Economic Growth and Environmental Sustainability in Low and Middle-Income Countries by Using System Generalized Method of Moments

Md. Mizanur Rahman[1], Arifur Rahman[2], Feroze Ali[3] and Khan Sher Khan[4]

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Abstract

This study estimated the relationship between environmental sustainability and economic growth in low and middle-income economic countries. The study used robust and strongly balanced panel data from 2008 to 2021. The advanced econometric approach two different variants of the System Generalized Method of Moments (one-step-SGMM and two-step-SGMM) were used for empirical analysis. The analysis shows a significant association between environmental sustainability and economic growth in projected economies. Logistic infrastructure, gross capital formation, labor force participation rate, and carbon dioxide emission are independent variables and significantly affect our dependent variable, GDP per capita. The finding of the one-step SGMM showed that the logistic performance index and CO2 emission are statistically significant for economic growth in particular countries. Thus, gross capital formation is also statistically significant and positively affects our economic growth of the economies. Similarly, the labor participation rate has a positive and significant impact on the economic growth of low-income countries. Besides, in two-step-SGMM, all independent variables, Logistic infrastructure, gross capital formation, labor force participation rate, and carbon dioxide emission, significantly affect our dependent variable economic growth. The results of the autocorrelation tests indicate potential serial correlation in the models' errors. The findings of this study suggested that policymakers must adopt complete approaches that arrange sustainable development goals, mitigate environmental degradation, and promote inclusive economic growth to ensure a prosperous and resilient future for all.

Keywords: Economic Growth, Environmental Sustainability, Low Income Countries.

Introduction

The economic growth determines the standard of living of a nation. It is significant for generating employment, reducing poverty, resolving socioeconomic issues, and so on. The primary focus of policy initiatives in third-world countries, especially those with high poverty levels (Rahman et al., 2019). The contemporary world is facing severe issues, climate change, and ongoing conflict.

[1]*Department of Logistic Engineering and Management, Chang'an University, China.*
Email: dr.md.mizanur.rahman998@gmail.com
[2]*Department of Logistic Engineering and Management, Chang'an University, China.*
Email: arifurrahman_1982@yahoo.com
[3]*Lecturer Economics, Roots International School and College Islamabad, Pakistan.*
Email: mferoze.iei12145@gmail.com
[4] *M.Sc Economics, Department of Economics, University of Science and Technology, Bannu, KP, Pakistan. Corresponding Author Email: khaansher40@gmail.com*

Unfortunately, these issues adversely impact low-and middle-income countries (LMICs). Most third countries of the world. LMICs economies are significant players in the global economy. It represents a substantial portion of the world's population and captures vast natural resources. These countries are characterized by diverse economic structures, varying levels of industrialization, and divergent integration into the global market. A critical aspect of their development trajectory involves balancing economic growth with environmental sustainability.

Poverty is a common characteristic of the LMIC. Poverty rates are dynamic and change with time. Most of the LMICs are experiencing the highest levels of poverty (World Bank, 2017). The significant aim of the 2030 Agenda (including 17 Sustainable Development Goals) is to address economic, environmental, and societal dimensions of sustainable development (Arora-Jonsson, 2023; Scholtz & Barnard, 2018; Abhiyan, 2017). SDGs include eradication of poverty and inequality, promoting comprehensive economic growth, and protecting the environment. The SDGs are interdependent, and they highlight the need to balance financial, societal, and environmental considerations (Goubran et al., 2023). The governments of the entire world must strive to minimize trade-offs between these goals and their implementation (Scrucca et al., 2023). The continuous burning of fossil fuels and greenhouse gas emissions contribute significantly to global warming and climate change. State authorities must implement environmental sustainability policies to curb ecological degradation effectively (Liu et al., 2023; Yawar & Seuring, 2017; Farooq et al., 2021). Studies highlight the importance of addressing social and environmental issues, noting concerns about the impact of global transportation and supply chain operations. High pollution levels are linked to diseases such as asthma and impaired lung function, affecting society at large (An et al., 2021). Since the 1970s, The CO2 level has increased by 90%, with fossil fuel burning and industrialization responsible for about 78% of total CO2 emissions. The International Energy Agency (IEA) attributes most carbon pollution to electricity production (42%), transportation (23%), and industry (19%) (IEA, 2015). Global supply chains and transportation rely heavily on energy consumption, and studies found a strong positive relationship between energy demand, logistics operations, and economic growth (Wang et al., 2023; Olivier et al., 2017; Jiang & Guan, 2016; Friedlingstein et al., 2014).

