Urbanisation, Rule of Law, and Environmental Quality in Sub-Saharan Africa

Sunday M.A. Posu[1], Matthew A. Dada[1], Ebenezer A. Olubiyi[1], Adedayo O. Adedeji[1], Ademola I. Adeniyi[2] and Bamidele P. Abalaba[3]

[1]*Department of Economics, Federal University of Agriculture, Abeokuta, Ogun, Nigeria.*

[2] *Department of Global Affairs & Sustainable Development, Osun State University, Osogbo, Osun, Nigeria.*

[3] *Department of Economics, Osun State University, Osogbo, Osun, Nigeria.*

Abstract

This study investigates the empirical relationship among urbanisation, rule of law, and environmental quality in 40 Sub-Saharan Africa countries based on a balanced panel data during 2000-2022. The study employs panel system of generalised method of moments (S-GMM) to examine the effects of urbanisation, rule of law, and its mediating role on environmental quality in the linkage between urbanisation and environmental quality in SSA. The study reveals rule of law and trade openness exerting negative pressures on ecological footprint, separately, to bring about improvement in environmental quality in the SSA region. However, urbanisation, industrialisation, and regulatory quality have positive effects on ecological footprint individually. The increase in ecological footprint due to these variables implies increasing pollution or reduction in environmental quality. Rule of law improves environmental quality but regulatory quality deteriorates it in the 40 SSA countries. The findings suggest the need for sustainable urban design, environmentally best practices in industrialisation, environmental management, strengthening legal institutions, enforcing environmental legislation, and promoting transparency and accountability in environmental governance through investment in judicial systems, and fostering partnerships among governments, civil society and the private sector.

Keywords: Environmental institution, Sustainable Development Goal, Economic activities, Regulatory enforcement, Energy consumption, Trade openness

JEL Classifications: K32, O13, P28, Q57, R11

Introduction

The urgency to prioritise (Gholamian *et al.,* 2019; Jay *et al.*, 2024) and enforce (Oruonye & Ahmed, 2020; Ogunkan, 2022) environmental sustainability globally, regionally, nationally, and locally has heightened in response to the escalating challenges posed by global warming and climate change. The emission level of carbon dioxide (CO_2) emissions surged up to 36.3 billion tons in 2021 (Duodu & Mpuure, 2023). These emerging natural phenomena are reshaping weather patterns, amplifying the frequency and severity of extreme weather events, and posing significant threats to both food security and human existence (IPCC, 2022; IOM, 2022), infrastructure, and socio-economic stability (Clement *et al.* 2021). Projections indicate that by 2050, over a billion individuals could encounter climate hazards and extreme weather events like sea-level rise, flood, storms, sand dunes, and droughts. Regulation enforcement has become a necessity to put economic agents under check against unsustainable environmental practices (Ogunkan, 2022), and to facilitate achievement of the Sustainable Development Goals on climate and environment.

The surge in CO_2 emissions is closely linked to urbanisation, featuring rapid urban expansion, intensive energy consumption arising from transportation, industrial activities, household demand, and other economic activities, most of which require burning of fossil fuels (Petkova *et al*., 2013; Boadu, 2016; Akorede & Afroz, 2020; Michael, 2024). Urban cities generate about 80% of global GDP and, accordingly, have high prospects to foster sustainable growth and cleaner environment (World Bank, 2024). In Sub-Saharan Africa (SSA), urbanisation and economic activities requiring burning of fossil fuels are on the increase (Petkova et al., 2013; Kamah et al., 2021; Duodu & Mpuure, 2023). Urbanisation contributes to higher emissions of pollutants such as particulate matter, nitrogen oxides, and CO_2 in SSA countries. Data on 46 SSA countries in Appendix 1 indicates disparities in air quality with some countries performing relatively well (Seychelles, Mauritius, Comoros, & Mozambique), but others poorly (Angola, Benin, Ghana, Nigeria, Cameroon, & Lesotho). It depicts high exposure ranking to PM2.5 in Mozambique, Malawi, and Ethiopia, but lowest in Gabon, Cameroon, and Djibouti. Also, per capita GHG emissions vary in the SSA countries, with Burundi, DR Congo, Liberia, Malawi, Rwanda, Sao Tome & Principe, and Sierra Leone ranking relatively low while South Africa ranked highest with Equatorial Guinea next to it. Similar rankings exist on the growth rates of CO_2 and methane (CH_4) emissions during 2010-2019. Uban expansion leads to output growth, overcrowding, poor solid waste management, and indiscriminate industrial wastes discharge, exacerbating air pollution and posing health risks to all (Wolf *et al.*, 2022).

