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Institutions and Environmental Sustainability in Africa: Pathways and Transmission Mechanisms

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Abstract

As the African continent wrestles with significant ecological threats alongside its pursuit of economic growth, this study explores how institutional frameworks can drive environmental sustainability. This study collects data for a sample of 33 African countries from 2008 to 2022 from World Governance Indicators, World Economic Freedom Database, Global Footprint database and World Development Indicators Database. Engaging a System GMM methodology, this paper investigates the direct and indirect effects of economic and regulatory institutional frameworks on environmental sustainability in Africa. The results suggest that economic institutions significantly impact environmental sustainability in Africa, with strong persistence of past sustainability levels. Government size and robust legal systems enhance sustainability, while foreign direct investment has negative effects. Regulatory institutions, such as control of corruption and government effectiveness, contribute positively to environmental sustainability. The interaction between economic and regulatory institutions indicates that effective government interventions depend on governance quality. Policymakers therefore should focus on strengthening regulatory frameworks and increasing government involvement in environmental management. Additionally, enhancing public awareness and community engagement is crucial for fostering local initiatives that address environmental challenges and promote resilience.

Keywords: *Economic Institutions, Regulatory Institutions, Environmental Sustainability, Economic Growth, Africa*

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1. Introduction

Environmental sustainability has emerged as a critical issue for policymakers and researchers, particularly in the context of developing regions like Africa where economic growth often comes at the expense of ecological integrity. The relation between economic and regulatory institutions is increasingly recognized as pivotal in shaping environmental outcomes in both theoretical and empirical debates across the globe. For instance, Alola et al. (2021) indicated the significance of economic institutions in driving sustainability within the G-20 economies, highlighting that well-structured economic policies can enhance ecological performance. In Africa where institutional frameworks may be weaker and governance issues prevalent, understanding the relationship between economic and regulatory institutions such as government size, legal systems, free trade policies, sound money and environmental sustainability is essential for formulating effective policies that promote sustainable development. Africa contributes less than 10% to global greenhouse gas emissions but it's one of the most vulnerable continents to climate change, with significant impacts on its development sectors and infrastructure. The continent is projected to experience a temperature increase of 1.5°C to 2°C above pre-industrial levels by 2030, which could lead to a 50% increase in the frequency of extreme weather events (IPCC, 2022; Wang & Dong, 2019).

Moreover, the integration of regulatory institutions within this framework provides a comprehensive understanding of how governance quality influences environmental sustainability. This is why Kaufmann et al. (2020) emphasized that effective governance is crucial in promoting sustainable practices, suggesting that regulatory institutions such as the rule of law, government effectiveness and control of corruption play significant roles in enhancing environmental outcomes. Recent studies have shown that the interaction of economic and regulatory institutions can yield synergistic effects, amplifying their collective impact on sustainability. For example, countries with stronger governance indicators, such as political stability and regulatory quality have been shown to perform better in environmental sustainability metrics, with a 30% improvement in sustainability scores for nations with high governance ratings compared to those with low ratings (Dinda & Coondoo, 2006; Zhang & Baranzini, 2021). In 2024, the Environmental Performance Index (EPI) ranked several African countries poorly, with an average score of 40 out of 100, indicating that despite their potential, they face significant challenges in achieving sustainability goals (Block et al., 2024). Given the unique challenges faced by African nations, exploring these relationships through rigorous empirical analysis is vital for identifying pathways toward improved environmental sustainability while fostering economic growth.

Notwithstanding the growing recognition of the importance of both economic and regulatory institutions in achieving environmental sustainability, there remain significant gaps in empirical research focused specifically on the African context. While studies in other regions such as the G-20 economies have demonstrated the positive impacts of robust institutional frameworks on environmental outcomes, similar investigations in Africa are limited (Alola et al., 2021; Kaufmann et al., 2020). This lack of comprehensive understanding hinders policymakers from effectively addressing the pressing environmental challenges faced by the continent, such as deforestation, pollution, and biodiversity loss.

Africa loses approximately 3.9 million hectares of forest annually, exacerbating climate change and threatening livelihoods, with an estimated economic loss of $68 billion per year due to deforestation (FAO, 2020). Furthermore, the interconnectedness of economic and regulatory institutions necessitates an integrated approach to

sustainability that is yet to be fully explored in the African context (Dinda & Coondoo, 2006). Therefore, this study aims to fill this gap by examining the direct and transmission effects of economic and regulatory institutions on environmental sustainability in Africa.

Despite the growing body of literature on environmental sustainability in Africa, significant gaps remain, particularly regarding the interplay between economic and regulatory institutions. First, while studies have examined the impact of economic institutions on sustainability, few have integrated regulatory institutional variables to provide a comprehensive understanding of their combined effects (Dinda & Coondoo, 2006). Second, existing research often focuses on specific regions or countries, neglecting a broader analysis across diverse African contexts, which limits the generalizability of findings (Kaufmann et al., 2020). Third, there is a lack of empirical evidence that quantifies the interaction effects between economic and regulatory institutions on environmental outcomes in Africa, which is crucial for effective policy formulation (Alola et al., 2021). Finally, the role of governance quality in mediating these relationships remains underexplored, particularly in the context of developing economies where institutional weaknesses are prevalent (Sachs et al., 2021). This study aims to fill these gaps by providing a holistic analysis of how economic and regulatory institutions interact to influence environmental sustainability across African nations.

This study is structured into six sections. Following the introduction, Section 2 reviews the relevant literature on economic institutions, regulatory institutions, and environmental sustainability. Section 3 presents the theoretical framework and empirical model specification. Section 4 discusses the data description and econometric methodology employed in the study. Section 5 presents and discusses the empirical findings on the direct and transmission effects of economic and regulatory institutions on environmental sustainability in Africa. Finally, Section 6 concludes the study and provides relevant policy implications.