In addition to the environmental and economic dimensions, the logistic performance of LMICs plays a crucial role in their development. The Logistics Performance Index (LPI), developed by the World Bank, provides a comprehensive measure of a country's logistics efficiency. It assesses various components such as customs performance, infrastructure quality, ease of arranging shipments, competence and quality of logistics services, tracking and tracing capabilities, and the timeliness of shipments. A high LPI score indicates a well-functioning logistics sector, which is essential for facilitating trade, reducing costs, and enhancing economic growth. Low-middle-income countries in Asia, Africa, and North America have been developing sustainable strategies since 1987, emphasizing regional cooperation to address environmental challenges, including climate-related disasters (Anser et al., 2020). This study focused on low-middle-income countries due to their significant population. Climate change has impacted all aspects of life globally. Efforts are being made worldwide to mitigate these issues and protect future generations. This regional study identifies factors adversely affecting human activities and will be beneficial for policymakers and environmentalists.

Furthermore, climate change stances a significant challenge to the global social and environmental business environment, mainly due to rising CO2 levels and their impact on global warming and sustainability. Addressing CO2 emissions requires collective international and regional efforts, as individual actions are insufficient (Kabir et al., 2023; Abbass et al., 2022; Zhang et al., 2022;

Khezri et al., 2021). With around 60% of the global population in Asia heavily reliant on fossil fuels, the region's CO2 emissions have surged from 2002 to 5158 billion tons in the past two decades. The World Health Organization reports that these emissions contribute to approximately 2.4 million annual deaths due to air pollution in South Asia alone (WTO, 2023). The region faces increased temperatures, erratic precipitation, extreme weather events, and rising sea levels, negatively impacting economic growth and millions of lives, especially among the impoverished. These effects are worsened by more frequent and severe climate fluctuations, such as floods, droughts, and hurricanes (Newman & Noy, 2023; Kabir et al., 2023; Harvey et al., 2023).
LMICs are often driven by industrialization, urbanization, and increased consumption, all of which can lead to higher CO2 emissions (Khalili & Breyer, 2022; Yikun et al., 2021). This relationship underscores the complexity of achieving sustainable development goals (SDGs) that aim to promote inclusive economic growth while reducing the carbon footprint. Understanding the dynamics between CO2 emissions and economic growth in these countries is essential for crafting policies that support both economic development and environmental conservation. Low-middle-income countries have expanded their global influence, fostering economic growth and social sustainability (Muruganadam et al., 2023; Ikram et al., 2020). Policymakers must prioritize sustainable long-term goals as the region continues to grow and invest in infrastructure, agriculture, and manufacturing. Challenges such as rising temperatures, extreme weather events, and rising sea levels are escalating. Despite these challenges, low-middle-income countries are reducing their dependence on land-based and non-renewable energy sources, with approximately 18% of their energy now coming from renewables (Kabir et al., 2023). The association between CO2 emissions and economic growth is a focal point of the study. This study tried to investigate the dual challenge of increasing development while mitigating environmental impact.

Literature Review

Larson (2021) examined the relationship between national logistics performance and sustainability dimensions. The different econometric approaches were used to investigate this association. This study tested several hypotheses of the Sustainable Society Index (SSI) and the World Bank's Logistics Performance Index (LPI) through secondary data. The study results showed that higher levels of logistics performance are associated with fundamental aspects of social sustainability and well-being, such as a healthy, educated population, equality, good governance, and reasonable income distribution. However, logistics performance while derived from economic activity and success. It also contributed to environmental degradation through harmful emissions. The study recommended that leaders focus on social well-being alongside investments in technologies and practices for greater energy efficiency in transportation to mitigate ecological impacts while pursuing economic growth.
Abbass et al. (2022) Examined that Climate change is a natural and significant global threat. It impacted almost every sector. The study extended to public health, with climate variations increasing the prevalence of food, waterborne, and vector-borne diseases, exemplified by recent events similar to the coronavirus pandemic. Moreover, climate change exacerbated antimicrobial resistance and affected further health risks due to the rise in resistant infections. The study estimated climate scenarios and evaluated evidence quality to engage readers critically. The study result showed that government intervention increased long-term development through resource accountability and robust climate policy implementation. Therefore, the study suggested that mitigating climate change demands a global commitment to reduce its dire implications and ensure global sustainability.

