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Strategic Integration: Fostering Sustainability in Low-Income Country through Poverty Alleviation, Carbon Efficiency, Energy and Economic Resilience

Ahmed Abdullah Saad Al-Dhubaibi[1]*, Aarif Mohammad Khan[2], Hussein H. Sharaf-Addin[3], Mochammad Solichin[4]

[1]Department of Accounting, College of Business Administration, Prince Sattam Bin Abdulaziz University, Saudi Arabia, [2]Department of Agricultural Economics and Business Management, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India, [3]Department of Accounting, Faculty of Administrative Sciences, Thamar University, Yemen, [4]Fakultas Bisnis dan Humaniora, Universitas Teknologi Yogyakarta, Indonesia. *Email: a.aldhubaibi@psau.edu.sa

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ABSTRACT

This study emphasizes the critical importance of strategic integration for sustainable development goals (specifically Goals 1 and 2) in low-income countries (LICs). The research uses econometric models to focus on poverty reduction, economic resilience, energy use, and carbon emissions in Indonesia from 1996 to 2022. The study reveals a long-run co-integration among the estimated parameters, with a significant speed of adjustment at a 1.04% level. ECM models highlight a positive relationship between energy use, poverty, and carbon emissions while indicating a negative association between economic growth and carbon emissions. Robustness checks support these findings, including Fully Modified Ordinary Least Squares (FMOLS) and Canonical Co-Integrating Regression (CCR). Granger causality analysis reveals a unidirectional causality from energy use to carbon emissions and economic growth, along with one-way causation from carbon emissions to economic growth and poverty. Diagnostic tests affirm the model's reliability. The study's outcomes contribute valuable insights to the discourse on strategic integration, offering policymakers and stakeholders guidance in formulating sustainable development strategies tailored to the unique challenges encountered by low-income countries.

Keywords: Sustainability, SDGs, Poverty, Economic growth, Carbon emissions
JEL Classifications: O44, Q56, Z13

1. INTRODUCTION

Every country aims to achieve a high and sustainable level of economic growth to improve social well-being. However, it is essential to ensure that economic progress and development do not come at the expense of future generations. This means that ecological sustainability and economic growth should work together. Sustainable development has now become a necessity for all economies worldwide. The United Nations Sustainable Development Goals (SDGs) have initials that emphasize the eradication of poverty in all its forms worldwide. The targets in these goals aim to eliminate extreme poverty for all individuals worldwide by 2030. In December 2015, a parallel United Nations initiative concluded with 195 countries endorsing the Paris Agreement under the United Nations Framework Convention on Climate Change. This agreement aims to maintain global warming well below 2°C above pre-industrial levels in the long run while acknowledging the rights of developing nations to eliminate extreme poverty and pursue sustainable development. While these agreements establish a foundation for steering the world's economies toward sustainability, they do not outline specific strategies for harmoniously achieving these ambitious goals nor delineate how their responsibility should be collectively shouldered.

These challenges necessitate examination within the framework of global economic inequality and past accountability. Advanced nations bear significant accountability for most fossil carbon dioxide emissions from 1750 to 2010 (IPCC, 2014), while only 18% of the global population enjoys living standards comparable to those in the First World (UN, 2016). Despite the profound impacts of current resource extraction and throughput levels, sizable segments of the world's population endure severe poverty. For instance, in 2013, 770 million people lived on <1.90 dollars a day in purchasing power parities (PPP), which is classified as life-threatening poverty (World Bank, 2015a). Approximately half the global population subsists on <2.97 dollars daily (World Bank, 2015b).

The international community has articulated many policy goals in response to the imperative of addressing extreme poverty and advancing sustainable development. The pursuit of sustainable development encompasses dual objectives: firstly, ensuring that every individual has access to fundamental resources like food, water, healthcare, and energy to fulfil their human rights, and secondly, ensuring that humanity's utilization of natural resources is conducted in a manner that does not unduly burden critical earth system processes.

As outlined in the United Nation's Council of the Sustainable Development Solutions Network (SDSN) report titled "The Action Agenda for Sustainable Development," the overarching goal is to achieve "sustainable economic growth," ensuring that "all low-income countries reach the per capita income threshold of middle-income countries by 2030." Within the context of national economic development, it becomes imperative to underscore the pivotal role of energy. Energy catalyzes heightened efficiency and productivity, playing a crucial role at individual and household levels. Much like human and physical capital, energy is a fundamental input for aggregate output, establishing itself as an indispensable resource for economic development and substantial infrastructure investment for societal improvement. As Klapper et al. (2016) asserted, identifying factors influencing economic growth is paramount to fostering sustainable development and prosperity.

According to Hubacek et al. (2017), the wealthiest global segment, representing the top 10% of income earners, accounted for 36% of global carbon emissions in the year 2010. In stark contrast, the extremely impoverished, comprising 12% of the global population, were responsible for a mere 4% of global emissions. The lowest half of the global income distribution contributed a minimal 13%. Analyzing these distinct carbon footprints across income categories on a global scale reveals that alleviating people from extreme poverty has relatively minor carbon implications, projecting an increase of approximately 0.05°C above the levels predicted by the IPCC by the end of the 21st century. However, transitioning the global poor—those earning below $2.97 (in PPP)—to the next income level, still considered relatively modest by industrialized country standards, could add 0.6°C by the century's end. Realizing this more aspiring scenario necessitates significantly accelerating and expanding future emission reduction efforts. Since efficiency gains have struggled to keep pace with additional emissions, there is an urgent need to emphasize demand-side measures and promote lifestyle and behavioural changes. This becomes especially critical in light of the substantial global carbon inequality hindering progress toward achieving a low-carbon society.