2. Literature Review

The relationship between economic institutions and environmental sustainability has garnered considerable attention in empirical research, particularly in developed economies, but increasingly in developing contexts such as Africa. Alola et al. (2021) established those economic institutions, such as government size and property rights, significantly influence environmental outcomes within G-20 nations. Their findings suggest that countries with robust economic policies are better positioned to implement sustainable practices. Similarly, studies have shown that sound monetary policies and trade openness can foster environmental sustainability through enhanced resource allocation and investment in green technologies (García & Mena, 2022; Zhang et al., 2023). For instance, research indicates that financial development and energy consumption are critical in shaping environmental quality, particularly in emerging economies (Yameogo et al., 2021). Conversely, weak economic institutions often correlate with poor environmental performance, as evidenced by the negative impacts of corruption and inadequate legal systems on ecological integrity (Sachs et al., 2021; Adekunle, 2021).

In exploring the role of regulatory institutions, Kaufmann et al. (2020) emphasize the critical importance of governance quality in shaping environmental outcomes. Their analysis indicates that effective regulatory frameworks—characterized by strong rule of law and accountability—are essential for promoting sustainable practices. This assertion is supported by empirical evidence suggesting that nations with higher regulatory quality tend to achieve better environmental performance metrics, such as reduced carbon

emissions and improved biodiversity indices (Adger et al., 2021; Mensah et al., 2019). Furthermore, the interaction between governance and environmental sustainability has been explored by several scholars, revealing that effective governance can amplify the positive effects of economic institutions on environmental outcomes (Boone et al., 2022; Mukherjee & Khatun, 2023; Asongu et al., 2020).

The interconnectedness of economic and regulatory institutions is further highlighted in studies analyzing their combined impact on environmental sustainability. Dinda and Coondoo (2006) propose a model that illustrates how economic institutions can influence environmental outcomes indirectly through regulatory frameworks. Recent empirical research supports this model, demonstrating that regions with higher levels of governance quality can significantly enhance the effects of economic variables on sustainability (Nhamo et al., 2021; Wang et al., 2022). For instance, countries that successfully integrate economic incentives with effective governance mechanisms have reported substantial improvements in environmental health, highlighting the need for a holistic approach to sustainability that encompasses both economic and regulatory dimensions (Khan et al., 2023; Lee & Mazzanti, 2023; Erdoğan et al., 2021).

Despite the growing body of literature on environmental sustainability in Africa, significant gaps remain, particularly regarding the interplay between economic and regulatory institutions. First, while studies have examined the impact of economic institutions on sustainability, few have integrated regulatory institutional variables to provide a comprehensive understanding of their combined effects (Dinda & Coondoo, 2006). Second, existing research often focuses on specific regions or countries, neglecting a broader analysis across diverse African contexts, which limits the generalizability of findings (Kaufmann et al., 2020; Adekunle et al., 2020). Third, there is a lack of empirical evidence that quantifies the interaction effects between economic and regulatory institutions on environmental outcomes in Africa, which is crucial for effective policy formulation (Alola et al., 2021; Amowine et al., 2021). Finally, the role of governance quality in mediating these relationships remains underexplored, particularly in the context of developing economies where institutional weaknesses are prevalent (Sachs et al., 2021; Adekunle, 2021). This study aims to fill these gaps by providing a holistic analysis of how economic and regulatory institutions interact to influence environmental sustainability across African nations.

3. Material and Methods

Theoretical Framework

Integrating the Dietz and Rosa (1994) STIRPAT model with the Dinda and Coondoo (2006) model allows for a comprehensive investigation into the pathways for overcoming the global challenge of environmental sustainability in Africa. The STIRPAT model, developed by Dietz and Rosa (1994), focuses on understanding the relationship between human activities and environmental impacts. It posits that environmental impact is a function of three primary factors: population, affluence, and technology. This foundational equation highlights that environmental impact is influenced by population size, economic wealth (which affects consumption patterns), and the level of technology employed. The model emphasizes that as population and affluence increase, environmental pressures also rise, unless mitigated by advancements in technology (Dietz & Rosa, 1994). Recent studies have reinforced the relevance of this model in analyzing CO2 emissions and other environmental outcomes, demonstrating its

applicability across various contexts, including developing regions like Africa (Xing et al., 2023).

The Dinda and Coondoo (2006) model, emphasizes the role of regulatory frameworks in shaping environmental quality. It suggests that economic growth can lead to increased environmental degradation, but as economies develop, they may also adopt cleaner technologies and better environmental practices. This model incorporates the concept of institutional quality, arguing that strong regulatory frameworks can significantly influence environmental sustainability (Dinda & Coondoo, 2006). The model expresses technology as a function of economic institutions and regulatory institutions, capturing how these institutional frameworks shape technological development and adoption, which is critical for achieving sustainable environmental outcomes (Acheampong et al., 2022). The basic foundational STIRPAT Model representing environmental impact is for this study is stated as follows:

$$I = f(P, A, T) \ldots\ldots\ldots\ldots (1)$$

This equation posits that environmental impact (I) is a function of population (P), affluence (A) which is economic wealth which influences consumption patterns and environmental pressures, and technology (T) (Dietz & Rosa, 1994). To incorporate the influence of economic and regulatory institutions (EI and RI), we express technology as a function of these institutions:

$$T = f(EI, RI) \ldots\ldots\ldots\ldots (2)$$

This function captures how economic and regulatory frameworks shape technological development and adoption (Dinda & Coondoo, 2006). Substituting this into the STIRPAT equation yields:

$$I = (P, A, EI, RI) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Incorporating institutions into the STIRPAT framework indicates that environmental impact is also a function of economic and regulatory institutions, highlighting their importance in shaping environmental outcomes (Dinda & Coondoo, 2006). We can model the function $f(EI, RI)$ as a multiplicative interaction:

$$f(EI, RI) = EI^{\alpha} RI^{\beta} \ldots\ldots\ldots\ldots\ldots\ldots . (4)$$