It is observed that all SSA countries show concern on environmental protection and formulate laws and policies accordingly, but implementation and enforcement have been weak and partial (The Access Initiative 2023; Muigua, 2024). Bekhechi and Merder (2021), and The Access Initiative (2023) found plurality of environmental regulations in 25 SSA countries, and Muigua (2024) concluded as existing "mostly on paper due to irregular, incomplete, and ineffective implementation and enforcement". The conflicts in implementation of the repetitive environmental formed endogenous impediments to achieving realistic environmental goals. World Justice Project (2024) rankings, in Appendix 2, show significantly weak rule of law and regulatory enforcement in 33 SSA countries. The scores are generally low on the two measures. Only 9 countries managed to have a score of 0.50 and above, the highest being 0.62 for Mauritius. None scored up to 70%.

The scores on the two measures for each country are the same, except for marginal difference in five countries, although the rankings differ. Mauritius ranked highest (45 & 36) while Mauritania ranked lowest (131 & 135), respectively, on rule of law and regulatory enforcement conducted by World Justice Project (2024) in 140 countries. Countries with high scores indicate relatively stronger adherence to legal frameworks and institutional structures conducive to environmental governance, and vice-versa. The report revealed, however, that weakness in implementation and enforcement was not peculiar to SSA as rule of law declined in 82 countries but improved in 58 countries.

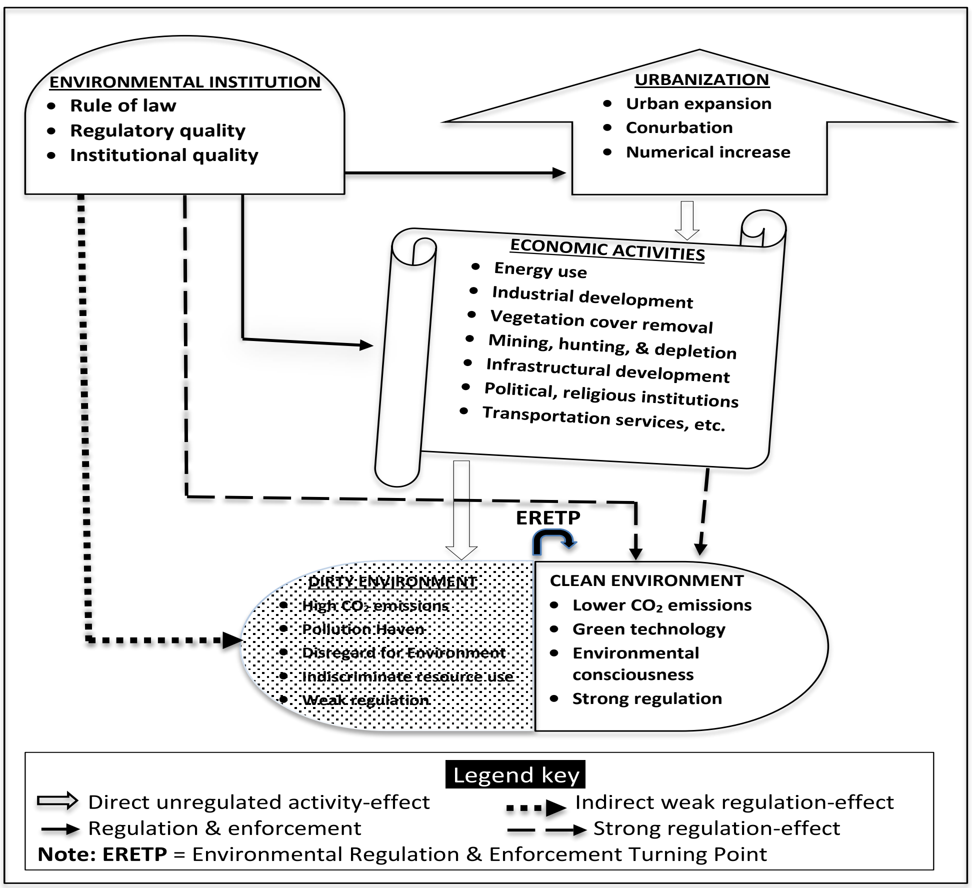
Economic agents have selfish tendencies to avoid cost, exploit natural resources without full compensation, cut corners, and beat the law where possible (Crocker et al., 2017; Oyebode, 2018; Oruonye & Ahmed, 2020; Jay *et al.*, 2024). Indiscriminate disposal of solid wastes and hunting of animals, deforestation, illegal mining, discharge of industrial wastes into the air, water, and on land, burning of bushes, excessive noise, smoking of fishes with firewood in riverine and coastal areas, and all forms of burning of fossil fuels take place in SSA. To achieve a healthy and sustainable environment, appropriate taxes and subsidies that suit and align with the complexity of each country (Boadu, 2016) and each community must be formulated and enforced. Enforcement of environmental laws, like other laws, require deliberate policy actions and monitoring by the regulatory authorities. When sustainable corrective taxes, user-charges, and fines are applied on all economic agents without fear or favour, and when the level of compliance is high, rule of law index will tend to rise, leading to improvement in environmental quality. Exploring and applying best practices to strengthen rule of law and enforce regulations are essential for improving environmental governance and addressing environmental challenges in SSA.