Warr (2000) undertook a comprehensive study investigating the correlation between economic growth and the prevalence of individuals living below the poverty line in six Asian economies. Examining India for South Asia, Taipei (China) for East Asia, and four Southeast Asian nations—Indonesia, Malaysia, the Philippines, and Thailand—the research analyzed data from the 1960s to the 1990s. The findings consistently indicated a significant relationship between economic growth and poverty reduction across all nations. Moreover, the study highlighted that the growth rate of real GDP per person pronouncedly impacted the rate of poverty reduction.

In alignment with Warr's conclusions, other researchers such as Pradhan (2010), Uddin et al. (2012), Jalilian and Kirkpatrick (2005), Jeanneney and Kpodar (2011), Sehrawat and Giri (2016, 2018), and Azra et al. (2012) have independently identified the pivotal role of financial development in poverty reduction. Additionally, Uddin et al. (2014) and Alam and Alam (2021) have presented evidence affirming the significance of both economic growth and financial development in the concerted effort to combat poverty.

Chancel and Piketty (2015) assessed global carbon inequality, revealing that in 2010, the highest-earning 10% globally (with incomes exceeding $23 PPP per day) were responsible for approximately 36% of global carbon emissions. This significant share emanates from their consumption patterns, involving goods and services with emissions generated during the production process in the expansive global supply chains. This affluent segment primarily consists of individuals from developed nations such as the US, the European Union, Japan, Australia, and Canada, alongside prosperous individuals in developing and transition economies. In contrast, the lowest-earning 50% globally, with a daily income below $2.97 PPP, contributed approximately 15% of global carbon emissions. This demographic encompasses individuals with minimal means, earning <$1.90 PPP, surpassing a billion people in 2010, and contributing to <4% of global carbon emissions.

In their investigation, Pao and Tsai (2010) identified a robust correlation between pollution and energy consumption and between energy consumption and output. They also noted a unilateral link between energy consumption and the escalation of pollutant emissions in the BRIC countries from 1971 to 2005 (excluding Russia, which underwent analysis from 1990 to 2005). Chen (2012) illustrated a reciprocal association between growth and energy utilization. Additionally, it was observed that a one-way correlation existed between capital accumulation and energy utilization in China from 1995 to 2010. Ali et al.

(2017) investigated the causal connections in Malaysia from 1971 to 2013, which showed that carbon emissions are linked to energy consumption and financial development, energy is linked to financial development, and growth is linked to energy consumption, Carbon dioxide emissions, financial development, and FDI. Bah and Azam (2017) also examined the scenario in South Africa from 1971 to 2012. Their findings suggested a one-way relationship between Carbon dioxide emissions and energy consumption, as well as between financial development and Carbon dioxide emissions.

In a separate analysis, Malik (2021) revealed a bidirectional causal relationship between energy consumption and economic growth, Carbon dioxide emissions and economic growth, and Carbon dioxide emissions and energy consumption. The study further illuminated a consistent increase in the correlation between Carbon dioxide emissions and economic growth, indicating the presence of Turkey's non-environmental Kuznets curve hypothesis from 1970 to 2014. The insights derived from these investigations offer potential utility for policymakers in formulating economic strategies conducive to sustainable growth.

Salahuddin et al. (2019) conducted a study to explore ecological modernization theories. They found that it is not easy to predict the environmental impact of urbanization in advance. Additionally, the concept of neoliberalism suggests that globalization can have a positive impact on developing economies by reducing poverty and inequality. However, the effect of globalization on the environment is not straightforward, and its influence on Carbon dioxide emissions in Sub-Saharan Africa (SSA) needs to be clarified. The researchers analyzed data from 44 SSA countries and used advanced methods to control for variables such as energy poverty and urbanization. The study found that urbanization contributes to Carbon dioxide emissions, while globalization has a minor impact on reducing emissions. Energy poverty did not show any significant effect on emissions.

Bansal et al. (2021) delved into the complex interplay of economic, social, and environmental factors influencing the economic growth of South Asian countries. Employing sophisticated econometric techniques and a panel data estimate method, the study meticulously analyzed data from 1990 to 2017. The study results reveal that biological capacity, financial development, the human development index, and income disparity exert a positive and enduring influence on economic growth. Conversely, energy use exerts a counteractive impact. The findings underscore the importance of proactive efforts by governments and relevant organizations to foster advancements in financial and human development and biocapacity for sustainable economic growth. Concurrently, initiatives should mitigate ecological footprints and address income inequality. Ensuring that energy consumption aligns harmoniously with the biocapacity of each economy emerges as a critical consideration.