Where α and β represent the elasticities with respect to economic and regulatory institutions (Dinda & Coondoo, 2006). Modeling the function of economic and regulatory institutions as a multiplicative interaction allows for assessing how changes in institutional quality can influence technological advancements and, consequently, environmental impacts. The elasticities associated with these institutions represent how sensitive technology is to variations in institutional quality (Sakariyahu et al., 2023). To capture temporal dynamics, we incorporate lagged variables:

$$I_t = f\left(P_t^{\gamma} A_t^{\delta} EI_t^{\alpha} RI_t^{\beta} I_{t-1}\right) \ldots\ldots\ldots\ldots\ldots\ldots . (5)$$

Where I_{t-1} is the lagged environmental impact representing the influence of past impacts (Dinda & Coondoo, 2006). To capture the temporal dynamics of environmental

impacts, incorporating lagged variables reflects the influence of past environmental impacts, acknowledging that previous conditions can affect current outcomes (Gutiérrez et al., 2020). We include a spatial component as follows:

$$I_{i,t} = P_{i,t}^{\gamma} A_{i,t}^{\delta} EI_{i,t}^{\alpha} RI_{i,t}^{\beta} + \sum_{j \in N(i)} w_{ij} I_{j,t} \ldots\ldots\ldots\ldots (6)$$

Where (i) is the set of neighboring units for unit i and wij indicates the influence of neighboring units (Gutiérrez et al., 2020). Including a spatial component allows for considering neighboring influences on environmental impacts. This spatial dimension is essential for understanding how environmental impacts can be affected by regional interactions and the interconnectedness of neighboring units (Gutiérrez et al., 2020). The STIRPAT model has been widely used to analyze the relationship between population, affluence, and technology on environmental impacts, emphasizing the importance of these factors in understanding CO2 emissions and other environmental outcomes (Dietz & Rosa, 1994). The role of economic growth and regulatory frameworks in shaping environmental quality has been highlighted by Dinda and Coondoo (2006), suggesting that institutional quality significantly influences environmental sustainability. Moreover, studies have shown that stronger institutions lead to better environmental performance (North, 1990). This framework integrates the Dinda and Coondoo (2006) model with the STIRPAT model to analyze the pathways for overcoming environmental sustainability challenges in Africa.

The integrated framework emphasizes the critical role of institutional quality in shaping environmental outcomes. Stronger institutions can lead to better enforcement of environmental regulations and promote sustainable practices, which is particularly important in the context of Africa, where institutional challenges often hinder environmental progress (North, 1990). Studies have shown that countries with robust regulatory frameworks tend to perform better in terms of environmental sustainability, suggesting that enhancing institutional quality could be a key strategy for addressing environmental challenges in the region (Dinda & Coondoo, 2006). Moreover, this framework allows for a nuanced analysis of how population growth and economic development interact with institutional factors to influence environmental sustainability. By understanding these dynamics, policymakers can design more effective interventions that leverage institutional strengths to mitigate environmental impacts (Acheampong et al., 2022).

Drawing from the framework established by Alola *et al.* (2021) in their study particularly within the context of the G-20 economies, the model for examining the impact of economic institutions on environmental sustainability in Africa is specified as follows:

$$ENV\ SUST_{\ it} = \beta + \alpha_i ECI_{it} + \gamma_i \chi_{it} + \xi_{it} \ldots\ldots\ldots (7)$$

Where: ENV SUST= Environmental Sustainability; ECI= A Vector of Economic Institutions (The economic institutional variables consist of Government Size (GOVSIZE), Legal Systems and Property Rights (LSPR), Sound Money (SM), Freedom to Trade (FT), International Regulations (INTERR)); χ = Vector of control variables (Inflation Rate (INFLA), Population Growth (POP GROWTH), Trade Openness (TOPEN), Logarithm of Foreign Direct Investment (LOGFDI)); β is the constant term, α_i is vector of parameters for the Economic Institution variables, γ_i is vector of parameters for the control variables

ξ = Error term.

To explore the effects of regulatory institutional variables on environmental sustainability, we can reference the study by Kaufmann et al. (2020), which highlights the critical role of governance quality in shaping environmental outcomes, emphasizing that effective regulatory institutions are essential for promoting sustainable practices. Therefore, the model for this study in the African continent is specified as follows:

$$ENV\ SUST_{\ it} = \beta + \rho_i REGI_{it} + \gamma_i \chi_{it} + \xi_{it} \dots \dots \dots (8)$$

Where: ENV SUST = Environmental Sustainability; REGI= A Vector of Regulatory Institutions (Control of Corruption (CC), Government Effectiveness (GE), Political Instability and Absence of Violence (PV), Regulatory Quality (RQ), Rule of Law (RL), Voice and Accountability (VA), and the Regulatory Institutions Index (RI INDEX)); χ = Vector of control variables (Inflation Rate (INFLA), Population Growth (POP GROWTH), Trade Openness (TOPEN), Logarithm of Foreign Direct Investment (LOGFDI)); β is the constant term, ρ_i is vector of parameters for the Regulatory Institutions variables, γ_i is vector of parameters for the control variables ξ = Error term.

To analyze the transmission effects of economic institutions through regulatory institutions on environmental sustainability, we can draw on the study by Dinda and Coondoo (2006) which highlights the interconnectedness of economic and regulatory institutions and their collective impact on environmental outcomes, the model is specified as follows:

$$ENV\ SUST_{\ it} = \beta + \alpha_i ECI_{it} + \rho_i REGI_{it} + \gamma_i \chi_{it} + \varphi_i (ECI_{it} * REGI_{it}) + \xi_{it} \dots \dots \dots (9)$$

Where: φ_i is a vector of coefficients for the impact of the interactions between the various economic institutional variables with the regulatory institution index on environmental sustainability in Africa. This coefficient highlights the need to consider both dimensions when assessing sustainability (Dinda and Coondoo, 2006).

