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Exploring the Relationship between Economic Growth, Renewable Energy and Carbon Emissions: A Case of Cuba

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ABSTRACT

In the modern era, balancing economic growth and environmental sustainability has become one of the greatest challenges, especially for the emerging nations. As a case of examining the decoupling of economic growth from carbon emissions, Cuba's historical reliance on fossil fuels, especially during the U.S. embargo, is quite interesting. In this article we have examined the impact of economic growth upon the carbon emissions of Cuba. We extracted annual time series data for the dependent variable (Carbon Emissions) and explanatory variables (Economic Growth and Renewable Energy Consumption) for the period spanning from 1990 to 2020. To determine the long run relationship between the variables, we used Auto regressive distributed lags (ARDL) bounds test of co-integration. The empirical findings revealed the existence of a long-run relationship among the variables of the model. We found that economic growth has a significant positive impact upon carbon emissions; furthermore, there is also a bi-directional causality between the economic growth and the carbon emissions. This research could help the policymakers to establish novel and efficient policies to tackle the environmental issues and move closer to the attainment of sustainable development goals.

Keywords: Economic Growth, Environmental Sustainability, Renewable Energy, Cuba
JEL Classifications: F43, Q42, Q48, Q53, Q58

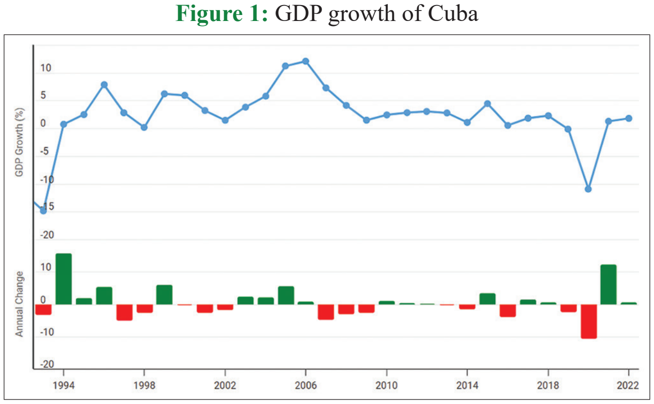
1. INTRODUCTION

In the contemporary era, maintaining the level of economic growth and environmental sustainability simultaneously was one of the biggest challenges of all time, particularly in the case of emerging nations. After the disintegration of the Soviet Union in 1991, Cuba experienced the "Special Period" of severe economic contraction as well as difficult shortages of energy (Piercy et al., 2010). In fact, it propelled Cuba's energy infrastructure—and economic model—into unprecedented adaptation. In response, the nation turned to organic agriculture and a localized production system (Altieri et al., 2012). Despite experiencing severe economic sanctions, Cuba has been determinedly committed to developing renewable energy, which has been supported through the Government's 'Energy Revolution' program, which first started in 2006 (Suárez et al., 2012). (Pedraza, 2018) have reported how recent studies have documented Cuba's efforts to modernize its energy infrastructure while respecting environmental concerns – particularly in the context of climate change vulnerability. They have resulted from the country's singular position as a Caribbean island state susceptible to natural phenomena and the socio-economic model. Cuba has made considerable reductions in its carbon footprint, which necessarily forced innovation alongside the efforts of the state to reduce emissions (Guevara-Luna et al., 2024). Additionally, the progressive opening of economic sectors has brought new dynamics into foreign trade patterns, namely in the exchange of renewable energy technology transfer and environmental cooperation agreements (Piñón, 2023).

Cuba is a case study that offers a unique and compelling inquiry into the relationship among economic development, environmental sustainability, and energy transition under unique institutional arrangements. Its experience reveals what other development pathways might be under resource constraints and external pressure. Drawing out important lessons for other developing nations confronted with equally limiting economic circumstances, Cuba's response to economic challenges by employing environmental solutions is evident (Suarez et al., 2016). Designed as a laboratory to shed light on sustainability transitions, the country's planned economy framework, combined with its goals on ambitious renewable energy targets and climate change vulnerability, highlights the idiosyncrasy all at once. As a case study in resilience and adaptation, (Käkönen et al., 2014) highlight Cuba's importance in developing locally appropriate environmental technologies. Beyond that, Cuba's ongoing economic reforms, in conjunction with the environmental policies, provide a unique opportunity to examine how institutional changes may influence sustainability outcomes. From a practical and theoretical angle, learning about the country's experience in balancing the tradeoff of economic growth and environmental protection, especially under resource scarcity, lends multiple insights into sustainable development (Cabello et al., 2012).

A compelling case of dependency and complexity in a unique socio-economic framework is the nexus between economic growth, renewable energy deployment and carbon emissions in the geographically isolated island, i.e., Cuba. As evident in Figure 1, Cuba's GDP growth has been very volatile, averaging approximately 2% a year between 1994 and 2022, with external shocks and domestic structural constraints playing a major role (World Bank, 2024). Still, the economy witnessed a significant growth peak in 2006, with a substantial drop of more than 10% during the Covid-19 pandemic period. Historically, over 95% of its electricity generation was based on fossil fuels, mainly heavy fuel oil and diesel (Luukkanen et al., 2022), and its energy matrix transformation has become increasingly critical. Its dependency has profound implications for both economic stability and environmental sustainability. This analysis looked at recent data, which shows that Cuba had around 648 MW of renewable energy capacity in 2020, which made up only 4.5% of total electricity generation at that time (IRENA, 2021). However, the government's goal was to attain 24% of electricity generated from renewables by 2030 (IRENA, 2021). This energy composition also reflects the carbon emissions trajectory: Cuba's per capita CO_2 emissions in 2019 were 2.4 metric tons, below many Caribbean nations but increasing rapidly over the past decade (Friedlingstein et al., 2022). Recently, research revealed a high correlation between carbon emissions and economic growth levels in Cuba during the last two decades—highlighting the need to decouple the economic and environmental development (Gomez-Caicedo et al., 2023).