A vast number of studies on general environmental issues in Africa exists. The focus of the literature is in various segments such as economic, health, poverty, social, spatial, scientific, biological, and chemical among others. Environmental issues have also taken institutional dimensions including studies on institutional quality, corruption, governance, quality of bureaucracy, and rule of law on country-specific and cross-sectional bases. The latter categories of studies include Mavragani *et al.* (2016), Adams & Klobodu (2017), Alimi & Ajide (2020), Hassan *et al.* (2020), Kamah *et al.* (2021), Azam *et al.* (2021), Haldar & Sethi (2021), Yasin *et al.* (2021), and Abaidoo & Agyapong (2022). The number of studies on rule law cum environmental protection is scanty, whether country specific or cross-sectional, particularly in SSA. While a few of the available studies adopted quantitative methodology, the larger proportion written by legal practitioners used qualitative analysis.

This study adopts a quantitative approach and attempts to provide answer to certain questions on rule of law-environment nexus. Do SSA countries have environmental laws? To what extent are the laws enforced? Are the environmental regulatory quality and enforcement effective and improve the environment or otherwise? Is urbanisation directly responsible for environmental outcomes? Could the role of institutional quality create a turning point in environmental outcomes from dirty environment to clean environment? This study provides answers to these questions as it investigates how urbanisation and rule of law relate to environmental quality in 40 SSA countries during 2000-2022. The study employs the generalised method of moments (GMM) on most recent available data to achieve the set objective and expand the literature on rule of law and environment. The findings of this study would dictate policy guidelines on enforcement of environmental law in SSA.

Literature Review

The complex roles of urbanisation on environmental quality might not be captured in a single geometrical or algebraical model. The analytical construct in Figure 1 is premised on the understanding that economic activity is central to urbanisation and that volume or value of economic activity rather than urban population define an urban territory. Some economic activities could take place in non-urban areas but a geographical location is not considered urban without great volume of economic activities. Thus, Urbanisation 'houses' great volumes of all Economic Activities in varying proportions. Urbanisation produces indirect effects on the environment through Economic Activities. The 'white' arrow in Figure 1 indicates the direction of unregulated effects of Urbanisation on all activities relating to production, consumption, and distribution of goods and services. These activities in their great volumes constitute a rise in ecological footprint and create direct spillover effect on the environment and pollute it (Dirty Environment), reducing environmental quality and harming the general ecosystem.