Dependent Variable

The dependent variable in this analysis to measure environmental sustainability (ENV SUST) is the Ecological Footprint is a critical measure that quantifies the environmental impact of human activities by calculating the amount of biologically productive land and water area required to sustain a population's resource consumption and waste generation. It encompasses various components, including cropland, forest land, fishing grounds, and carbon footprint, and is expressed in global hectares (gha) to facilitate comparisons across different regions and populations. The Ecological Footprint serves as an essential indicator of sustainability, revealing whether human demand exceeds the Earth's ecological capacity, which can lead to ecological overshoot and degradation of natural resources (Wackernagel *et al.,* 2018; Mancini *et al.,* 2018). Recent studies have shown that the global Ecological Footprint continues to rise, with many countries operating in ecological deficit, highlighting the urgent need for sustainable resource management practices to mitigate environmental impacts (Galli *et al.,* 2014; Borucke *et al.,* 2013). Furthermore, the Ecological Footprint is increasingly used in policy-making to guide efforts toward achieving sustainability goals and reducing carbon emissions (Lazarus *et al.,* 2014; Global Footprint Network, 2018).

Economic Institutional Variables

The economic institutional variables examined in this study include a vector comprising Government Size (GOVSIZE), Legal Systems and Property Rights (LSPR), Sound Money (SM), Freedom to Trade (FT), and International Regulations (INTERR). Government Size is quantified as the total government expenditure expressed as a percentage of GDP, which indicates the government's influence on economic management. Legal Systems and Property Rights are evaluated through indices that measure the effectiveness of legal frameworks and the safeguarding of property rights. Sound Money is typically assessed by analyzing inflation stability and the predictability of currency values. Freedom to Trade reflects a country's free trade policies. Lastly, International Regulations are appraised through indices that assess the strength of international agreements and adherence to global standards (Gwartney et al., 2023; Tchamyou, 2020).

Regulatory Institutional Variables

The regulatory institutional variables consist of Control of Corruption (CC), Government Effectiveness (GE), Political Instability and Absence of Violence (PV), Regulatory Quality (RQ), Rule of Law (RL), Voice and Accountability (VA), and the Regulatory Institutions Index (RI INDEX). These variables are generally assessed through perception-based indices derived from surveys conducted by institutions like the World Bank and Transparency International. Control of Corruption is evaluated using corruption perception scores, while Government Effectiveness is gauged through indicators related to service delivery and bureaucratic efficiency. Political Instability and Absence of Violence indicate the risks associated with governance, and Regulatory Quality measures the effectiveness of regulatory frameworks. The Rule of Law is determined by the fairness of law application, and Voice and Accountability reflect the extent of citizen participation in political processes. Understanding these regulatory dimensions is vital for analyzing governance dynamics and their broader implications (Bertelsmann Stiftung, 2022; World Bank, 2023).

Control Variables

In this analysis, the control variables include the Inflation Rate (INFLA), Population Growth (POP GROWTH), Trade Openness (TOPEN), and the Logarithm of Foreign Direct Investment (LOGFDI). The Inflation Rate is generally represented as the annual percentage change in consumer prices, which reflects the economic environment's stability. Population Growth is measured as the annual percentage increase in the population, indicating demographic pressures that may affect economic conditions. Trade Openness is determined by the total of exports and imports as a percentage of GDP, showcasing a nation's involvement in global trade. The Logarithm of Foreign Direct Investment is utilized to signify the inflow of foreign capital, with its logarithmic transformation applied for normalization purposes. These control variables are essential for environmental sustainability outcomes (Ghazalian, 2023; Aisen & Veiga, 2013).

4. Data Description

The data was collected for 33 African countries spanning from 2008 to 2022 inclusive due to global footprint data availability for environmental sustainability. The countries include; Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Eswatini, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau,

Kenya, Lesotho, Liberia, Madagascar, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia. Table 1 presents the descriptive statistics for various variables relevant to the study. The mean value for Environmental Sustainability is 1.528, indicating a moderate level of sustainability among the observed entities, while Government Size has a mean of 6.727, suggesting significant government involvement in the economy. Legal Systems and Property Rights average at 3.98, reflecting a generally effective legal framework. Sound Money shows a mean of 7.315, indicating relative currency stability. Freedom to Trade has a mean of 6.188, suggesting a reasonably free environment.

Table 1: Descriptive Statistics

VARIABLE	OBS	MEAN	STD. DEV.	MIN	MAX
ENV SUST	510	1.528	.675	.757	3.491
GOVSIZE	613	6.727	1.024	3.716	8.879
LSPR	613	3.98	1.232	1.861	7.077
SM	613	7.315	1.222	1.27	9.759
FT	606	6.188	.872	2.353	8.86
INTERR	613	5.68	.89	3.261	7.803
CC	646	-.536	.627	-1.573	1.23
GE	646	-.648	.59	-1.878	1.057
PV	646	-.463	.834	-2.699	1.2
RQ	646	-.538	.501	-1.577	1.127
RL	646	-.576	.585	-1.884	1.029
VA	646	-.431	.66	-1.896	.979
RI INDEX	646	0	2.204	-4.473	5.599
INFLA	664	5.994	5.952	-8.975	44.391
POP GROWTH	684	4.841	16.533	-2.629	167.442
TOPEN	676	86183.259	553107.11	.207	5180100
LOGFDI	655	19.608	1.69	10.361	23.026

Source: Author's Own Creation

The regulatory institutional variables, such as Control of Corruption, Government Effectiveness, and Political Instability and Absence of Violence, present negative means, indicating challenges in governance, while the Regulatory Institutions Index centers around zero, suggesting a balance in regulatory perceptions. Inflation shows considerable variability, with a mean of 5.994, and Population Growth reflects substantial differences among countries, highlighted by a high standard deviation.