Figure 1: GDP growth of Cuba



Source: (World Bank, 2024)

Particularly, the development of the renewable energy sector has entailed considerable challenges with investment needs of $3.5 billion to meet the 2030 targets (Citaristi, 2022). Yet success in this transition could generate important economic returns, with estimated savings of up to $780 million in fossil fuel imports and approximately 1.2 million tons of CO_2 annually by 2030 (Valdmaa and Ehrström Eklöf, 2020). The rise in prominence can be substantial considering that energy security directly affects vital economic sectors, tourism in particular, accounting for approximately 10.3% of GDP pre-pandemic and is a main source of foreign exchange (Statistical Yearbook of Cuba, 2021). The latest research by (Stepanov et al., 2024) shows that an increase in renewable energy deployment is associated with a decrease in the carbon intensity of GDP while promoting economic growth via a reduction in energy import dependency and energy security. Cuba's implications for this nexus are reinforced by its vulnerability to climate change, where combined economic losses from extreme weather events were estimated at $12.5 billion during 2001-2020. This close relationship emphasizes why understanding and aligning economic development imperatives with the need to transition to a low-emission economy alongside environmental sustainability principles within a highly specific context within Cuba is imperative.

Among several other factors, environmental technologies and international trade are playing a crucial role in the nexus between economic growth, renewable energy deployment and carbon emissions in Cuba. Renewable energy and energy efficiency are key enablers of decoupling economic growth from carbon emissions, where environmental technologies are essential. (Guevara-Luna et al., 2024) find that advances in environmental technologies in the Cuban industrial sector reduced the energy intensity of the sector by 15% during the last few years. The pace of environmental technology adoption is shaped by international trade patterns, with limited access to global markets in Cuba preventing the diffusion of such technology. A report by (UNDP, 2022) shows that while South-South cooperation has long been an important venue of technology transfer, the increasing size of Chinese investment in Cuba's renewable energy sector (USD 500 million between 2015 and 2020) demonstrates that this is becoming more and more prominent. In addition, (Núñez et al., 2013) point out the paradox that trade restrictions have sharpened domestic innovation for environmental technologies, notably in biogas and small-scale solar technologies. Although constrained, Cuba's growing environmental goods and services sector has averaged 5.7% annual growth due to the intersection of environmental technologies and trade. Current dynamics on Cuban technological capability building have arisen with recent bilateral agreements in environmental technology transfer, mainly with European Union countries (Caballero and Guevara Fernández, 2023). However, implementation is still challenged by institutional and infrastructural shortcomings.

Due to urban development and rapid economic growth natural resources have been adversely affected around the globe (Suleman et al., 2024; Kayani, 2024; Nawaz et al., 2024; Kayani and Alzaid, 2024; Kayani and Gan, 2022). The developing countries are trying to achieve development by skipping the usual long process of industrialization (Aysan et al., 2020; Kayani, 2021; Nawaz et al., 2024; Kayani, 2022). Despite Cuba's advances in environmental sustainability and renewable energy initiatives, significant challenges remain between achieving economic development and protecting the environment. The initial research problem lies in how Cuba can become a low-carbon economy while meeting its urgent economic development needs under constrained resources and international trade restrictions. Mature infrastructure, coupled with limited means to access international financing for renewable projects and the difficulties associated with introducing market reforms in a planned economy setting, exacerbates this challenge (Cederlöf and Kingsbury, 2019). The research gap that specifically motivated this study is the missing link between Cuba's particular institutional arrangement and its capabilities for adopting environmental technology and reducing carbon emissions. Secondly, Cuba's experience provides relatively little empirical evidence as to how it might inform the ways in which other developing countries can reap the dividends of sustainable development under resource scarcity. Given the global imperative to limit climate change while promoting economic development in the Global South, this investigation is particularly relevant.

This investigation makes several important contributions to the current body of knowledge related to sustainable development and energy transition literature. The nexus of economic growth and green energy with pollution levels, particularly CO_2 emissions in the context of Cuba, is not fully explored. Therefore, this research may help policymakers to establish novel and efficient policies to tackle environmental issues and move closer to the attainment of sustainable development goals. Moreover, the empirical evidence of this study can be replicated in other emerging economies with similar governance structures. The rest of the article is organized as follows: Section 2 is comprising of extensive literature review; Section 3 is about the data and methodology; Section 4 details the results and their interpretation; and Section 5 has concluded the article.

2. LITERATURE REVIEW

This section provides a critical review of the literature covering the nexus of various economic, energy, technological, and trade factors' nexus with the CO_2 emissions in different economies. A substantial body of research explores the relationship between economic growth and carbon emissions across different regions and contexts. In this body of work, Gbadeyan et al. (2024) and Sajeev and Kaur (2024) argue that economic growth is consistently linked to increased carbon emissions, highlighting the need for strategies that decouple economic activities from carbon output to achieve sustainable development. Recent studies, such as those by Hunjra et al. (2024), Hossain et al. (2023), and Aye and Edoja (2017), refer to the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental damage indicators increase with economic growth until a tipping point is reached. After this point, further economic growth is expected to promote cleaner technologies. This pattern is observed in both developed and developing economies, although the specific income thresholds and policy effectiveness vary (Aye and Edoja, 2017). For instance, Almeida et al. (2024) finds that in high-income countries, carbon emissions decline as income increases, while in low-income countries, emissions continue to rise alongside economic growth, indicating the need for targeted policy interventions to decouple economic development from environmental harm. Guo and Shahbaz (2024) review over 100 studies, concluding that while the EKC hypothesis has potential, its validation depends largely on the selection of variables and econometric methods, with newer studies incorporating renewable energy and additional indicators.

