(1)$.

6. Panel Estimation Results

The panel least squares approach was used to assess the long-run amidst GDP-CO₂ emissions correlation. A one-way model with fixed cross-section effects is also used to determine the GDP equation. **Table 3** shows the outcomes of computing the lnGDP equation.

The outputs of the long-run lnGDP equation calculation support the conclusion that there is a statistically significant relationship connecting economic

Table 2. Panel unit root results.

Variables	Method			
	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF-Fisher Chi-square	PP-Fisher Chi-square
GDP	-1.38578	-0.70643	26.7452	27.5865
$\Delta \ln \text{GDP}$	0.0829**	0.24**	0.0839**	0.0686**
CO ₂	3.3075	3.46676	4.42422	3.28478
$\Delta \ln \text{CO}_2$	0.9995**	0.9997**	0.9995**	0.9999**
GFC	1.97807	2.40531	8.22227	14.2619
$\Delta \ln \text{GFC}$	0.976**	0.9919**	0.9751**	0.7119**
REC	3.57497	2.3286	6.42687	12.2496
$\Delta \ln \text{REC}$	0.9998**	0.9901**	0.9941**	0.8341**
REO	0.27176	1.60946	15.5787	14.108
$\Delta \ln \text{REO}$	0.6071**	0.9462**	0.6219**	0.722**

**Denotes that we can acknowledge the stationarity for 5% significance level. Source: own calculation.

Table 3. Long-run $\ln \text{GDP}$ equation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.178747	0.098344	83.16507	0.0000
$\Delta \ln \text{CO}_2$	0.812077	0.046633	17.41422	0.0000
Weighted Statistics				
R-squared	0.775083	Mean dependent var		9.173282
Adjusted R-squared	0.772527	S.D. dependent var		1.592501
S.E. of regression	0.75953	Sum squared resid		50.76595
F-statistic	303.2549	Durbin-Watson stat		0.055106
Test Results for Z unit root				
Variable	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF-Fisher Chi-square	PP-Fisher Chi-square
Z	-1.12274	-0.0186	19.7982	20.5359
$\Delta \ln \text{Z}$	0.1308**	0.4926**	0.3443**	0.3035**

Source: Own calculation.

growth and CO₂ emissions, indicating the presence of cointegration relations, see **Table 4**. We used an eight-panel cointegration method to evaluate the estimation results.

With the exception of the Pedroni panel ADF-statistic, Pedroni Group PP-statistic, and Kao Residual cointegration test-statistic, five statistics signifi-

cantly do not reject the null hypothesis of no cointegration for all sample countries. In general, taking the 5% significance level into account, the minority of statistical tests reject the null hypothesis of no cointegration. In the long run, the assessed variables move jointly, hence there is a long-term link between the GDP and the emissions of CO₂. The short-run panel EGLS equation was then analyzed using endogenous variables $\ln\text{GDP}(-1)$ and $\ln\text{CO}_2(-1)$ as well as exogenous inputs renewable energy consumption (REC), renewable energy output (REO), government total consumption expenditures (GFC), and the variable Z. **Table 5** summarizes the findings of computing the short-run GDP equation, as well as the econometrical assessments of the estimated model.

The one-way fixed effects short-run equation developed with panel EGLS (Cross-section weights) matches the regression assumptions. Because the model's estimated DW (Durbin-Watson) test statistic is 0.8179, we can assume that the residuals are uncorrelated and that heteroscedasticity is not apparent. We also ran a test for residual normality, and the Jarque-Bera statistic doesn't really reject the hypothesis of normal distribution. Since the p-value is 0.320, we have no reasons to reject the null hypothesis and therefore we accept the normality of the residuals distribution. In addition, for the assessment of the equations, we employed stationary variables.

For our variables $\ln\text{GDP}(-1)$, $\ln\text{CO}_2(-1)$, $\ln\text{REC}$, $\ln\text{REO}$, and $\ln\text{GFC}$, the panel EGLS estimator produces different results in terms of signs and statistically with no significance except variable GFC which is statistically significant, while the amplitudes of the computed coefficients are completely different. The estimator generates a positive statistical significant coefficient for the variable $\ln\text{Z}(-1)$ (residuals from the long-run equation). At the 5% level of significance, all the coefficients are statistically significant. Our study highlights a negative relationship between GDP and CO₂ emissions in the short-run. The panel EGLS estimations suggest that in the short-run, a 1% increase in CO₂ emissions decreases GDP by 0.04%, a 1% increase in renewable energy consumption increases GDP by 0.01%, a 1% increase in government final consumption increases GDP by 0.80% and that a 1% increase in renewable energy output increases GDP

Table 4. Residual cointegration test.