According to a study by Baz et al. in 2022, there is a direct relationship between increased energy consumption and a decrease in environmental quality. This is because the greater use of fossil fuels leads to the release of carbon dioxide emissions. As a result, providing more electricity to boost economic growth has increased the risk of environmental pollution, especially in terms of air quality. In alignment with this perspective, Raihan et al. (2022) argue that energy consumption poses a substantial hurdle to achieving environmental sustainability, mainly due to the emission of greenhouse gases from non-renewable energy sources. Therefore, amid the ongoing discourse on sustainability, it is advisable to curtail emissions associated with energy consumption. This reduction is imperative for advancing the goals and objectives of sustainable development. Despite the fact that there is frequently a positive correlation between increased energy consumption and economic growth, Murshed et al. (2023a) emphasize the necessity of prioritizing the sustainability of such growth.

Azam (2019) emphasizes that economic growth serves as a potent instrument, contributing to generating employment opportunities, alleviating poverty, and enhancing living standards. As Rahman et al. (2019) noted, economic growth has become a top priority for developing nations where poverty is pervasive. The South Asian region has experienced a high poverty level that varies among its countries. For instance, Indonesia has a poverty rate of 9.5%, with 2.3% of employed people below the $1.90 purchasing power parity (PPP) expected in 2022, according to the Asian Development Bank (2023). Murshed et al. (2023b) emphasize the importance of the 2030 agenda's commitment to adopting nationally determined decarbonisation strategies. This agenda comprises Seventeen Sustainable Development Goals (SDGs) that aim to tackle various aspects of sustainable development, spanning social, economic, and environmental realms. These goals aim to address diverse challenges such as poverty and inequality eradication, promotion of equitable economic growth, and preservation of the Earth's health.

Existing research tends to prioritize one aspect over the others or needs a cohesive approach that considers the intricate connections between poverty, carbon emissions, and economic development. Additionally, more empirical investigations should be conducted into Indonesia's outcomes of integrated policies in real-world low-income country settings. Bridging this gap is essential for informing evidence-based policy decisions and providing practical insights to guide sustainable development efforts.

A subtle understanding of how strategic integration unfolds in practice will contribute significantly to the global discourse on sustainable development goals 1 and 2. It will also offer actionable guidance to policymakers, researchers, and practitioners working towards fostering sustainability in low-income countries. The paper's structure is as follows: Second section dedicated to the methodology, third argues the results and data interpretations, and finally, concluding remarks and policy suggestions.

2. METHODOLOGY AND DATA

2.1. Data

This model relies on British Petroleum (BP) statistics and World Development Indicators (WDI) data. British Petroleum provides information on primary energy use, measured in Exajoules, and carbon dioxide emissions, expressed in millions of metric tons, resulting from energy usage. In contrast, the World Development Indicators furnish details on economic growth, measured as GDP in constant US dollars, and poverty, quantified by the Gini Index.

The study encompasses the period from 1996 to 2022 to incorporate a more extensive dataset, essential for a comprehensive analysis of the past. This timeframe effectively elucidates the relationships between the variables under examination over short and long durations.

2.2. Model Specification

Poverty, energy consumption, economic growth, and carbon emissions represent a subset of the study variables for low-income countries like Indonesia by scrutinising them through econometric models employed by previous researchers. The formulation of the model is enunciated as follows:

Carbon emission = *f* (*energy consumption, economic growth, poverty*) (1)

Various research works have suggested the preliminary normalization of data series to enhance their integration into an econometric model. Employing a natural logarithmic transformation on all variables in our study ensures consistent measurements, addressing issues related to distributional properties and potentially inducing stationarity in the variable series. This approach is especially relevant for variables like carbon dioxide emissions from energy and primary energy consumption, measured as indices, and other variables assessed in diverse units. Consequently, all variables are realistically expressed and subjected to a logarithmic transformation (Pachiyappan et al. 2022).

Stationarity tests are utilized to determine the order of integration for each variable within a system. Various tests assess the integration order in analytical and empirical research, considering different factors. We will only apply the Augmented Dickey-Fuller (ADF) and Phillips-Perron tests in our empirical stationarity analysis, considering intercepts.

The autoregressive distributed lag (ARDL) bounds testing method was used for cointegration. The ARDL framework was used for the error correction method (ECM), and the pairwise Granger causality analysis. We applied Pesaran et al. (2001) ARDL bounds testing technique to check for cointegration to look at the long-term changes in the variables and the stability of the results. The procedural steps of the ARDL bounds testing approach are outlined below.

$$\Delta y_t = \partial_o + \partial_1 y_{t-1} + \sum_{i=1}^{n}\delta_i \Delta y_{t-i} + \sum_{j=0}^{n}\theta_i \Delta x_{t-j} + \varepsilon_t \quad (2)$$

According to Pesaran et al. (2001), two tests are employed to ascertain a long-term relationship in the given model, known as "bounds tests." In these tests, ∂_o represents the drift component, and εt denotes the white noise error. The initial test involves a t-test to assess the validity of the null hypothesis H0 ($\partial_1 = 0$). The subsequent F-test examines whether the coefficients of the lagged levels in Eq. (2) are collectively significant (H0: $\partial_1 = \partial_2 = 0$).

Cointegration is evaluated using two asymptotic critical value bounds, considering scenarios where independent variables are I(d) with $0 \leq d \leq 1$. The lower bound assumes that the regressors are I (0), while the upper bound assumes I (1). If the test statistics exceed their respective upper critical values, it indicates the presence of a long-run relationship.