The relationship between carbon emissions, greenhouse gas emissions, and environmental quality is widely explored in the literature on green energy, with a focus on various aspects. Polat and Arslan (2023) highlights that the integration of green finance and renewable energy improves environmental sustainability, especially when income levels are considered. However, greener energy sources and energy efficiency have been identified as effective strategies to reduce emissions in developed countries, even when economic growth, which usually increases emissions, acts as a counterbalance (Pi et al., 2024). Recent research has increasingly focused on the acceptance and integration of renewable energy sources and their potential to reduce carbon emissions and enhance environmental quality. The adoption of renewable energy has been found to significantly reduce carbon emissions in leading European countries and varies depending on the country and energy type (e.g., hydro, solar, wind) (Kartal et al., 2024). Adanma and Ogunbiyi (2024) argue that transitioning to renewable energy is not only vital for reducing emissions but is also essential for achieving other sustainable development goals, such as job creation, price stabilization, and market dynamics.

Studies on the influence of green technologies on carbon emissions and environmental quality are rooted in the multifaceted issues that green technologies may potentially influence and challenge in environmental mitigation. Green technologies like renewable energy sources – solar, wind and hydro – are crucial in reducing the carbon emissions responsible for many human contributions to climate change and, therefore, for sustainable development. However, they meet the challenges of discontinuity and infrastructure (Biswas et al., 2024) and are designed to offer cleaner energy alternatives. In particular, (Shamim et al., 2023) argued that green finance and environmental innovation are strongly related to CO_2 emissions reduction. Concerning dynamic causal relationships between CO_2 emissions, renewable energy consumption and environmental technology, (Bozkaya et al., 2023) empirically found such causalities in high-emission countries, suggesting opportunities for promoting a greener economy.

However, domestic and international technology spillovers have been effective in climate abatement for greenhouse gas emissions, particularly in the industrial sector in smaller economies (Alola and Rahko, 2024). For example, (Wu et al., 2023) asserted that green technology innovation has notably decreased CO_2 emissions in economically developed regions in China with large scientific resources. However, (Zeng et al., 2024) claimed that progress in green technology is spatially limited in that its impact on emissions is unequally distributed across regions. While among G20 nations, (Ali et al., 2024) demonstrate that environmental goods tend to increase environmental quality, low-carbon technologies have been found to decrease environmental quality, with a complex underlying relationship between growth and environmental quality. On top of that, adopting green technologies involves high costs and inadequate infrastructure, which need collaborative effort for adoption (Inovasi et al., 2023). Taken together, the literature suggests that green technologies promise to reduce carbon emissions and improve environmental quality, yet success in adopting green technologies may be hampered by economic, infrastructural and policy barriers (Altaee and Azeez, 2023).

International trade and carbon emissions are intricate issues that have been studied in various aspects. Carbon emissions are shown to be associated with trade openness, sometimes measured as import, export and trade volume. For instance, (Wang et al., 2024) claimed that trade openness could generate increased carbon emissions in industry activities but also reduce such emissions due to technological improvements and structural changes in the economy. Embodied carbon in international trade is critical for realizing carbon displacement across borders, which creates carbon avoidance and shifting responsibility for emissions (Wang and Fujita, 2023). In developing countries, (Pham and Nguyen, 2024) fail to find strong support for the pollution hypothesis, where companies go to countries with laxer environmental regulations in order to exploit them. Also, the study finds weak evidence that trade openness affects environmental pollution. Increased trade enabled by the Belt and Road initiative also confirms that, even with maintained higher levels of carbon emissions, balancing economic growth with environmental sustainability can still be balanced out by more careful trade policies (He, 2024).

Enabled by a variety of trade portfolios, it is found that import diversification can reduce carbon emissions (Wang et al., 2024). However, the role of global value chains (GVCs) is also essential, as they can create global emissions savings without causing job fatalities (Bai et al., 2023), i.e., environmental benefits versus employment tradeoff. Completing this picture further complicates the interaction between trade and environmental performance by factors such as energy efficiency and financial risk that influence consumption-based carbon emissions. For example, (Wang et al., 2022) claimed that there is a connection between lower carbon emissions and energy efficiency and, consequently, lower financial risk in the BRICS countries. In addition, trade barriers in carbon-intensive industries have significant environmental effects: Some developed countries allow implicit subsidies for carbon-intensive imported goods, which can heighten carbon emissions (Lin and Zhao, 2024). In general, the literature indicates that although international trade can raise economic growth, rejuvenating international trade necessitates regulation and policy efforts to ensure that international trade will generate a positive impact on environmental quality and sustainable development (Sorroche-del-Rey et al., 2023).