Source: Authors' Formulation (2024)
Fig. 1: Analytical flow chart of urbanisation-rule of law-environment effect

Environmental Institution, a form of economic activity connected to rule of law and regulatory enforcement, is singled out and institutionally empowered to monitor, regulate, and tax or subsidise economic activities to achieve sustainable environment. The normal black arrow describes the direction of regulation and enforcement on Urbanisation and Economic Activities, producing direct effects on Urbanisation and Economic Activities but indirect effects on Dirty Environment and / or Clean Environment. If the effects are corrective and lead to achievement of Sustainable Development Goals on the environment, regulation and enforcement is considered strong. Otherwise, it is weak. For political reasons among others, the degree of regulation could be weak or strong. The dotted dash-arrow shows the indirect effect of weak regulation and enforcement on the environment, Dirty Environment. On the other hand, the hyphenated dash-arrow captures the effects of strong regulation and enforcement indirectly from Environmental Institution and directly from Economic Activities to Clean Environment.

Unregulated Economic Activities result in Dirty Environment. With strong regulation and enforcement put in place, polluting economic activities reduce to the barest minimum, and Clean Environment is achieved. A mixture of polluting and green economic activities exists in a situation characterised by weak regulation and enforcement, but the proportion of polluting economic activities is excessively higher. The Environmental Regulation and Enforcement Turning Point (ERETP) occurs between the stages of Dirty Environment and Clean Environment. It describes the situation where regulation and enforcement of environmental rule of law is strong enough to translate the environment from Dirty to Clean. ERETP in this model is equivalent to the hypothesised Environmental Kuznets Curve (EKC). This model identifies, among others, the key variables affecting environmental quality globally, and particularly in SSA, with a cursory focus on rule of law.

This study reviews a few of the available studies, on SSA and beyond, which are empirically analysed with quantitative technique including any or all of urbanisation, rule of law, environmental quality, and related variables. Castiglione *et al*. (2015) explored the interplay among pollution, institutional quality, and economic growth by examining CO_2 emissions, rule of law, and income for 33 high-income countries during 1996-2010, using a panel-VAR technique. The study found a mutually reinforcing link between rule of law and income, suggesting that higher income levels correspond to stronger rule of law, and vice versa; and a negative association between rule of law and pollution. The latter finding emphasised the effectiveness of rule enforcement in emission control. The study found no causal relationship between pollution and income. Adams and Klobodu (2017) analysed the relationship between urbanisation and environmental degradation with a focus on the political structure for 38 African countries during 1970-2011. With panel cointegration and causality tests, the study established significant cointegration among urbanisation, CO_2 emissions, democracy, and bureaucratic quality. Democracy and bureaucratic quality improved the environment in the long-run. The panel VAR and IRF indicated positive bidirectional connection between CO_2 emissions and affluence as well as population, but a negative unidirectional relationship from CO_2 emissions to bureaucratic quality.

Hassan *et al.* (2020) examined the influence of institutional quality on CO_2 emissions in Pakistan using an autoregressive distributed lag model (ARDL) with data spanning 1984-2016. The study found institutions contributing to increase in CO_2 emissions, and a bidirectional causality between institutional quality and CO_2 emissions. Also, CO_2 emissions reduced at higher income level, confirming the EKC, and underscoring the importance of strengthening institutions to improve the environment. Feng *et al.* (2020) investigated the spatial spillover effects of environmental regulations on air pollution in urban agglomerations in China using the STIRPAT framework. The study found varying spatial correlations in PM2.5 concentrations among different urban centres. The study revealed that air pollution was influenced by environmental laws of each city and the neighbouring settings. The study concluded that PM2.5 concentration increased in urban agglomerations with each unit increase in environmental regulation of neighbouring cities, turning cities with weak regulations into pollution haven.

On the role of financial development, political institutions, urbanisation, and trade openness on CO_2 emissions in 59 less-developed countries during 1996-2016, Yasin *et al.* (2021) employed weighted estimated generalised least square, Arellano-Bond GMM, and Orthogonal-Deviation GMM and found that financial development, urbanisation, capital/labor ratio, and energy consumption degrade the environment. The results confirmed the EKC at higher income level just as institutions and foreign trade improved the environment. Muhammad and Long (2021) explored the impact of political stability, corruption control, and rule of law on CO_2 emissions during 2000-2016 for 65 countries of different income groups in the Belt and Road Initiative. The findings underscored the significance of institutional factors in reducing CO_2 emissions. Political stability and rule of law led to a decrease in CO_2 emissions, but foreign direct investment had varying effects on carbon emissions across income groups, supporting both the pollution haven and pollution halo hypotheses. Trade openness improved the environment in low-income and high-income countries but polluted it in lower-middle-income countries. The study also emphasised the role of regulation enforcement in achieving environmental targets.