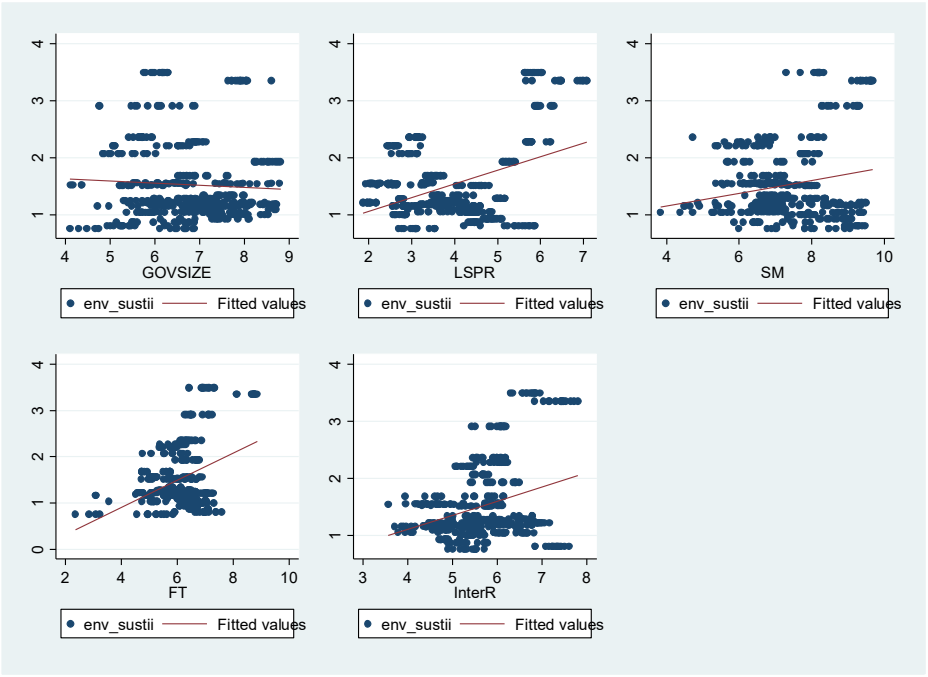

Figure 1 *Fitted Scatter Plots on the Expected Link Between Economic Institutions and Environmental Sustainability in Africa.*

Source: Author's Own Creation

The plots reveal that the relation between government size and environmental sustainability is non-linear, while the relation between legal systems and property rights, sound money, freedom to trade, and international regulations present positive links with environmental sustainability in the African continent.

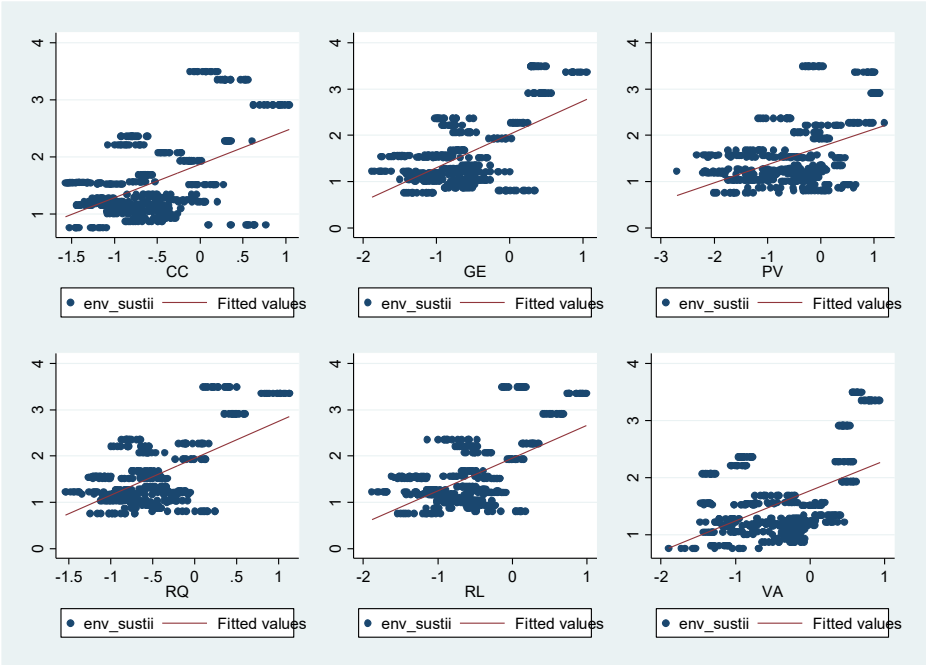

Figure 2 *Fitted scatter plots on the expected relation between regulatory institutional variables and environmental sustainability*

Source: Author's Own Creation

The different scatter plots on the relation between regulatory institutional variables and environmental sustainability all present positive relations. Worth noting from figure 3.1 and figure 3.2 is the fact that the exact link between these variables maybe affected by other control variables which the scatter plots do not account for. As such, proper econometric methods are needed to give meaning to these relationships. These will be examined in the subsequent sections of this paper.

Econometric Method

In this study, we utilize the system Generalized Method of Moments (GMM) because the dependent variable exhibits a high correlation with its first-period lag. Consequently, we include the lagged dependent variable as one of the explanatory variables. Additionally, the time frame of 2008 to 2022, is smaller than the number of cross-sectional units, which includes 33 countries (Roodman, 2009). The inclusion of the first-period lagged dependent variable, which correlates with fixed effects in the error term, can lead to dynamic panel bias if the model is estimated using methods like Ordinary Least Squares (Nickell, 1981). One advantage of the GMM technique is its ability to resolve this bias while also controlling for cross-country dependence across panels (Nchofoung et al., 2021). Thus, we begin with the following regression:

$$ENV\ SUST_{it} - ENV\ SUST_{it-1} = n + \tau + (\alpha - 1)ENV\ SUST_{it-1} + \beta ECI_{ti} + \varphi REGI_{ti} + \gamma X_{ti} + \xi_{it} \dots \dots (10)$$