Carbon emissions are affected by economic growth, renewable energy adoption, environmental technologies, and trade throughout the globe, and therefore, provide insight into the global climate change response. The existing research shows that economic growth is most often associated with rising carbon emissions until renewable energy sources are integrated. For example, (Bhuiyan et al., 2022) argue that countries spending on renewable energy technologies can decouple economic development from carbon emissions and fulfill sustainable development goals. In parallel, environmental technologies, particularly carbon capture and storage (CCS), can potentially reduce fossil fuel consumption emissions (Dubey and Arora, 2022). Along the same line, international trade has a dual role: on the one hand, it increases emissions through the transportation of goods; on the other hand, it enables the diffusion of green technologies and practices and can help decrease emissions worldwide (Peters and Hertwich, 2008). An important idea referred to as 'carbon leakage' emphasizes the importance of coordinated international policies (Böhringer et al., 2012). However, the interaction between these factors is complicated, but policies that support renewable energy, environmental technology and trade management can effectively reduce carbon emissions. For nations to work out a growth-environmental sustainability balance, these dynamics must be understood for their basis in crafting effective climate policies.

Considering the growing literature examining the interaction between economic growth, renewable energy adoption, environmental technology, and international trade in carbon emissions, relatively little work has been devoted to the specific case of Cuba. Although studies are essential for understanding how renewable energy and environmental technologies can help reduce global emissions, they fail to account for the idiosyncrasies that Cuba faces in developing such an economy. As a case of examining the decoupling of economic growth from carbon emissions, Cuba's historical reliance on fossil fuels, especially during the U.S. embargo, is especially interesting and particularly relevant given its reliance on renewable energy sources and environmental technologies. Finally, the issue of carbon leakage is of critical importance regarding the impact of stringent environmental regulations in Cuba on emissions from adjacent countries. Because of Cuba's growing drive towards more sustainable development under economic reform, it is essential to comprehend these dynamics to adequately frame climate policies. Therefore, investigations ought to concentrate on the Cuban scenario as regards the intersection of these factors and their capacity to enable a transition to renewable energy and sustainable strategy while addressing the country's distinctive challenges.

3. DATA AND METHODOLOGY

3.1. Data and Variables

We took carbon emissions as dependent variables and GDP growth (annual %) and renewable energy consumption (% of total final energy consumption) as independent variables. We took the annual time series data from 1990 to 2020 from World Development Indicators. The further description of the variables is shared in Table 1.

Carbon emission measures CO_2 emissions in metric tons per capita, which refers to the amount of carbon dioxide emissions produced by a country per person, typically within a specific year. Economic growth measures the annual growth rate of Gross Domestic Product (GDP) as a percentage, which reflects the rate at which a country's economy is growing or shrinking over a specific period. Renewable energy indicates the share of renewable energy consumption as a percentage of the country's total final energy consumption. It measures how much of the energy consumed comes from renewable sources (e.g., wind, solar, hydroelectric, geothermal).

3.2. Econometric Model

In this study we are aiming to assess the impact of economic growth upon carbon emissions of Cuba. Carbon emissions are dependent upon economic growth & renewable energy.

$$CO2_t = f(GDP_t, REW_t) \tag{1}$$

The general model to be estimated is shared below

$$CO2_t = b_0 + b_1 GDP_t + b_2 REW_t + e_t \tag{2}$$

where

CO_2 = CO_2 emissions (metric tons per capita)
GDP = GDP growth (annual %)
REW = Renewable energy consumption (% of total final energy consumption)
t = time from 1990 to 2020
et = error term

The long-run relationship can be specified via Auto Regressive Distributed Lag Model equation as below

$$CO2_t = b_0 + b_1 CO2_{t-1} + b_2 GDP_{t-1} + b_3 REW_{t-1} + e_t \tag{3}$$

Where $CO2_t$ is the carbon emissions from 1990 to 2020. Whereas b_1, b_2 and b_3 are the long-run coefficients and e_t is the error term. We apply ARDL co-integration when the variables have mixed integration i.e. the variables have stationarity at either I(0) or I(1).

Table 1: Data and Variables Description

Variables	Symbols	Description & Measurement Scale	Data Source
Carbon Emissions	CO_2	CO_2 emissions (metric tons per capita)	WDI, 2024
Gross Domestic Product	GDP	GDP growth (annual %)	WDI, 2024
Renewable Energy Consumption	REW	Renewable energy consumption (% of total final energy consumption)	WDI, 2024

Source: WDI, 2024

4. EMPIRICAL RESULTS

The study examined the summary statistics of the dataset employed for specific variables, Carbon Dioxide (CO_2) emissions, Gross Domestic Product (GDP), and Renewable Energy Consumption (REW), as shown in Table 2. The average CO2 emissions, expressed in (metric tons/capital), stand at 3.383, with maximum value reaching 3.352 and minimum value of 1.858, with standard deviation of 0.253. Moreover, the average GDP is 1.488, ranging from the maximum value of 12.065 to −14.878, and a standard deviation of 6.167. In addition, Renewable Energy Consumption (REW) has a standard error of 29.896, with values ranging from the maximum of 51.300 to 15.600, and a standard deviation of 10.534. Furthermore, the number of observations utilized for the study is 30.

The study used ADF test to check the stationarity and integration of the variables CO_2, GDP, and Renewable Energy (REW). As illustrated in Table 3, ADF test confirms that all variables are integrated and stationarity where CO_2 emissions are stationarity at I(0). Both GDP and REW are stationarity at I(1). As a result, the study employed ARDL model to identify the long-term relationship among the variables.