Alola *et al.* (2022) investigated the environmental implications of law and order in comparison to legal systems and socio-economic indices, controlling for economic growth, in 80 Global South countries during 1984-2014. Employing different mean group estimators, legal system was not significant but improvement in socio-economic conditions and economic growth pollute the environment. However, CO_2 emissions exhibited bidirectional relationship with each of law and order, socio-economic factors, and economic growth. Tang *et al.* (2023) investigated how environmental governance (or institution) enhanced urbanisation quality using the entropy value method on panel data spanning 2000-2017 for 30 provinces and cities. The study found overall significant effect of environmental governance on improving urbanisation quality. Market governance made greater significant contribution to urbanisation quality than did government governance and public governance while government governance facilitated innovative development but hindered open development and shared development. The study found government governance within environmental governance significantly promoting urbanisation quality in all regions unlike other forms of governances promoting or inhibiting urbanisation quality in some regions.

The foregoing shows that environmental institution is crucial in the discourse on the relationship between urbanisation and environmental quality. The empirical evidence attested to this. However, the existence of environmental institution is a mere first conditionality. Environmental institutions must be strong enough to bring about the theoretical expectation of improving environmental quality. On the spatial impacts of environmental outcomes, adjoining territories, cities, countries, and regions, too, have significant roles to play in the pursuit of achieving Sustainable Development Goal on the environment. Available studies have stressed the significance of how institutional indices promote environmental quality. Accordingly, it is imperative to analyse the role of rule of law in the relationship between urbanisation and environmental quality in SSA countries.

Research Methodology

This study employs a balanced panel data on 40 SSA countries from 2000 to 2022, based on availability of data on some key variables, sourced from Global

Footprint Network (2022), World Development Indicators (2022), World Justice Project (2024), and Global Indicator Framework (2022). Nathaniel *et al.* (2021), and Oteng-Abayie *et al.* (2022) specify environmental quality as a function of natural resources, urbanisation, and some control variables. This study adapts the model and introduces rule of law as a modification to explain the urbanisation-environmental quality nexus, specified as:

$$EFP_{it} = \alpha_0 + \pi_1 UP_{it} + \pi_2 RL_{it} + \pi_3 AP_{it} + \pi_4 UP{*}RL_{it} + \pi_5 PCY_{it} + \pi_6 NV_{it} + \pi_7 EN_{it} + \pi_8 TO_{it} + \pi_9 RQ_{it} + \varepsilon_{it} \quad (1)$$

Ecological footprint, which is the proxy for environmental quality, denoted by EFP, is a more comprehensive measure of human ecological demand on earth. Increase in EFP implies more pollution and, thus, lower environmental quality, and vice versa. UP is urbanisation with urban population as proxy. RL is rule of law and AP stands for air pollution, adequately captured by CO_2 emissions. PCY is per capita GDP growth rate as a measure of the level of affluence. Industrial value-added is denoted by NV just as EN stands for energy consumption, TO for trade openness, and RQ for environmental regulatory quality. UP*RL captures the interaction between urbanisation and rule of law. α_0 is the intercept while π_i represents parameter estimates, and ε_{it} is stochastic error term. Theoretically, $\alpha_0<0$, $\pi_1>0$, $\pi_2<0$, $\pi_3>0$, $\pi_4<0$, $\pi_5>0$, $\pi_6>0$, $\pi_7>0$, $\pi_8>$ or <0, and $\pi_9<0$.

Ecological footprint is captured by biocapacity in terms of the productivity of global hectares while urban population is the percentage of urban population to total population of each country. Percentile rank of each variable is used as a measure for rule of law and regulatory quality. Air pollution is measured by CO_2 emission in kilotons just as PCY is the ratio of real GDP to total population. Industrial value-added is measured by the value addition of the sector as percentage of real GDP. Energy consumption is measured in kilogram of oil equivalent per person, and trade openness is measured by the value of trade as percentage of GDP.