On the contrary, if the statistics register values below the lower critical values, we cannot reject the null hypothesis, suggesting the absence of cointegration. More definitive conclusions can be drawn when the statistics fall within their bounds. This methodology has demonstrated its appropriateness and robustness, even when dealing with minor or predictable sample sizes, as Pesaran et al. (2001) indicated. Moreover, for the examination of long-run relations, we employ the general form of the conditional ARDL(p,q) model as follows:

$$y_t = \partial_o + \sum_{i=1}^{p}\partial_{1i} y_{t-1} + \sum_{i=0}^{q}\partial_{2i} x_{t-i} + \varepsilon_t \quad (3)$$

After confirming the long-run relationship's existence, we examine cointegration and causal connections in this study. This is accomplished by applying the Error Correction Model (ECM) based on Autoregressive Distributed Lag (ARDL) and the Granger causality procedure. With the ECM-ARDL method, if both y_t and x_t are stationary variables at levels, then the least squares method can be used to estimate Eq. (4) and Eq. (5) without the error correction term in their level forms. However, in cases where y_t and x_t are non-stationary variables (I (1)) and are not cointegrated, the ECM model, such as equations (4) and (5), without the error correction term in the first difference form, can be utilized. On the other hand, if y_t and x_t are I (1) and cointegrated, Eq. (4) and Eq. (5) within the ECM-ARDL framework are applicable.

$$\Delta y_t = \partial_o + \sum_{i=1}^{n}\delta_{1i} \Delta y_{t-i} + \sum_{j=0}^{n}\partial_{2j} \Delta x_{t-j} + \partial_3 \varepsilon_{t-1} + \mu_t \quad (4)$$

$$\Delta x_t = \theta_o + \sum_{i=1}^{n}\theta_{1i} \Delta x_{t-i} + \sum_{j=0}^{n}\theta_{2j} \Delta y_{t-j} + \theta_3 \varepsilon_{t-1} + \upsilon_t \quad (5)$$

The error correction term ε_{t-1} comes from cointegration tests. X_t is the Granger cause of y_t if all of ∂_{2j} in Eq. (4) is significant without considering θ_{2j} in Eq. (5). On the other hand, it would cause x_t if all θ_{2j} in Eq. (5) were significant without taking ∂_{2j} in Eq. (4) into account. A bilateral causal relationship exists between y_t and x_t if all ∂_{2j} and all θ_{2j} are significant. If you look at coefficients ∂_3 and θ_3, you can see that they both show how different variables in yt and xt respond to the cointegrating error, which is $y_{t-1} - \partial_o - \partial_1 x_{t-1} = \varepsilon_{t-1}$ or $y_{t-1} - \theta_o - \theta_l x_{t-1} = \varepsilon_{t-1}$.

3. RESULTS AND DISCUSSION

Table 1 presents descriptive statistics for four variables labelled carbon dioxide emissions (LNC), energy use (LNE), economic growth (LNG), and poverty (LNP). The mean values indicate that, on average, LNC is around 5.98, LNE is approximately 1.74, LNG is about 27.17, and LNP is roughly 3.58. The median values are close to the means, suggesting a relatively symmetric distribution. The standard deviations provide insights into the spread of the data, with LNC having the highest variability (0.64) compared to the other variables. Skewness measures indicate that LNC and LNE have slight negative skewness, while LNG is slightly positively skewed and LNP exhibits moderate negative skewness. The Jarque-Bera statistics and associated probabilities offer insights into the normality of the data, with all variables having relatively low Jarque-Bera values and high probabilities. This suggests that the data may not deviate significantly from a normal distribution. Overall, the descriptive statistics provide a comprehensive overview of the four variables' central tendency, variability, and distribution characteristics.

The pairwise correlations among the four variables reveal strong positive correlations between LNC and LNE (0.999), LNC and LNG (0.95), LNE and LNG (0.95), and LNP and LNG (0.82). These high correlation coefficients suggest a close linear relationship between these pairs of variables. Additionally, LNP shows a moderately strong positive correlation with LNC (0.77) and LNE (0.76). These findings imply that changes in one variable are associated with systematic changes in the other variables, providing insights into potential patterns and relationships within the dataset.

Table 2 presents stationarity tests for the level and first differences of the variables LNC, LNE, LNG, and LNP. Stationarity is crucial in time series analysis; as non-stationary series may lead to spurious regression results. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed to assess the stationarity of the differenced series.

It is important to note that the Augmented Dickey-Fuller and Phillips-Perron tests for the first difference (I (1)) all show negative t-statistics for all variables (LNC, LNE, LNG, and LNP), with P-values that are very close to 0.01. This suggests that the first differences of the variables are stationary, indicating that a single differencing operation is sufficient to achieve stationarity.

In lieu the ADF and PP tests, do not reject the null hypothesis of non-stationarity for all variables at the levels (I (0)). This is shown by t-statistics close to or greater than zero and P-values higher than the commonly used significance levels (Prob. >0.05). Therefore, the original variables are non-stationary. In outline, the results indicate that the first differences of the variables are stationary, supporting the notion that the variables are integrated of order one, or I (1), after differencing. This suggests that further differencing may not be necessary for achieving stationarity in the context of this analysis.