The study used ARDL bounds test to examine the long-term relationship between variables. As shown in Table 4, F-Statistic value exceeded both the lower bounds and upper bounds value at 10%, 5%, 2.5%, 1% significance levels, indicating co-integration is existing in the model. If the F-statistics are greater than the critical value for I(1), this suggests that we reject the null hypothesis of no cointegration and conclude that there is a long-run relationship between the variables. If the F-statistics are between the critical values for I(0) and I(1), the result is inconclusive, and further tests may be needed. If the F-statistic is less than the critical value for I(0), we would fail to reject the null hypothesis, indicating no cointegration. Given that the F-statistic of 36.530 is significantly higher than the critical value for I(1) (which is 4.14 at the 10% level, 4.85 at the 5% level, and 5.52 at the 2.5% level), we can conclude that there is evidence of cointegration, meaning that the variables in our model are likely to have a long-run equilibrium relationship.

Table 5 indicates the results generated by using the ARDL approach. GDP coefficient (0.014) represents the long-run effect of GDP on the dependent variable. A positive value means that an increase in GDP leads to an increase in the dependent variable. The t-statistics of 4.490 and a P = 0.000 show that this relationship is statistically significant, and GDP is positively correlated with the dependent variable. REW coefficient (−0.003) suggests that an increase in REW (leads to a decrease in the dependent variable by 0.003 units. The t-statistics are −2.039, and the P = 0.051. The p-value is very close to the 0.05 threshold, so this result is

Table 2: Descriptive statistics

Variables	Mean	Median	Maximum	Minimum	SD	Jarque-Bera	P	Sum
CO_2	2.383	2.378	3.352	1.858	0.253	48.131	0.000	73.879
GDP	1.488	2.457	12.065	−14.878	6.167	7.748	0.020	46.129
REW	29.896	26.300	51.300	15.600	10.534	2.543	0.2803	926.800

SD: Standard deviation, GDP: Gross domestic product, REW: Renewable energy consumption

Table 3: ADF unit root

Variables	Symbol	ADF (level)	ADF (1st difference)
Carbon emissions	CO_2	Stationary	N/A
Gross domestic product	GDP	Non-stationary	Stationary
Renewable energy	REW	Non-stationary	Stationary

GDP: Gross domestic product, REW: Renewable energy consumption

Table 4: ARDL bounds test results

F-bound test				
Test statistic	Value	Significant (%)	I (0)	I (1)
F-statistic	36.530	10	3.17	4.14
K	2	5	3.79	4.85
		2.5	4.41	5.52

Sample: n=30

Table 5: ARDL long-run estimate results

Variables	Coefficient	SE	t-statistic	P
C	1.307	0.191	6.814	0.000
GDP**	0.014	0.003	4.490	0.000
REW**	−0.003	0.001	−2.039	0.051

Dependent variable: CO_2. SE: Standard error, GDP: Gross domestic product, REW: Renewable energy consumption

Table 6: Pairwise granger causality test

Variables	Obs	F-statistic	P
GDP-CO_2	30	22.968	5.E-5
CO_2-GDP		6.339	0.018
REW-CO_2	30	7.940	0.008
CO_2-REW		7.352	0.011
REW-GDP	30	0.105	0.748
GDP-REW		6.180	0.019

GDP: Gross domestic product, REW: Renewable energy consumption

marginally significant at the 5% level. It suggests a weak negative relationship, but it is not as strong as the other variables.

Table 6 shows the pairwise granger causality test; GDP → CO2 (P = 5.E-5): The P-value is very small (well below the typical 0.05 significance level), so we reject the null hypothesis that GDP does not Granger cause CO_2. This means GDP does Granger cause CO_2, indicating that past values of GDP can help predict future CO_2 emissions. CO_2 → GDP (P = 0.018): The P = 0.018 is <0.05, meaning that we reject the null hypothesis that CO_2 does not Granger cause GDP. This indicates that CO_2 emissions also have a predictive relationship with GDP, implying that past CO_2 emissions can help predict future GDP.

REW → CO_2 (P = 0.008): The P = 0.008 is <0.05, so we reject the null hypothesis that REW does not Granger cause CO_2. This suggests that the past values of REW can help predict future CO_2 emissions. CO_2 → REW (P = 0.011): The P = 0.011 is <0.05, meaning we reject the null hypothesis that CO_2 does not Granger cause REW. This indicates a causal relationship, where past CO_2 emissions have predictive power over future REW values.

REW → GDP (P = 0.748): The P = 0.748 is much >0.05, so we fail to reject the null hypothesis that REW does not Granger cause GDP. This means that REW does not have a significant causal effect on GDP, suggesting no predictive relationship from REW to GDP. GDP → REW (P = 0.019): The P = 0.019 is <0.05, so we reject the null hypothesis that GDP does not Granger cause REW. This suggests that past GDP values have predictive power over REW values, meaning GDP can influence REW.

Figure 2: Cumulative sum of recursive residuals

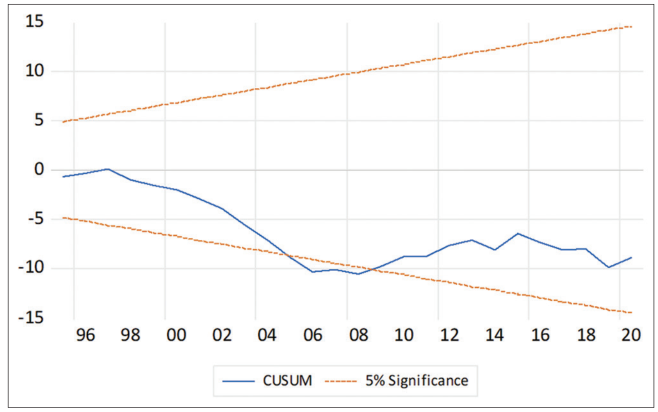
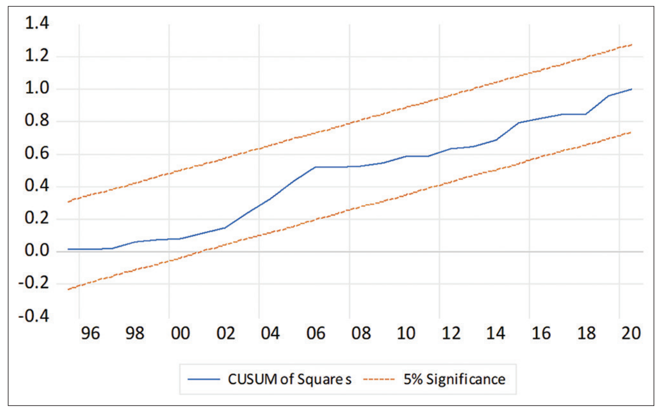