The study employed the panel system of generalised method of moments (S-GMM) by Arellano and Bond (1991) and Blundell and Bond (1998) to examine the effects of urbanisation, rule of law, and its mediating role on environmental quality in the relationship between urbanisation and environmental quality in SSA. The technique is superior to other conventional panel estimators. It is capable of handling panel data from a large number of cross-sectional series over a shorter period. In this study, T=23 and N=40. Non-stationarity of any variable has no effect on the validity of the estimates (Alimi & Ajide, 2020). S-GMM employs the lags of the endogenous regressor as internal instruments as a check against any endogeneity issues that might arise due to the inclusion of the lagged dependent variable in the regressors. In accordance with the baseline model, the S-GMM of Equation (1) is re-specified as Equation (2) in levels and Equation (3) in first difference.

$$EFP_{i,t} = \alpha_0 + \phi_1 EFP_{i,t} - \text{r} + \phi_2 UP_{i,t} + \phi_3 RL_{i,t} + \phi_4 AP_{i,t} + \phi_5 (UP^* RL)_{i,t} + \phi_6 PCY_{i,t} + \pi_7 NV_{i,t} + \pi_8 EN_{i,t} + \pi_9 TO_{i,t} + \sum_{h=1}^{n} \theta_h RQ_{h,i,t-\tau} + \pi_i + \varpi_t + e_{i,t} \quad (2)$$

$$EFP_{i,t} - EFP_{i,t-\Upsilon} = \alpha_0 + \phi_1 (EFP_{i,t} - EFP_{i,t-2\Upsilon}) + \phi_2 (UP_{i,t} - UP_{i,t-\Upsilon}) + \phi_3 (RL_{i,t} - RL_{i,t} - \Upsilon) + \phi_4 (AP_{i,t} - AP_{i,t} - \Upsilon) + \phi_5 [(UP^*RL)_{i,t} - (UP^*RL)_{i,t} - \Upsilon] + \phi_6 (PCY_{i,t} - PCY_{i,t-\Upsilon}) + \pi_7 (NV_{i,t} - NVD_{i,t} - \Upsilon) + \pi_8 (EN_{i,t} - EN_{i,t} - \Upsilon) + \pi_9 (TO_{i,t} - TO_{i,t-\Upsilon}) + \sum_{h=1}^{n} \theta_h \left(RQ_{h,i,t-\tau} - RQ_{h,i,t-2\tau} \right) + (\varpi_t - \varpi_{t-\tau}) + e_{i,t-\tau} \quad (3)$$

From Equation (3), tau is denoted by τ; the parameters are ϕ_0, ϕ_1 and θ_h; π_i is the country-specific effect; the time specific constant is ϖ_t while the stochastic term is $e_{i,t}$.

Presentation and Analysis of Results

Table 1 shows that the mean and median values of some variables in the panel dataset lie about the midpoint between the maximum and minimum values. The particular variables include UP, RL, and UP*RL. Minimum values of zero on NV, EN, TO, and RQ are due to non-availability of a few of the dataset. All the variables are positively skewed except UP*RL. Specifically, UP, RL, UP*RL, PCY, TO, and RQ have skewness about zero, suggesting high central tendency. However, EFP, AP, UP*EFP, PCY, NV, and EN are leptokurtic with the kurtosis statistic exceeding 3.0 while UP, RL, UP*RL, TO, and RQ are mesokurtic with values about or approximately 3.0. In confirmation on the descriptive distribution of the variables, the Jarque-Bera statistics reveal normal distribution of the series except the two interaction variables. The J-B statistics for all the non-interactive variables have p-values greater than 0.05, in support of the null hypothesis on normality of the residuals.