Test equation	lnGDP(CO ₂)	
	Statistic	Prob.
Pedroni Panel v-Stat.	-0.47323	0.682
Pedroni Panel rho-Stat.	0.464736	0.6789
Pedroni Panel PP-Stat.	-0.95957	0.1686
Pedroni Panel ADF-Stat.	-2.02675	0.0213
Pedroni Group rho-Stat.	1.397932	0.9189
Pedroni Group PP-Stat.	-1.233	0.1088
Pedroni Group ADF-Stat.	-1.98645	0.0235
Kao Residual Cointegration Test	-2.25787	0.012

Table 5. Equation of short-run GDP.

One Way Fixed—Panel EGLS (Cross-section weights)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-10.1641	1.149888	-8.83921	0.0000
$\Delta \ln \text{GDP}(-1)$	-0.13045	0.126381	-1.03221	0.3057
$\Delta \ln \text{CO}_2(-1)$	-0.04227	0.076618	-0.55172	0.583
$\Delta \ln \text{REC}$	0.014209	0.038231	0.371658	0.7113
$\Delta \ln \text{GFCE}$	0.80061	0.062238	12.8636	0.0000
$\Delta \ln \text{REO}$	0.012318	0.035217	0.349762	0.7276
$\ln Z(-1)$	0.284994	0.121478	2.346059	0.022
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.999473	Mean dependent var	12.64313	
Adjusted R-squared	0.999361	S.D. dependent var	7.28753	
S.E. of regression	0.043192	Sum squared resid	0.123124	
F-statistic	8941.463	Durbin-Watson stat	0.94291	
Prob (F-statistic)	0.0000			
Unweighted Statistics				
R-squared	0.999301	Mean dependent var	9.189422	
Sum squared resid	0.140656	Durbin-Watson stat	0.817963	
Test cross-section fixed effects				
Effects Test		Statistic	d.f.	Prob.
Cross-section F		33.17649	(8.66)	0.0000
Normality Test of Residuals		Statistic		Prob
Jarque-Bera		2.278811		0.320009

by 0.01%. The coefficient for variable Z is positive (0.284), indicating that the system of error correction is not running normally and that the system cannot revert to a long-term stable trajectory.

7. Conclusions and Implications

We used the ECM estimation, panel unit root tests, panel cointegration test, and the EGLS estimator to study the long-run nexus between economic growth and CO₂ emissions for 10 different countries from 2010 to 2019. The outcomes of the panel cointegration test verified the findings of the long-run equation of GDP, which showed that CO₂ emissions are positively associated with economic growth. The economic growth and carbon dioxide emissions are cointegrated for the entire chosen countries. As a result, the study's first hypothesis—The long-run relationship between GDP and CO₂ emissions is positive, due to the

slow implementation of new low carbon policies which does not allow for the long-run achievement of the same output level with lower carbonic acid gas emissions, thus the hypothesis cannot be rejected. The positive correction is undoubtedly caused by the insufficient application of energy-saving and low-carbon political development in our selected countries.

The last GDP short-run equation supports the second hypothesis of the study—The short-run relationship between GDP and CO₂ emissions is negative, because a rapid increase in development can be achieved through more intensive energy use by latest coherent energy policies, consequently our result ascertains that growth decreases as the emissions of carbon dioxide increases, thus our hypothesis cannot also be rejected. The estimated regression model of GDP covers not only endogenous CO₂ emissions variable but also renewable energy consumption, renewable energy output, and government final consumption expenditures as well. According to the findings of the study, energy consumption is an essential component of economic growth, and hence the economic growth of the investigated countries is energy-dependent. The use of energy produces waste, especially pollution with carbonic acid gas emissions. Finally, the empirical findings of the study, we may conclude that the ongoing policy of pollution treatment in the investigated countries is effective, but the issue is how effective it is? Maybe too slow. This study should be regarded as a preliminary research to be followed up on for future consideration. We did not comprise an analysis of the speed with which CO₂ emissions are being reduced in the countries under investigation in this work. This potential to implement carbonic acid gas emission reductions more quickly appears to be an intriguing topic for future investigation.

Conflicts of Interest

The authors declare no conflicts of interest.

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