Figure 3: Cumulative sum of squares of recursive residuals



4.1. Stability Diagnostic Test

For gauging the stability of long-run model we used the cumulative sum and cumulative sum of square test of recursive residuals. The CUSUM stability test in Figure 2 shows partial stability whereas CUSUM SQUARE in Figure 3 displays a complete stability as it is within 5% of the critical boundary.

As per Figure 2, the CUSUM curve is showing some fluctuations but is not exceeding the critical threshold. This suggests that the process has some small deviations or variations, but these fluctuations are not large enough to indicate a complete instability. Essentially, the process is somewhat stable but might be showing early signs of change or small deviations.

As per Figure 3, CUSUM SQUARE value is within 5% of the critical boundary. This indicates that the process is in a stable state since the cumulative sum of squared deviations is not reaching or surpassing the critical limit. This "complete stability" suggests that the process is maintaining consistent performance without significant shifts. The fact that the CUSUM SQUARE stays within a small margin (5% of the critical boundary) reinforces that the process is not showing any meaningful or sustained changes.

5. CONCLUSION

Many developing countries face the challenge of providing universal access to affordable and reliable energy, often relying on traditional, non-renewable sources like coal, oil, and biomass. The debate centers around how to balance the urgent need to expand energy access to underserved populations while also transitioning to more sustainable and cleaner energy sources. In this article we tried to study the impact of economic growth upon carbon emissions of Cuba. To determine the long run relationship between the variables, we used Auto regressive distributed lags (ARDL) bounds test of co-integration.

The empirical findings revealed the existence of a long-run relationship among the variables of the model. We found that economic growth has a significant positive impact upon carbon emissions; furthermore, there is also a bi-directional causality between economic growth and the carbon emissions. Cuba's energy policy needs to focus on advancing and promoting the renewable energy development. Expanding the share of renewables would have a substantial impact on reducing emissions, especially in the manufacturing sector. Policymakers could explore enforcing stricter coal usage regulations while boosting investments in alternate sources of energy.

This research could help policymakers to establish novel and efficient policies to tackle the environmental issues and move closer to the attainment of sustainable development goals. The only limitation of this study is that it focused only upon Cuba from Caribbean and the time-series data from WDI was available only up to the year 2020. The future research could include the other Central and North American countries so that a comprehensive and comparative panel data analysis could be carried out across the whole region.

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REFERENCES

Adanma, U.M., Ogunbiyi, E.O. (2024), Assessing the economic and environmental impacts of renewable energy adoption across different global regions. Engineering Science and Technology Journal, 5(5), 1767-1793.

Ali, E.B., Shayanmehr, S., Radmehr, R., Bayitse, R., Agbozo, E. (2024), Investigating environmental quality among G20 nations: The impacts of environmental goods and low-carbon technologies in mitigating environmental degradation. Geoscience Frontiers, 15(1), 101695.

Almeida, D., Carvalho, L., Ferreira, P., Dionísio, A., Haq, I.U. (2024), Global dynamics of environmental Kuznets curve: A cross-correlation analysis of income and CO_2 emissions. Sustainability, 16(20), 9089.

Alola, A.A., Rahko, J. (2024), The effects of environmental innovations and international technology spillovers on industrial and energy sector emissions - evidence from small open economies. Technological Forecasting and Social Change, 198, 123024.

Altaee, H.H.A., Azeez, S.J. (2023), Impacts of environment-related technology, structural change, and globalization on greenhouse gas emissions: Evidence from top twenty emitter countries. International Journal of Energy Economics and Policy, 13(6), 690-697.

Altieri, M.A., Funes-Monzote, F.R., Petersen, P. (2012), Agroecologically efficient agricultural systems for smallholder farmers: Contributions to food sovereignty. Agronomy for Sustainable Development, 32(1), 1-13.

Aye, G.C., Edoja, P.E. (2017), Effect of economic growth on CO_2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics and Finance, 5(1), 1379239.

Aysan, A., Kayani, F., Kayani, U.N. (2020), Chinese inward FDI and economic prospects amid COVID-19 crisis. Pakistan Journal of Commerce and Social Science, 14(4), 1088-1105.

Bai, S., Zhang, B., Ning, Y. (2023), Comprehensive assessment of the environmental and employment impacts of international trade from the perspective of global value chains. Frontiers in Environmental Science, 10, 1099655.

Bhuiyan, M.A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., Huang, X. (2022), Renewable energy consumption and economic growth nexus - a systematic literature review. Frontiers in Environmental Science, 10, 878394.

Biswas, H.S., Kundu, A.K., Poddar, S. (2024), Releasing the power of nature: Exploration of sustainable energy for a flourishing future. In: Green Transition Impacts on the Economy Society and Environment. United States: IGI Global. p108-124.