Budzianowski (2018) explored how middle-income countries can shape their economies to foster low-carbon economic growth and turn the low-carbon transition into an opportunity. It compared and analyzed CO2 emissions and income for 138 countries. The study outcomes showed that climate policy is tailored for middle-income countries and focused on low-carbon technologies and affordable assets. The study highlighted that effective technology and asset choices, along with reduced system costs. Middle-income countries provide cheap energy, drive industrialization, and enhance economic growth.

Shamout (2024) examined the impact of logistics performance (LP) on environmental performance (EP), considering macroeconomic factors like income, trade openness, foreign direct investment, and industrialization. The study is motivated by the UN Sustainable Development Goals (SDGs 11 and 13). The study used Poisson pseudo maximum likelihood with high-dimensional fixed effects (PPMLHDFE) and periods 2007 and 2018. The study results showed that logistics performance and components such as customs, trade and transport infrastructure, and tracing and tracking positively impact environmental performance, environmental health, and ecosystem vitality. Moreover, economic growth, trade, and industrialization negatively affected ecological quality and health from a logistics and supply chain management perspective. The study concludes with policy recommendations to address these issues.

Magazzino et al. (2022) Studied the impact of fossil fuel dependence and polluting emissions from the transport sector on logistics operations within the framework of Green Supply Chain Management (GSCM). The balanced panel data used and periods from 2007 to 2018. The study used a new Artificial Neural Networks (ANN) algorithm in a multivariate framework to explore the dynamic interactions among Logistics Performance Indexes (LPI), demand for oil products, and CO2 emissions from fuel combustion in transport. The study results revealed that oil product consumption and CO2 emissions significantly affected transport logistics indexes. However, the study also found that where environmental pollution does not significantly drive oil use by supply chain performance. Based on these results, the study suggested some policy recommendations to direct the logistics sector toward greater sustainability in Europe.

Methodology

Data Sources

Data and data sources play a significant role in estimating any variables (Dependent variables and independent variables). This study used five variables. The GDP per capita (constant 2015 US$) is a dependent variable, while the logistic performance index (used proxy as a logistic infrastructure (LPIit), gross capital formation, labor force participation rate (LABit), and carbon dioxide emissions are independent variables. Therefore, this study used solid and balanced data and a period from 2008 to 2023. The data was taken from different sources, such as the World Development Indicator (WDI). The study was conducted in low-middle-income countries, through data to investigate aforementioned projected variables.

Model Specification

Econometric Model

$GDPpc_{it} = f\,(LPI_{it}, GCF_{it}, LAB_{i}, CO2_{it})$

$$GDPpc = \alpha_i + \beta_1 LPI_{it} + \beta_2 GCF_{it} + \beta_3 LAB_{it} + \beta_4 CO2_{it} + \varepsilon_{it}$$

The description of dependent variables GDPpc is dependent variables while LPI, GCF, LAB, and CO2 are independent variables.

Descriptive Statistics

Descriptive statistics are a basic set of quantitative measures used to summarize and describe the main features of a dataset. They provide a concise overview of the data such as central tendency, variability, and distribution. Therefore, without making inferences beyond the observed dataset. Common descriptive statistics include measures such as the mean, median, mode, standard deviation, range, and percentiles (Rehman et al., 2023; Gul et al., 2023; Gul et al., 2023).

Correlation

Correlation is a statistical measure that describes the strength and direction of the relationship between two variables. It indicates whether and how much two variables change together. Correlation values range from -1 to 1. Correlation is useful for understanding the association between variables in a dataset. However, it does not imply causation; a high correlation between two variables does not necessarily mean that changes in one variable cause changes in the other (Khan et al., 2023; Khan et al., 2023; Akhtar et al., 2023).