Table 1: Descriptive statistics

Variable	LNC	LNE	LNG	LNP
Mean	5.98	1.74	27.17	3.58
Median	5.96	1.75	27.15	3.6
Maximum	6.53	2.28	27.75	3.71
Minimum	5.33	1.21	26.65	3.38
Standard Deviation	0.64	0.28	0.37	0.09
Skewness	−0.3	−0.24	0.08	−0.5
Jarque-Bera	1.003	0.89	2.37	1.67
Prob.	0.61	0.64	0.31	0.44

Analysed using the ARDL bounds test, this study investigates the existence of a persistent co-integration relationship. The data in Table 3 shows that endogenous and exogenous variable series are co-integrated, meaning they tend to move toward equilibrium over time. The findings from this empirical analysis imply that both variables might display co-integration over long periods.

The computed F-Statistics value is 185.41, exceeding the upper and lower bound test values in Table 3. The upper bound has a critical value of 5.61 at a significance level of 1%. Consequently, the null hypothesis can be refuted, which suggests the absence of a co-integrating link. Similarly, the t-statistic value of −29.11 significantly exceeds the upper bound test value of −4.37 at a 1% significance level. This indicates that the null hypothesis, which states no co-integrating connection, can be rejected. Therefore, this suggests a close relationship among economic growth, energy, poverty, and carbon emissions. Therefore, these parameters have a persistent correlation over an extended period.

Table 4 presents the ARDL (1,0,0,0) model, displaying the computed parameters' short- and long-run estimations. The co-integration equation has a negative value, specifically Coint

Table 2: Stationarity tests

Difference	Tests	Parameters	LNC	LNE	LNG	LNP
I (0)	ADF	t-Stats	−1.79	−1.45	0.75	−0.92
		Prob.	0.38	0.54	0.99	0.77
	PP	Adj t-Stats	−0.38	−0.14	0.67	−1.036
		Prob.	0.89	0.94	0.99	0.73
I (1)	ADF	t-Stats	−4.9	−4.62	−4.04	−4.21
		Prob.	0.0007	0.001	0.005	0.003
	PP	Adj t-Stats	−3.66	−3.06	−4.04	−4.2
		Prob.	0.01	0.04	0.005	0.003

Table 3: ARDL bound test (1,0,0,0)

Test	Value	Significance (%)	Lower bound	Upper bound
F-Stats	185.41	10	2.72	3.77
		5	3.23	4.35
		2.5	3.69	4.89
		1	4.29	5.61
t-Stats	-29.11	10	−2.57	−3.46
		5	−2.86	−3.78
		2.5	−3.13	−4.05
		1	−3.43	−4.37

Table 4: ARDL error correction regression (1,0,0,0)

Period	Variable	Coefficient	Standard Error	t-Stats	Prob.
Short	C	5.36	0.64	8.3	0.00
	LNC (-1)	−1.04	0.04	−23.94	0.00
	LNE	1.19	0.05	24.17	0.00
	LNG	−0.07	0.027	−2.68	0.014
	LNP	0.22	0.06	3.86	0.0009
	Coint. Eq (−1)	−1.04	0.036	−29.11	0.00
Long	LNE	1.15	0.038	29.85	0.00
	LNG	−0.07	0.028	−2.62	0.016
	LNP	0.21	0.05	4.105	0.0005
Diagnostic tests					
R^2		0.97	Adj. R^2	0.97	
F-Stats		847.57	Prob.	0.00	
Durbin Watson				1.7	

Table 5: Results of pairwise granger causality test

Y	X	F-stats	Prob.	Inference
LNE	LNC	4.574	0.04	Energy use granger causes carbon emissions unidirectional
LNC	LNE	2.55	0.12	
LNG	LNC	1.94	0.18	Carbon emissions granger causes economic growth unidirectional
LNC	LNG	7.36	0.01	
LNP	LNC	0.07	0.79	Carbon emissions granger causes poverty unidirectional
LNC	LNP	9.07	0.006	
LNG	LNE	1.21	0.28	Energy use granger causes economic growth unidirectional
LNE	LNG	7.85	0.01	
LNP	LNG	0.72	0.41	There is no causality among the variables
LNG	LNP	1.53	0.23	

Eq. (−1). This is a favourable indication since the coefficient estimate is −1.04, accompanied by a t-Stats value of −29.11 and a significant probability of 1%. The negative coefficient signifies that the system adjusts towards the long-run equilibrium at a rate of 104%, which corrects its prior period disequilibrium by 104% within one period. In the immediate term, carbon exerts a negative influence of −1.04 on emissions from the preceding year, but economic expansion diminishes carbon emissions. The relationship between energy and poverty positively influenced Indonesia's carbon emission levels. Furthermore, the long-term coefficients confirm the same results, indicating that energy and poverty have a favourable influence, whereas economic expansion negatively affects carbon emissions levels in Indonesia. The initial diagnostic test also indicated that the model is stable and has the best match.