Where n is a time invariant country specific effect, and τ is a deterministic time trend which is used to account for period specific effects. We can simplify equation (10) in terms of the $ENV\ SUST_{it}$ variable, so that:

$$ENV\ SUST_{it} = n_i + \tau + \alpha ENV\ SUST_{it-1} + \beta ECI_{ti} + \varphi REGI_{ti} + \gamma X_{ti} + \xi_{it} \dots \dots (11)$$

We use a first difference transformation of equation (11) and exclude the temporal trend for notational simplicity in order to remove the country-specific effect n as follows:

$$(ENV\ SUST_{it} - ENV\ SUST_{it-1}) = \alpha(ENV\ SUST_{it-1} - ENV\ SUST_{it-2}) + \beta(ECI_{it} - ECI_{it-1}) + \varphi(REGI_{it} - REGI_{it-1}) + \gamma(\chi_{it} - \chi_{it-1}) + (\xi_{it} - \xi_{it-1}) \dots \dots (12)$$

We therefore apply the difference operator (△), to obtain equation 13 as follows:

$$\triangle ENV\ SUST_{it} = \alpha \triangle ENV\ SUST_{it-1} + \beta \triangle ECI_{it} + \varphi \triangle REGI_{it} + \gamma \triangle \chi_{it} + \triangle \xi_{it} \dots \dots (13)$$

One significant limitation of using GMM is the potential for an excessive number of instruments. While there is no universally accepted threshold for what constitutes "too many," Roodman (2009) extended the Arellano and Bover (1995) procedure to manage instrument proliferation while maximizing the sample size. Therefore, this study adopts Roodman's (2009) approach to limit the increase in instruments. Recognizing that the one-step procedure is consistent under homoscedasticity, we implement the two-step procedure to account for heteroscedasticity. Additionally, GMM estimation may encounter issues related to identification, simultaneity, and restrictions. Thus, all our explanatory variables are considered sources of endogeneity and are treated as

endogenous (Asongu and Nwachukwu, 2016; Asongu and Leke, 2019; Nchofoung et al., 2021).

5. Econometric Results

Direct Effects of Economic Institutions on Environmental Sustainability in Africa

The results from Table 2 reveal several diagnostic tests that assess the model's validity and robustness. The Hansen test indicates the validity of the over-identifying restrictions, with p-values ranging from 0.235 to 0.473 across the models, suggesting that the instruments used are appropriate and the model is correctly specified. Second-order autocorrelation test (AR2) shows p-values between 0.234 and 0.413, which suggests that the null hypothesis of no second-order autocorrelation cannot be rejected. The first-order autocorrelation test (AR1) yields low p-values (around 0.000), indicating the presence of first-order autocorrelation as expected in dynamic panel data models.

Table 2: Direct Effects of Economic Institutions on Environmental Sustainability in Africa

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Global Ecological Footprint (ENV SUST)				
L.ENV SUST	0.900***	1.068***	0.945***	0.953***	1.125***
	(0.108)	(0.221)	(0.114)	(0.0451)	(0.288)
INFLA	0.00888***	0.0186**	0.0133**	0.0106***	0.0150**
	(0.00286)	(0.00683)	(0.00510)	(0.00231)	(0.00561)
TOPEN	0.647***	1.720***	1.718***	0.330***	2.018***
	(0.131)	(0.309)	(0.134)	(0.0574)	(0.0808)
LOGFDI	-0.0336***	-0.0449**	0.0164	0.0539***	0.0617***
	(0.0114)	(0.0209)	(0.0123)	(0.00764)	(0.0214)
POP GROWTH	0.0846	0.383***	0.427***	0.0684*	0.720***
	(0.102)	(0.0746)	(0.0623)	(0.0363)	(0.0673)
GOVSIZE	0.152***				
	(0.0283)				
LSPR		0.566***			
		(0.0856)			
SM			0.341***		
			(0.0550)		
FT				0.0403***	
				(0.0135)	
INTERR					0.593***
					(0.0195)
Constant	-0.934**	-3.709***	-5.102***	-1.717***	-8.145***
	(0.416)	(0.956)	(0.251)	(0.253)	(0.868)
Observations	403	403	403	398	403
Number of id	33	33	33	33	33
F	1843***	7866***	26467***	31054***	51788***
hansenp	0.473	0.364	0.370	0.235	0.401
sarganp	0	0	0	0	1.38e-10

ar2p	0.328	0.358	0.413	0.234	0.391
ar1p	0.000323	0.000209	0.000356	0.000539	0.000254

Standard errors in parentheses. *** = p<0.01, ** = p<0.05, * = p<0.1.
Source: Author's Own Creation

The lagged dependent variable shows strong positive coefficients across all models, ranging from 0.900 to 1.125, indicating a high degree of persistence in environmental sustainability measures. This suggests that past levels of sustainability significantly influence current levels, aligning with findings from recent studies that emphasize the importance of historical context in environmental outcomes (Galeotti et al., 2021). The economic institutional variables exhibit significant impacts on environmental sustainability, measured by the Global Ecological Footprint. The coefficient for government size is positive and significant at 0.152, suggesting that larger government involvement may contribute positively to sustainability efforts, reinforcing the argument that government interventions can play a crucial role in environmental management (Rosen & Gayer, 2019). Legal systems and property rights and sound money also show significant positive effects, with coefficients of 0.566 and 0.341, respectively, underscoring the crucial role of effective legal frameworks and economic stability in promoting sustainability (Asongu & Nwachukwu, 2016).