Böhringer, C., Carbone, J.C., Rutherford, T.F. (2012), Unilateral climate policy design: Efficiency and equity implications of alternative instruments to reduce carbon leakage. Energy Economics, 34, S208-S217.

Bozkaya, Ş., Duran, M.S., Awan, A. (2023), Technological innovations in environmental sustainability: A quantitative exploration of their impact on carbon dioxide emissions. Natural Resources Forum, 48(4), 1169-1185.

Caballero, E.B., Guevara Fernández, E. (2023), Technology transfer and creative economies for local development in Cuba. Cooperativismo Y Desarrollo (COODES), 11(3), e625.

Cabello, J.J., Garcia, D., Sagastume, A., Priego, R., Hens, L., Vandecasteele, C. (2012), An approach to sustainable development: The case of Cuba. Environment Development and Sustainability, 14(4), 573-591.

Cederlöf, G., Kingsbury, D.V. (2019), On petrocaribe: Petropolitics, energopower, and post-neoliberal development in the Caribbean energy region. Political Geography, 72, 124-133.

Citaristi, I. (2022), Economic commission for Latin America and the Caribbean-ECLAC. In: The Europa Directory of International Organizations 2022. England: Routledge.p148-150.

Dubey, A., Arora, A. (2022), Advancements in carbon capture technologies: A review. Journal of Cleaner Production, 373, 133932.

Friedlingstein, P., Jones, M.W., O'Sullivan, M., Andrew, R.M., Bakker, D.C.E., Hauck, J., Le Quéré, C., Peters, G.P., Peters, W., Pongratz, J., Sitch, S., Canadell, J.G., Ciais, P., Jackson, R.B., Alin, S.R., Anthoni, P., Bates, N.R., Becker, M., Bellouin, N., Zeng, J. (2022), Global carbon budget 2021. Earth System Science Data, 14(4), 1917-2005.

Gbadeyan, O.J., Muthivhi, J., Linganiso, L.Z., Deenadayalu, N. (2024), Decoupling economic growth from carbon emissions: A transition toward low-carbon energy systems-a critical review. Clean Technologies, 6(3), 1076-1113.

Gomez-Caicedo, M.I., Gaitan-Angulo, M., Suárez, Á.L.M., Eugenia, R., Gil, R., Quintero, A., Arroyave, E. (2023), Relationship as per capita gross domestic product to environmental conservation: An application in Latin American countries. Revista Investigación Operacional, 44(3), 383-394.

Guevara-Luna, M.A., Madrazo, J., Meneses, E., Mora, H., Clappier, A. (2024), Strategies toward an effective and sustainable energy transition for Cuba. Renewable and Sustainable Energy Reviews, 197, 114387.

Guo, X., Shahbaz, M. (2024), The existence of environmental Kuznets curve: Critical look and future implications for environmental management. Journal of Environmental Management, 351, 119648.

He, S. (2024), The impact of import and export trade on carbon emissions: Based on the perspective of belt and road countries. Frontiers in Business Economics and Management, 13(2), 5-9.

Hossain, R., Kumar Roy, C., Akter, R. (2023), Dynamic effects of economic growth, foreign direct investment, and trade openness on environmental quality: Evidence from Asian economies. Croatian Economic Survey, 25(1), 79-114.

Hunjra, A.I., Bouri, E., Azam, M., Azam, R.I., Dai, J. (2024), Economic growth and environmental sustainability in developing economies. Research in International Business and Finance, 70, 102341.

Inovasi, B., Hijau, T., Tantangan, M., Menentukan, D, Yusmaneli, D., Masri, K.K. (2023), Bagaimana inovasi teknologi hijau menanggapi tantangan dan menentukan dampaknya? Journal Digital Technology Trend, 2(1), 43-55.

IRENA. (2021), Renewable Energy Statistic 2021. Vol. 56. p1-460. Available from: https://www.irena.org

Käkönen, M., Kaisti, H., Luukkanen, J. (2014), Energy Revolution in Cuba: Pioneering for the Future. Turku: FFRC EBook, 4, 2014.

Kartal, M.T., Pata, U.K., Alola, A.A. (2024), Renewable electricity generation and carbon emissions in leading European countries: Daily-based disaggregate evidence by nonlinear approaches. Energy Strategy Reviews, 51, 101300.

Kayani, F.N. (2021), Renewable energy and economic growth nexus: A case of United Arab Emirates. International Journal of Energy Economics and Policy, 11(5), 504-509.

Kayani, F.N. (2022), Analyzing the impact of inward FDI and economic growth on CO_2 emissions in case of Ukraine. International Journal of Energy Economics and Policy, 12(5), 202-208.

Kayani, F.N. (2024), Relationship between foreign direct investment and economic growth: A case of Romania. Pakistan Journal of Commerce and Social Sciences, 18(4), 832-847.

Kayani, F.N., Alzaid, O. (2024), Navigating the classical relationship between foreign direct investment and economic growth: A case of Saudi Arabia. International Journal of Sustainable Development and Planning, 19(11), 4315-4322.

Kayani, F.N., Gan, C. (2022), Foreign direct investment inflows and governance nexus: Evidence from United States, China, and Singapore. Review of Pacific Basin Financial Markets and Policies, 25(4), 2250030.

Lin, B., Zhao, H. (2024), Asymmetric trade barriers and CO_2 emissions in carbon-intensive industry. Journal of Environmental Management, 349, 119547.