GMM Model

An econometric equation refers to a statistical model that represents the relationship between variables in an economic context. These equations are typically derived from economic theory and are estimated using statistical methods such as ordinary least squares (OLS), instrumental variables (IV), maximum likelihood estimation (MLE), or GMM, among others. Econometric equations may include variables representing economic concepts such as demand, supply, production, consumption, investment, or any other relevant economic factors. The choice of equation and estimation method depends on the specific research question, the nature of the data, and the underlying assumptions of the economic model being tested. The econometric equation for the Generalized Method of Moments (GMM) model depends on the specific context and the problem being analyzed. However, in the context of dynamic panel data models, which are often estimated using GMM, the general econometric equation can be represented as follows

$y_{it}=\alpha+\beta x_{it}+u_{it}$

Where:

y_{it} represents the dependent variable for individual i at time t.

x_{it} represents the independent variable(s) for individual i at time t.

α is the intercept term.

β is the coefficient(s) associated with the independent variable(s).

u_{it} is the error term, representing unobserved factors or random shocks affecting the dependent variable.

In the context of GMM estimation for dynamic panel data models, this basic equation is often extended to account for individual and/or time effects, lagged dependent variables, and potential endogeneity issues. GMM estimation involves specifying moment conditions based on the orthogonality conditions between the instruments and the error term, which are then used to estimate the model parameters (Fatima et al., 2022; Bakhsh et al., 2021; Naseem & Guang, 2021)

Results and Discussion

Table 1: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) $LNGDPpc_{it}$	1.000				
(2) $LNLPI_{it}$	0.260*	1.000			
	(0.000)				
(3) $LNCO2_{it}$	-0.251*	-0.227*	1.000		
	(0.000)	(0.000)			
(4) LAB_{it}	-0.277*	-0.074*	0.342*	1.000	
	(0.000)	(0.049)	(0.000)		
(5) GCF_{it}	0.064*	0.310*	-0.394*	-0.140*	1.000
	(0.094)	(0.000)	(0.000)	(0.000)	
**** p<0.01, ** p<0.05, * p<0.1*					

The correlation coefficient not only shows an association between the variables but also refers to the direction of this association. The correlation also provides an accurate and exact form of a theoretical framework. The observed correlations in our analysis parallel our theoretical framework, providing empirical support for our hypotheses. The positive correlation between $GDPpc_{it}$ capita and logistic infrastructure indicates that as $GDPpc_{it}$ increases, so does the development and efficiency of logistic infrastructure. This finding aligns with economic theories positing that higher economic development levels typically coincide with logistical capability improvements. Enhanced logistic infrastructure can facilitate the movement of goods and services, reduce transportation costs, and stimulate economic growth. Similarly, the negative correlation between $LNGDPpc_{it}$ and $LNCO2_{it}$ implies that higher GDP per capita may correspond to lower $CO2_{it}$ emissions, supporting the notion that economic development could lead to the adoption of cleaner technologies and environmental regulations. Additionally, the negative correlations between $LNCO2_{it}$ and GCF_{it} and LAB_{it} and $LNCO2_{it}$ affirm our theoretical understanding that environmental concerns and labor market dynamics are intertwined with economic activities, potentially necessitating policies that balance economic growth with ecological sustainability and workforce participation. Correlations provide insight into potential relationships between economic variables, environmental factors, and labor market dynamics.

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
$LNGDPpc_{it}$	817	7.601	.529	6.506	9.109
$LNLPI_{it}$	817	.825	.176	-.105	1.457
$LNCO2_{it}$	817	3.407	.617	1.451	4.576
LAB_{it}	797	58.45	11.93	31.40	87.36
GCF_{it}	807	3.420	1.087	-7.298	9.982
Obs. 19*43 =817					

Descriptive statistics describes and summarizes the fundamental features of a dataset. It measures means, median standard deviation, etc. Therefore, descriptive statistics help researchers understand the characteristics of their data, identify outliers or patterns, and make initial interpretations. The descriptive statistics presented in Table 2 provide an overview of the specific variables. The $LNGDPpc_{it}$ has a mean of 7.601 with a standard deviation of 0.529, indicating that the logarithm of $GDPpc_{it}$ varies around this mean value. Similarly, $LNLPI_{it}$ has a mean of 0.825 with a standard deviation of 0.176, suggesting a relatively stable distribution around the mean. $LNCO2_{it}$ shows a mean of 3.407 and a standard deviation of 0.617, representing some variability in the logarithm of $CO2_{it}$ emissions across observations. LAB_{it} has a mean of 58.45 with a standard deviation of 11.93, reflecting variation in labor force participation rates across the dataset. Lastly, GCF_{it} shows a mean of 3.420 and a standard deviation of 1.087, indicating variability in gross capital formation across observations.