Among the control variables, inflation has a positive and significant effect on environmental sustainability, with coefficients ranging from 0.00888 to 0.0186, suggesting that moderate inflation may be associated with a more proactive approach to sustainability. This finding aligns with recent literature indicating that inflation can incentivize investment in sustainable practices (Khan et al., 2022). Population growth displays mixed results, being significant in some models but not in others, indicating its complex relationship with environmental sustainability. The variable representing trade openness consistently shows positive and statistically significant effects, with coefficients ranging from 0.330 to 2.018, indicating that greater trade openness is associated with improved environmental sustainability. This result is consistent with empirical evidence suggesting that trade can facilitate the transfer of environmentally friendly technologies (Zhang & Baranzini, 2021).

Direct Effects of Regulatory Institutions on Environmental Sustainability in Africa

The results presented in Table 3 include several diagnostic tests that evaluate the reliability and robustness of the model. The Hansen test indicates the validity of the over-identifying restrictions, with p-values ranging from 0.243 to 0.550 across different models, suggesting that the instruments employed are appropriate and the model is well-specified. In contrast, the Sargan test displays p-values ranging from 0.0419 to 0.0755, indicating some potential issues with instrument validity, although none of the values are alarming. The second-order autocorrelation test (AR2) shows p-values between 0.639 and 0.860, implying that the null hypothesis of no second-order autocorrelation cannot be rejected, which aligns with expectations in dynamic panel data models. The first-order autocorrelation test (AR1) yields extremely low p-values (around 4.85e-05), confirming the presence of first-order autocorrelation, which is typical in such models.

Table 3: Direct Effects of Regulatory Institutions on Environmental Sustainability in Africa

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Global Ecological Footprint (ENV SUST)					
L.ENV SUST	0.741***	0.688***	0.739***	0.729***	0.706***	0.736***
	(0.0290)	(0.0351)	(0.0169)	(0.0249)	(0.0272)	(0.0190)
INFLA	0.0114***	0.0119***	0.00771***	0.0134***	0.0130***	0.00986***
	(0.00243)	(0.00174)	(0.00232)	(0.00193)	(0.00241)	(0.00329)
TOPEN	0.123***	0.371***	-0.0778	0.0709*	0.334***	0.0408
	(0.0352)	(0.0857)	(0.0550)	(0.0383)	(0.0294)	(0.0318)
LOGFDI	-0.0492***	-0.0478***	-0.0344***	-0.0479***	-0.0443***	-0.0607***
	(0.0118)	(0.01000)	(0.00721)	(0.00554)	(0.00525)	(0.00933)
POP GROWTH	0.109***	0.0669***	-0.0724**	-0.0663**	0.0906***	0.0410
	(0.0169)	(0.00941)	(0.0338)	(0.0299)	(0.0179)	(0.0449)
CC	0.223**					
	(0.0892)					
GE		0.413***				
		(0.0830)				
PV			0.172***			
			(0.0307)			
RQ				0.301***		
				(0.0688)		
RL					0.300***	
					(0.0488)	
VA						0.0197
						(0.0366)
Constant	1.074***	1.190***	1.357***	1.548***	0.966***	1.431***
	(0.163)	(0.186)	(0.136)	(0.0722)	(0.107)	(0.112)
Observations	400	400	400	400	400	400
Number of id	33	33	33	33	33	33
F	2.450e+07	239609	239305	1.030e+07	148929	1.483e+06
hansenp	0.394	0.550	0.441	0.243	0.325	0.308
sarganp	0.0755	0.0419	0.0988	0.101	0.0426	0.0618
ar2p	0.726	0.639	0.692	0.842	0.860	0.652
ar1p	4.85e-05	4.82e-05	4.67e-05	4.30e-05	4.77e-05	5.26e-05

Standard errors in parentheses. *** = p<0.01, ** = p<0.05, * = p<0.1.
Source: Author's Own Creation

The regulatory institutional variables demonstrate significant effects on environmental sustainability, as measured by the Global Ecological Footprint. The lagged dependent variable shows strong positive coefficients across all models, ranging from 0.688 to 0.741, indicating a high level of persistence in environmental sustainability measures. This finding aligns with recent studies that highlight how past sustainability performance heavily influences current outcomes (Pérez-López et al., 2021). The variables representing control of corruption, government effectiveness, political instability and absence of violence, regulatory quality, and rule of law all show positive and statistically significant effects, with coefficients of 0.223, 0.413, 0.172, 0.301, and

0.300, respectively. These results indicate the importance of effective regulatory frameworks in enhancing environmental sustainability, consistent with findings that robust governance structures lead to better environmental outcomes (Asongu & Leke, 2019). However, the variable for voice and accountability does not show a significant effect, indicating that citizen participation alone may not be sufficient to drive improvements in environmental sustainability without the backing of other strong regulatory institutions.

Among the control variables, inflation has a positive and statistically significant effect on environmental sustainability, with coefficients ranging from 0.00771 to 0.0134, suggesting that moderate inflation may correlate with more proactive sustainability measures. This finding is consistent with literature indicating that inflation can incentivize sustainable investments (Khan et al., 2022). Population growth yields mixed results, being significant in some models but not in others, which reflects the complex relationship between population dynamics and environmental sustainability. The negative coefficient for foreign direct investment across all models, ranging from -0.0344 to -0.0607, suggests that greater inflows of foreign investment may be associated with detrimental environmental impacts, a finding supported by studies indicating that FDI can sometimes lead to environmental degradation (Basu & Das, 2021).

Indirect Effects of the Transmission Effects of Economic Institutions Through Regulatory Institutions on Environmental Sustainability in Africa

Table 4 presents several diagnostic tests that assess the validity and robustness of the model examining the transmission effects of economic institutions through regulatory institutions on environmental sustainability. The Hansen test results show p-values ranging from 0.189 to 0.805, indicating that the over-identifying restrictions are valid and that the instruments used are appropriate for the model. The Sargan test yields p-values from 0.0494 to 0.980, suggesting that there may be some concerns about instrument validity, particularly in Model 2, where the p-value is close to the conventional threshold of 0.05. The second-order autocorrelation test (AR2) shows p-values between 0.151 and 0.816, suggesting that the null hypothesis of no second-order autocorrelation cannot be rejected, which is expected in dynamic panel data models. The first-order autocorrelation test (AR1) consistently indicates low p-values (around 3.71e-05), confirming the presence of first-order autocorrelation.