Table 5 displays the outcomes of the pair-wise Granger causality tests that investigate the time connection between the dependent variable Y and the independent variable X. The table comprises F-statistics, probabilities (prob.), and qualitative inferences for each pair that shed light on the potential causal links between the variables. The qualitative inferences provide valuable insights into the relationship between each pair of variables. The table identifies unidirectional causal relationships, indicating the influence direction between the variables. For instance, the table shows that energy use (LNE) by Granger causes carbon emissions (LNC) and economic growth one-way causality. This implies that changes in energy use precede changes in carbon emissions and economic growth, not vice versa. Similarly, carbon emissions (LNC) caused by Granger cause economic growth (LNG) and poverty (LNP) one-way causality. The table also reports instances where no significant causality is detected between specific pairs, providing valuable insights into the dynamic interactions among the variables studied.

Table 6 displays the outcomes of a significant test that used two distinct econometric methods: Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR). The table displays coefficients, t-statistics, and probabilities for each examined variable. High t-stats of 1.18 and 1.189 for FMOLS and CCR show that the variable LNE has a strong and statistically significant relationship. On the other hand, the variable LNG has negative coefficients of −0.098 (FMOLS) and −0.101 (CCR), indicating an inverse relationship with the dependent variable. Their low P-values confirm the statistical significance of these coefficients.

Table 6: Robust check

Variable	FMOLS			CCR		
	Coefficient	t-stats	Prob.	Coefficient	t-stats	Prob.
LNE	1.18	28.9	0	1.189	34.21	0
LNG	−0.098	−3.13	0.005	−0.101	−3.48	0.002
LNP	0.19	3.44	0.002	0.19	3.27	0.004
C	5.84	8.02	0	5.93	9.16	0

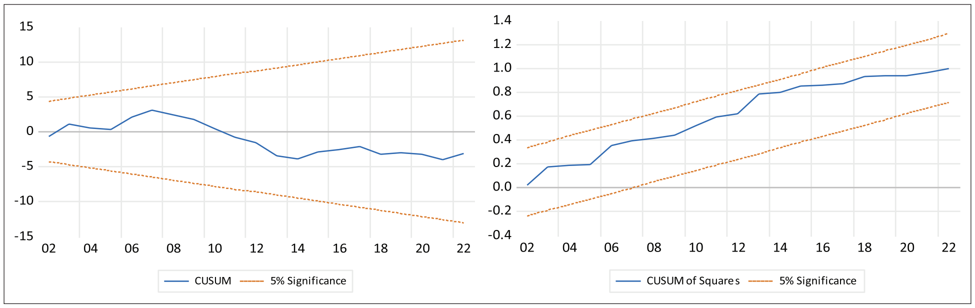
Table 7: Diagnostic tests for the carbon emissions

Variable	Tests			Inference
Breusch-Godfrey serial correlation LM test				
LNC	F-stats	0.629	0.44	The Null hypothesis of no serial Correlation could not be rejected
	Obs*R-squared	0.79	0.37	
Heteroscedasticity Test: Breusch-Pagan-Godfrey				
LNC	F-stats	0.8	0.54	The Null hypothesis of Homoscedasticity could not be rejected
	Obs*R-squared	3.45	0.19	
Normality Test				
LNC	Jarque-Bera	0.777	0.68	The Null hypothesis of normal distribution could not be rejected

Moreover, both models show positive coefficients (0.19) for the LNP, suggesting a positive relationship with the dependent variable. The constants (C) in both FMOLS and CCR models are highly significant, indicating the overall significance of the models. These results provide robustness checks for the relationships among the variables, offering valuable insights into the reliability of the estimated coefficients.

The results of diagnostic tests to assess the robustness of a statistical model are presented in Table 7. The Breusch-Godfrey Serial Correlation LM Test for the variable LNC shows an F-statistic of 0.629 and a corresponding P = 0.44. This suggests that the null hypothesis of no serial correlation cannot be rejected. Similarly, the Breusch-Pagan-Godfrey test for heteroscedasticity gives an F-statistic of 0.8 and a P = 0.54. This means that the null hypothesis of homoscedasticity for the variable LNC cannot be rejected. The normality test using the Jarque-Bera statistic yields a value of 0.777 with a P = 0.68, supporting the conclusion that the null hypothesis of normal distribution cannot be rejected. These tests show how well the model works and suggest that the variable LNC has limited serial correlation, heteroscedasticity, or departure from normality. Furthermore, the CUSUM and CUSUM square tests demonstrate that the model is statistically significant, as shown in Figure 1.

Figure 1: CUSUM and CUSUM Sq



4. CONCLUSION AND POLICY IMPLICATIONS

In contrast to prior research, which has predominantly examined the individual links between economic, environmental, and societal factors, our empirical study adopts a novel approach by exploring the interconnections among economic, societal, and environmental indicators in the context of Indonesia from 1996 to 2022. Our study aims to unravel the complex factors influencing Indonesia's carbon emissions, economic growth, and development, particularly in light of its high poverty levels.

Our investigation is characterized by its comprehensive scope, which involves meticulous variable selection and the application of dependable and robust econometric methodologies. The distinctive contribution of our study lies in the incorporation of a broad set of variables encompassing societal indicators (GINI index), economic indicators (GDP), and environmental indicators (energy use) to gauge their collective impact on carbon emissions. Employing reliable and robust econometric techniques, we aim to generate conclusive insights. This study represents a novel endeavour, utilizing efficient and reliable econometric techniques to scrutinize the relationships between variables and provide meaningful results for Indonesia.