Table 3: Outcome for OLS, FE, and System GMM

	Model (1)	Model (2)	Model (3)	Model (4)
	OLS	FE	1-SGMM	2-SGMM
Variables			GDPpc	GDPpc
L. $LNGDPpc_{it}$			0.630***	0.562***
			(0.0508)	(0.0259)
$LNLPI_{it}$	5.877***	1.545***	2.13.2***	3.274**
	(1.55.8)	(4.674)	(3.573)	(1.596)
$LNCO2_{it}$	-13.01***	-1.421	-8.982***	-10.85***
	(3.813)	(1.689)	(1.350)	(3.808)
GCF_{it}	1.500***	3.51e-09***	4.171***	1.160
	(5.391)	(5.1210)	(1.031)	(1.490)
	-4.257***	-6.989	14.31***	0.546***
	(5.696)	(9.423)	(1.601)	(0.0624)
Constant	4,091***	2,343***	757.2***	591.8
	(491.0)	(595.2)	(126.3)	(406.2)
Observations	817	817	778	778
AR (1)			-1.76 [0.079]	-1.56 [0.118]
AR (2)			0.05 [0.964]	0.30 [0.765]
Sargan test			55.65 [0.000]	1.89 [0.943]
R-Squared	0.206	0.138		

Standard errors in parentheses and probability in [],
*** p<0.01, ** p<0.05, * p<0.1

Table 3 presents the outcomes of four different models: Ordinary Least Squares (OLS), Fixed Effects (FE), and two different variants of the System Generalized Method of Moments (One-Step-SGMM and Two-Step-SGMM). Each model evaluates the relationship between GDP per capita ($GDPpc_{it}$) and various independent variables, including L. $LNGDPpc_{it}$, $LNLPI_{it}$, $LNCO2_{it}$, GCF_{it}, and LAB_{it}. In Model 1, the OLS results show that lagged $GDPpc_{it}$ (L. $LNGDPpc_{it}$) has a statistically significant positive coefficient of 0.630 ($p<0.01$), indicating a strong positive relationship with current GDP per capita. Moreover, $LNLPI_{it}$ has a statistically significant positive coefficient of 5.877 ($p<0.01$), suggesting that increases in the logistic infrastructure are associated with higher $GDPpc_{it}$. On the other hand, $LNCO2_{it}$ has a statistically significant negative coefficient of -13.01 ($p<0.01$), indicating that higher CO2 emissions are associated with lower $GDPpc_{it}$. GCF_{it} also has a statistically significant positive coefficient of 1.500 ($p<0.01$), indicating that higher levels of gross capital formation may be associated with higher $GDPpc_{it}$. LAB_{it} has a statistically significant negative coefficient of -42.57 ($p<0.01$), suggesting that higher labor force participation rates are associated with lower $GDPpc_{it}$. The same table, Model 3, describes the results of the one-step-SGMM technique. The coefficient for lagged GDP per capita (L. $LNGDPpc_{it}$) is highly significant ($p < 0.01$), indicating a robust positive relationship between past and current $GDPpc_{it}$. The $LNLPI_{it}$ shows a statistically significant coefficient ($p < 0.01$), showing that increases in the $LNLPI_{it}$ are associated with higher $GDPpc_{it}$. Conversely, the $LNCO2_{it}$ it's a statistically significant negative coefficient ($p < 0.01$), indicating that higher $CO2_{it}$ emissions are associated with lower $GDPpc_{it}$. Moreover, GCF_{it} shows a statistically significant positive coefficient ($p < 0.01$), indicating that higher levels of GCF_{it} may positively affect $GDPpc_{it}$. Finally, the LAB_{it} has a statistically significant positive coefficient ($p < 0.01$), suggesting that increased labor force participation contributes positively to $GDPpc_{it}$. Similarly, in the same table, model four presents the results of the two-step-SGMM estimation technique; the statistical significance of the coefficients varies, providing insights into the determinants of $GDPpc_{it}$. The coefficient for lagged GDP per capita (L. $LNGDPpc_{it}$) is statistically significant ($p < 0.01$), suggesting a positive relationship between past and current $GDPpc_{it}$. However, the $LNLPI_{it}$, $LNCO2_{it}$, and GCF_{it} coefficients are not statistically significant. At the same time, LAB is statistically significant at a 10% level. Similarly, the insignificant coefficients for $LNCO2_{it}$ and GCF_{it} suggest that, in this specification, neither CO2 emissions nor GCF_{it} significantly affect $GDPpc_{it}$. When comparing models 3 and 4, model 3 accounts for potential endogeneity and addresses issues related to omitted variables or measurement errors more effectively than OLS or FE. Therefore, all variables significantly affect $GDPpc_{it}$. However, the issue in model 3 is that it may still suffer from weak instrument bias or other limitations associated with the specific implementation of the SGMM technique. Meanwhile, in model or two-step, SGMM offers further improvements over Model 3 by utilizing an additional moment condition. Therefore, The Sargan test statistic is 1.89 with a p-value of 0.943, which indicates that the instruments used in the estimation of Model 4 are valid and not correlated with the error term, supporting the reliability of the estimates obtained using the 2-SGMM technique. In Model 3, the results of the autocorrelation tests indicate potential serial correlation in the models' errors. Specifically, the negative coefficients of -1.76 and -1.56, respectively, for AR (1) in Models 3 and 4 suggest the presence of first-order autocorrelation in these models. Additionally, the insignificant coefficients for AR (2) across all models indicate the absence of second-order autocorrelation.