Table 4: The Transmission Effects of Economic Institutions Through Regulatory Institutions on Environmental Sustainability in Africa

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Global Ecological Footprint (ENV SUST)				
L.ENV SUST	0.761***	0.728***	0.775***	0.594***	0.622***
	(0.0488)	(0.0347)	(0.0190)	(0.0567)	(0.0488)
INFLA	0.0244***	0.0127***	-6.35e-05	0.00346	0.00971**
	(0.00445)	(0.00356)	(0.00733)	(0.00646)	(0.00459)
TOPEN	0.394**	0.161	0.115	0.755***	0.309***
	(0.151)	(0.107)	(0.107)	(0.138)	(0.0899)
LOGFDI	-0.0312	-0.0819***	-0.0899***	-0.0815***	-0.0885***
	(0.0194)	(0.0116)	(0.0167)	(0.0135)	(0.0179)
POP GROWTH	-0.318***	-0.163**	-0.0755	-0.494***	-0.290***
	(0.0639)	(0.0682)	(0.0467)	(0.111)	(0.104)

GOVSIZE	0.175***				
	(0.0350)				
IQ INDEX	0.418***	-0.212***	-0.731**	-1.121***	-1.184***
	(0.117)	(0.0691)	(0.324)	(0.236)	(0.154)
GOVSIZE*IQ INDEX	-0.0469***				
	(0.0124)				
LSPR		0.110***			
		(0.0255)			
LSPR*IQ INDEX		0.0554***			
		(0.0138)			
SM			0.0899		
			(0.0752)		
SM*IQ INDEX			0.100**		
			(0.0444)		
FT				0.283***	
				(0.0547)	
FT*IQ INDEX				0.180***	
				(0.0415)	
INTERR					0.299***
					(0.0509)
INTERR*IQ INDEX					0.207***
					(0.0296)
Constant	0.172	1.725***	1.513***	1.021*	0.875
	(0.380)	(0.346)	(0.497)	(0.572)	(0.534)
Observations	400	400	400	397	400
Number of id	33	33	33	33	33
F	3761***	4162***	468009***	314255***	64563***
hansenp	0.438	0.213	0.450	0.805	0.189
sarganp	0.153	0.0494	0.243	0.980	0.517
ar2p	0.165	0.816	0.435	0.364	0.151
ar1p	3.87e-05	3.71e-05	2.72e-05	5.10e-05	3.86e-05

Standard errors in parentheses. *** = p<0.01, ** = p<0.05, * = p<0.1.
Source: Author's Own Creation

Economic institutional variables such as government size and the regulatory institutional quality index demonstrate significant effects on environmental sustainability. Government size has a positive coefficient of 0.175, suggesting that increased government involvement can positively influence sustainability efforts. This finding supports the argument that government interventions are crucial in promoting environmental policies (Rosen & Gayer, 2019). The institutional quality index, however, exhibits a more complex relationship: it shows positive effects in certain models and negative interactions when multiplied with government size, Legal Systems and Property Rights, and other economic measures. For instance, the interaction term between government size and the institutional quality index has a negative coefficient of -0.0469, suggesting that the effectiveness of government size may diminish in contexts where the quality of governance is low. This is consistent with findings that emphasize the importance of effective governance in achieving environmental sustainability (Asongu & Leke, 2019).

Furthermore, legal systems and property rights and freedom to trade, also have significant positive effects on sustainability. Legal systems and property rights show a coefficient of 0.110, while freedom to trade has a coefficient of 0.283, indicating that

robust legal frameworks and free trade policies can enhance environmental outcomes. The interaction effects between legal systems and property rights with institutional quality index and free trade policies multiplied by the institutional quality index, are both positive and significant, further supporting the idea that effective regulatory institutions can amplify the positive impacts of economic institutions on environmental sustainability in Africa (Zhang & Baranzini, 2021).

6. Conclusion and Policy Implications

The analysis reveals that economic institutions significantly influence environmental sustainability in Africa, with a high persistence of past sustainability levels indicated by strong coefficients for the lagged dependent variable. Government size and robust legal systems positively affect sustainability, while the presence of foreign direct investment tends to have negative environmental impacts. Regulatory institutions, including control of corruption and government effectiveness, also demonstrate significant positive effects. Lastly, the interaction between economic and regulatory institutions suggests that the effectiveness of government interventions is contingent upon the quality of governance.
This study highlights the significant role of both economic and regulatory institutions in influencing environmental sustainability in Africa, as evidenced by the robust results from the dynamic panel data analysis. The findings indicate that government size, legal systems and property rights, and free trade policies all have positive effects on environmental outcomes, reinforcing the need for effective governance and regulatory frameworks. The persistence of past sustainability measures emphasizes the importance of historical level of environmental sustainability on current level of environmental sustainability.

To enhance environmental sustainability in Africa, policymakers should prioritize strengthening regulatory institutions and frameworks. This includes increasing government involvement in environmental management, ensuring that policies are effectively implemented and enforced. Investments in legal systems and property rights are critical to creating a stable environment that promotes sustainable practices. Moreover, fostering free trade policies can facilitate the transfer of environmentally friendly technologies, promoting innovation and sustainability. Policymakers should also focus on enhancing the quality of governance through initiatives aimed at reducing corruption and improving government effectiveness. Strategies should be developed to mitigate the potential negative impacts of foreign direct investment on the environment, ensuring that such investments align with sustainable development goals. Also, enhancing public awareness and community engagement in sustainable practices can drive local initiatives that address environmental challenges, ensuring more resilient ecosystems and livelihoods.

Conflict of Interest

The authors declare that there are no conflicts of interest. We confirm that the submitted manuscript is an original work and is not under consideration or review by any other publication.

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