In order to achieve meaningful progress in reducing poverty, policymakers must prioritize developing and implementing a comprehensive policy framework that integrates poverty alleviation, carbon efficiency, energy access, and economic resilience. Such a framework must be developed through collaborative efforts across government departments and agencies to ensure a coordinated and holistic approach to addressing the complex and interconnected challenges of poverty reduction, carbon emission reduction, energy access, and economic growth.

It is essential that the proposed framework prioritizes the needs of marginalized communities and ensures that all policies and initiatives are designed with equity and inclusivity in mind. To that end, a meticulous and thorough analysis of the various factors contributing to poverty is necessary. By conducting micro-empirical studies, valuable insights can be gained into the specific needs and circumstances of those most affected by poverty and policy solutions tailored accordingly.

Furthermore, the proposed framework should focus on identifying additional strategies and interventions that can be implemented alongside economic growth and carbon emission reduction efforts to further promote poverty reduction. This would require the collaboration of various stakeholders, including businesses, non-governmental organizations, and academic institutions, to develop innovative solutions to address the multifaceted challenges of poverty reduction, carbon emission reduction, energy access, and economic growth.

In conclusion, we recommend developing and implementing a comprehensive policy framework that prioritizes poverty alleviation, carbon efficiency, energy access, and economic resilience while ensuring equity and inclusivity. This framework should be developed through collaborative efforts across government departments and agencies and involve the participation of various stakeholders. The proposed framework should be flexible, adaptable to changing circumstances, and continuously evaluated and refined to ensure its effectiveness in achieving the desired outcomes.

It is essential to investigate further the underlying causes of the diverse effects of carbon emissions, economic growth, and energy consumption on poverty. This will help improve the quality of outcomes and evaluate the effectiveness of relevant policies in different economies. Poverty alleviation policies must consider the broader implications for the impoverished population and the subtle effects within different subgroups. Therefore, robust micro-empirical research is highly significant in this particular situation. The varied consequences observed can provide valuable insights into the additional steps governments can take to eliminate poverty, promote economic growth, and minimize global carbon emissions. Ultimately, the main objective should be to alleviate poverty, reduce poverty rates, promote economic growth, ensure energy accessibility, and achieve cleaner carbon emissions.

Here are some policy suggestions:

1. Develop and implement a comprehensive policy framework that integrates poverty alleviation, carbon efficiency, energy access, and economic resilience. This should involve collaboration across government departments and agencies to ensure a holistic and coordinated approach.
2. Design and implement targeted poverty alleviation programs that address the specific needs of the most vulnerable populations. This could include access to education, healthcare, and social safety nets to lift communities out of poverty.
3. Invest in developing renewable energy infrastructure to enhance energy access in low-income countries. Reducing

reliance on fossil fuels and promoting sustainable energy sources like solar, wind, and hydro can achieve this.
4. Implement policies that promote carbon efficiency and reduce greenhouse gas emissions. This may involve adopting cleaner technologies, energy-efficient practices, and developing sustainable transportation systems.
5. Facilitate capacity-building programs and technology transfer initiatives to empower local communities and businesses. This can enhance their ability to adopt sustainable practices, improve productivity, and contribute to economic resilience.
6. Introduce financial incentives and mechanisms to attract green investments. This may include tax breaks, subsidies, and favourable financing for projects promoting sustainability, renewable energy, and low-carbon technologies.
7. Encourage economic diversification to build resilience against climate-related shocks. This involves supporting industries and sectors less vulnerable to environmental risks and promoting long-term economic stability.
8. Foster community engagement and participation in decision-making processes. Ensuring local communities have a voice in developing and implementing sustainability policies can lead to more effective and culturally sensitive initiatives.
9. Establish robust monitoring, reporting, and evaluation mechanisms to track the progress of sustainability initiatives. Regular assessments enable policymakers to make data-driven decisions, identify challenges, and refine strategies.
10. Seek international collaboration and support to enhance the effectiveness of sustainability efforts. This involves partnerships with donor organizations, international agencies, and other countries to share best practices, technology, and financial resources.

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6. REFERENCES

Alam, M.Q., Alam, M.S. (2021), Financial development, economic growth, and poverty reduction in India. Etikonomi, 20(1), 13-22.

Ali, W., Abdullah, A., Azam, M. (2017), Re-visiting the environmental Kuznets curve hypothesis for Malaysia: Fresh evidence from ARDL bounds testing approach. Renewable and Sustainable Energy Reviews, 77, 990-1000.

Asian Development Bank. (2023), Available from: https://www.adb.org/where-we-work/indonesia/poverty

Azam, M. (2019), Relationship between energy, investment, human capital, environment, and economic growth in four BRICS countries. Environmental Science and Pollution Research International, 26(33), 34388-34400.

Azra, Khan, D., Ahmad, E., Jan, W.U. (2012), Financial development and poverty alleviation: Time series evidence from Pakistan. World Applied Sciences Journal, 18(11), 1576-1581.