Luukkanen, J., De Rozas, M.L.F.S., Vázquez, A.S., Hernández, A.M. (2022), I.3.Historical development of Cuban energy sector. Cuban Energy Futures, 1990(2000), 31.

Nawaz, F., Sadiq, M., Oudat, M., Saleem, A.K., Kayani, U., Khan, M. (2024), The relationship between inward foreign direct investment, economic growth and carbon emissions: A case of Italy from G7 countries. International Journal of Energy Economics and Policy, 14 (5), 19-25.

Nawaz, F., Saleem, A.K., Kayani, U. (2024), The made in China 2025 strategy: Perceptions and reservations of China's state capitalist economic model. Corporate and Business Strategy Review, 5(1), 432-439.

Núñez, J., Armas, I., Castro, F., Macías, M.E., Montalvo, L.F. (2013), Science, Technology and Innovation Policy in Cuba: Overview and Prospects. Cham: Springer.

Pedraza, J.M. (2018), Renewable energy sources in Cuba: Current situation and development prospects. In: Focus on Renewable Energy Sources. United States: Nova Science Publishers Incorporated. p49-104.

Peters, G.P., Hertwich, E.G. (2008), CO_2 Embodied in International Trade with Implications for Global Climate Policy. Washington, DC: ACS Publications.

Pham, D.T.T., Nguyen, H.T. (2024), Effects of trade openness on environmental quality: Evidence from developing countries. Journal of Applied Economics, 27(1), 2339610.

Pi, K., Khan, S., Raza, S.A., Shahzadi, I. (2024), Sustainable energy efficiency, greener energy and energy-related emissions nexus: Sustainability-related implications for G7 economies. Geological Journal, 59(1), 301-312.

Piercy, E., Granger, R., Goodier, C. (2010), Planning for peak oil: Learning from Cuba's 'special period'. Proceedings of the Institution of Civil Engineers-Urban Design and Planning, 163(4), 169-176.

Piñón, J.R. (2023), Cuba's Energy Challenges. Contemporary Cuba: The Post-Castro Era. Lanham: Rowman and Littlefield. p185.

Polat, M.A., Arslan, F. (2023), The Nexus Between Green Finance, Renewable Energy and Environmental Quality. Netherlands: Elsevier.

Sajeev, A., Kaur, H. (2024), Sustainable synergy: Exploring the environmental landscape of energy transition and economic growth for India. In: ESG Frameworks for Sustainable Business Practices. United States: IGI Global. p356-386.

Shamim, A., Raza, S., Rahman, S.U., Sheikh, S.M. (2023), Examining the influence of green finance, Fin tech, and environmental innovation on environmental degradation in G-20 nations: A comprehensive review. Bulletin of Business and Economics (BBE), 12(4), 621-627.

Sorroche-del-Rey, Y., Piedra-Muñoz, L., Galdeano-Gómez, E. (2023), Interrelationship between international trade and environmental performance: Theoretical approaches and indicators for sustainable development. Business Strategy and the Environment, 32(6), 2789-2805.

Statistical Yearbook of Cuba. (2021), Available from: https://instituciones.sld.cu/socientificas/2022/09/15/anuario-estadistico-de-cuba-2021

Stepanov, I., Teschner, N., Zemah-Shamir, S., Parag, Y. (2024), How sustainable is the energy transition? Implications of trade on emissions and energy security. Renewable and Sustainable Energy Reviews, 206, 114844.

Suárez, J.A., Beatón, P., Escalona, R.F., Montero, O.P. (2012), Energy, environment and development in Cuba. Renewable and Sustainable Energy Reviews, 16(5), 2724-2731.

Suarez, J.A., Beaton, P.A., Faxas, R., Luengo, C.A. (2016), The state and prospects of renewable energy in Cuba. Energy Sources, Part B: Economics, Planning, and Policy, 11(2), 111-117.

Suleman, S., Nawaz, F., Sohail, M., Kayani, U., Thas Thaker, H.M., Wing Hoh, C.C. (2024), Empirical analysis of trade market dynamics on CO_2 emissions: A study of GCC economies. International Journal of Energy Economics and Policy, 14(6), 114-126.

UNDP. (2022), China-Zambia South-South Cooperation on Renewable Energy Technology Transfer United Nations Development Programme. Available from: https://www.undp.org/china/projects/china-zambia-south-south-cooperation-renewable-energy-technology-transfer

Valdmaa, A., Ehrström Eklöf, V. (2020), Transition Towards Renewable Energy in Developing Countries: A Case Study of Cuba. Available from: https://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1440475&dswid=608

Wang, C., Elfaki, K.E., Zhao, X., Shang, Y., Khan, Z. (2022), International trade and consumption-based carbon emissions: Does energy efficiency and financial risk ensure sustainable environment?

Sustainable Development, 30(6), 1451-1461.
Wang, H., Fujita, T. (2023), A review of research on embodied carbon in international trade. Sustainability, 15(10), 7879.
Wang, Q., Zhang, F., Li, R. (2024), Free trade and carbon emissions revisited: The asymmetric impacts of trade diversification and trade openness. Sustainable Development, 32(1), 876-901.
World Bank. (2024), Data Bank World Development Indicators. The World Bank. Available from: https://www.databank.worldbank.org
Wu, Y., Zeng, S., Zhong, Z. (2023), Study on the emission reduction effect of green technology innovation. Advances in Management and Applied Economics, 13(6), 277-295.
Zeng, S., Li, T., Wu, S., Gao, W., Li, G. (2024), Does green technology progress have a significant impact on carbon dioxide emissions? Energy Economics, 133, 107524.