Conclusion and Policy Recommendations

The study investigates relationships between various economic, environmental, and infrastructure variables, and their impact on GDP per capita (GDPpcit). There is a strong association among the projected variables. The GDPpcit and logistic infrastructure (LNLPIit) have a positive correlation. Economic growth is often accompanied by improvements in logistical capabilities, supporting the idea that economic development fosters infrastructure enhancement. Besides, there is a negative correlation between GDPpcit and CO2 emissions (LNCO2it) indicating that higher economic development might be linked with reduced emissions, possibly due to the adoption of cleaner technologies and stricter environmental regulations. The regression analysis using OLS, Fixed Effects (FE), and System GMM models provides robust evidence of the determinants of GDP per capita. The OLS results indicate that past GDP per capita (lagged LNGDPpcit), logistic infrastructure (LNLPIit), and gross capital formation (GCFit) have positive and significant impacts on current GDP per capita. In contrast, CO2 emissions (LNCO2it) negatively impact GDPpcit.

The FE model reinforces these findings, although with some variations in significance levels. The System GMM models (both one-step and two-step) address potential endogeneity issues more effectively. The one-step SGMM results show strong positive effects of lagged GDP per capita, logistic infrastructure, and gross capital formation on GDPpcit, while CO2 emissions negatively impact GDPpcit. The two-step SGMM results, which further refine the estimation by using additional moment conditions, confirm the significance of these relationships, except for logistic infrastructure and CO2 emissions, which lose statistical significance in this specification. The overall conclude that the study investigates importance of logistic infrastructure and gross capital formation in driving economic growth while highlighting the adverse effects of CO2 emissions. The findings suggest that policymakers should focus on enhancing infrastructure and capital formation while implementing environmentally sustainable practices to foster economic development. The validity of the instruments used in the GMM models, as confirmed by the Sargan test, adds credibility to these results, although potential issues such as weak instrument bias should be considered. Based on the results, the study suggests some recommendations to policymakers. The state focuses investment in logistical infrastructure and gross capital formation to stimulate economic growth. Additionally, implementing environmentally sustainable practices, such as promoting cleaner technologies and enforcing stricter environmental regulations, can help mitigate the adverse effects of CO2 emissions while fostering sustainable development. By focusing on these measures, policymakers can create a conducive environment for long-term economic prosperity while addressing environmental concerns.

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