Bah, M.M., Azam, M. (2017), Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa. Renewable and Sustainable Energy Reviews, 80, 531-537.

Bansal, S., Sharma, G.D., Rahman, M.M., Yadav, A., Garg, I. (2021), Nexus between environmental, social and economic development in South Asia: Evidence from econometric models. Heliyons, 7, e05965.

Baz, K., Xu, D., Ali, H., Khan, U., Cheng, J., Abbas, K., Ali, I. (2022), Nexus of minerals-technology complexity and fossil fuels with carbon dioxide emission: Emerging Asian economies based on product complexity index. Journal of Cleaner Production, 373, 133703.

Chancel, L., Piketty, T. (2015), Trends in the Global Inequality of Carbon Emissions (1998-2013) Prospects for an Equitable Adaptation Fund. France: Paris School of Economics.

Chen, S. (2012), Energy consumption and economic growth in China: New evidence from the co-integrated panel VAR model. Journal of International Energy Policy, 1(2), 51-64.

Hubacek, K, Baiocchi, G., Feng, K., Patwardhan, A. (2017), Poverty eradication in a carbon constrained world. Natures Communications, 8(1), 912.

IPCC. (2014), In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T., Minx, J.C., editors. Climate Change 2014: Mitigation of Climate Change. Cambridge: Cambridge University Press.

Jalilian, H., Kirkpatrick, C. (2005), Does financial development contribute to poverty reduction? The Journal of Development Studies, 41(4), 636-656.

Jeanneney, S.G., Kpodar, K. (2011), Financial development and poverty reduction: Can there be a benefit without a cost? Journal of Development Studies, 47(1), 143-116.

Klapper, L., El-Zoghbi, M., Hess, J. (2016), Achieving the Sustainable Development Goals-the Role of Financial Inclusion. Washington, DC: CGAP. Available from: https://www.cgap.org

Malik, M.A. (2021), Economic growth, energy consumption, and environmental quality nexus in Turkey: Evidence from simultaneous equation models. Environmental Science and Pollution Research, 28(31), 41988-41999.

Murshed, M., Khan, A.M., Khan, U., Khan, M.S., Parvin, R.A. (2023b), Can utilizing renewable and nuclear energy harness the environmental sustainability agenda of the G7 countries? The importance of undergoing clean energy transition. International Journal of Ambient Energy, 44(1), 958-972.

Murshed, M., Khan, U., Khan, A.M., Ozturk, I. (2023a), Can energy productivity gains harness the carbon dioxide-inhibiting agenda of the Next 11 countries? Implications for achieving sustainable development. Sustainable Development, 31(1), 307-320.

Pachiyappan, D., Alam, M.S., Khan, U., Khan, A.M., Mohammed, S., Alagirisamy, K., Manigandan, P. (2022), Environmental sustainability with the role of green innovation and economic growth in India with bootstrap ARDL approach. Frontiers in Environmental Science, 10, 975177.

Pao, H.T., Tsai, C.M. (2010), CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy, 38, 7850-7860.

Pesaran, M.H., Shin, Y., Smith, R.J. (2001), Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16, 289-326.

Pradhan, R.P. (2010), The nexus between finance, growth and poverty in India: The cointegration and causality approach. Asian Social Science, 6(9), 114-122.

Rahman, M.M., Rana, R.H., Barua, S. (2019), The drivers of economic growth in South Asia: Evidence from a dynamic system GMM approach. Journal of Economic Studies, 46(3), 564-577.

Raihan, A., Begum, R.A., Nizam, M., Said, M., Pereira, J.J. (2022), Dynamic impacts of energy use, agricultural land expansion, and deforestation on CO_2 emissions in Malaysia. Environmental and

Ecological Statistics, 29(3), 477-507.

Salahuddin, M., Ali, M.I., Vink, N., Gow, J. (2019), The effects of urbanization and globalization on CO_2 emissions: Evidence from the sub-Saharan Africa (SSA) countries. Environmental Science and Pollution Research International, 26(3), 2699-2709.

Sehrawat, M., Giri, A.K. (2016), Financial development and poverty reduction in India: An empirical investigation. International Journal of Social Economics, 43(2), 106-122.

Sehrawat, M., Giri, A.K. (2018), The impact of financial development, economic growth, income inequality on poverty: Evidence from India. Empirical Economics, 55, 1585-1602.

Uddin, G.S., Kyophilavong, P., Sydee, N. (2012), The casual nexus of banking sector development and poverty reduction. International Journal of Economics and Financial Issues, 2(3), 304-311.

Uddin, G.S., Shahbaz, M., Arouri, M., Teulon F. (2014), Financial development and poverty reduction nexus: A cointegration and causality analysis in Bangladesh. Economic Modelling, 36, 405-412.

UN. (2016), World Population Prospects: The 2015 Revision. New York: United Nations, Population Division.

Warr, P. (2000). Poverty reduction and economic growth: The Asian experience. Asian Development Review 18(2), 131-147.

World Bank. (2015a), Povcal Net. Washington, DC: The World Bank. Available from: https://blogs.worldbank.org/opendata/global-poverty-2015-povcalnet-s-new-estimates-and-improved-documentation

World Bank. (2015b), The World Bank-Working for a World Free of Poverty. Washington, DC: The World Bank.