Table 1: Summary statistics

	EFP	UP	RL	AP	UP*RL	UP*EF	PCY	NV	EN	TO	RQ
Mean	0.825	40.66	-0.642	17949541	-25.417	36.70	1.52	24.67	3516.28	58.513	28.258
Median	0.716	40.28	-0.649	3238976	-20.012	27.5	1.80	22.55	1311.92	55.066	25.728
Maximum	2.338	90.74	1.024	4.95E+08	42.450	147.5	55.5	84.35	38771.4	165.15	86.057
Minimum	0.319	8.246	-1.881	117248.0	-104.08	3.71	-36.7	0.000	0.000	0.000	0.000
Std. Dev.	0.397	16.56	0.619	69738419	29.554	29.46	5.05	13.71	5971.03	33.102	19.332
Skewness	1.663	0.384	0.292	5.665	-0.043	1.76	0.38	1.241	3.034	0.378	0.625
Kurtosis	5.349	2.992	2.603	34.634	2.556	5.91	24.9	5.539	12.425	3.121	2.864
J-B	635.13	22.63	19.124	43233.88	7.799	802.5	18523.	482.8	4811.78	22.47	60.601
Probability	0.670	0.764	0.200	0.170	0.020	0.00	0.83	0.400	0.310	0.780	0.110

*EFP= ecological footprint, UP= urban population, RL= rule of law, AP= air pollution, PCY= per capita GDP growth rate, N= industrial value-added, EN= energy consumption, TO= openness, RQ= regulatory quality, and interaction variables: UP*RL, and UP*EFP.*
Source: Authors' Compilation (2024)

As a standard procedure established by Bond (2001), the choice for employing S-GMM is guided by the coefficient of lagged dependent variable of OLS-Fixed Effect and coefficient of lagged dependent variable of Difference-GMM. If the coefficient of lagged dependent variable of OLS-FE is greater than the coefficient of lagged dependent variable of D-GMM, S-GMM is the appropriate model, and vice versa.

Table 2: Presentation of results

MODEL →	OLS-Fixed Effect		Difference-GMM	
DEP. VAR. →	Ecological Footprint (EFP)	UrbanPop & Ecolog. Footprint (UP*EFP)	Ecological Footprint (EFP)	UrbanPop & Ecolog. Footprint (UP*EFP)
PARAMETER →	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)
C	0.5531*** (0.0000)	4.9754 (0.1440)		
EFP(-1)	0.6173*** (0.0000)		0.3174*** (0.0000)	
UP*EFP(-1)		0.7469*** (0.0000)		0.6840*** (0.0000)
UP	0.0020** (0.0357)		0.0021*** (0.0012)	
RL	0.1311*** (0.0000)	1.6098 (0.4417)	-0.0133 (0.7541)	0.1835 (0.3960)
AP	3.2E-09*** (0.000)	7.7E-08*** (0.0000)	3.1E-09*** (0.0000)	2.0E-07*** (0.0000)
UP*RL	-0.0031*** (0.0000)		0.0005 (0.5922)	
PCY	6.7E-06 (0.9920)	-0.3885*** (0.0014)	0.0007** (0.0355)	0.0591*** (0.0000)
NV	0.0011** (0.0269)	0.4104*** (0.0000)	0.0008*** (0.0000)	0.0356*** (0.0000)
EN	6.4E-06*** (0.000)	0.0023*** (0.0000)	1.9E-06 (0.1239)	-3.7E-05*** (0.0001)
TO	0.0008*** (0.0000)	0.1044*** (0.0000)	0.0012*** (0.0000)	-0.0312*** (0.0000)
RQ	0.0014*** (0.0000)	0.2740*** (0.0001)	0.0004* (0.0507)	0.0459*** (0.0000)
F-Statistic	333.024*** (0.000)	60.607*** (0.000)		
Adj. R-Squared	0.9455	0.6531		
J-Statistic			35.0861 (0.2395)	32.967 (0.4196)

**** => 1%; **=> 5%; * =>10% significance level.*
Source: Authors' Compilation (2024)

The results in Table 2 satisfy the necessary conditions for S-GMM while the D-GMM indicates a downward bias. The lagged coefficients of the two models are significant for OLS-FE and D-GMM with 0.617 > 0.316. Similarly, on the lagged coefficient of the interactive variable of urban population with ecological footprint, the parameters are significant and 0.746 > 0.684. Accordingly, in the OLS-FE, except for PCY, all the variables significantly affect ecological footprint; and the same pattern of results emerge on all the variables, except rule of law, on the interaction of urban population and ecological footprint.

Table 3: System-GMM

VARIABLES	Ecological Footprint (EFP)	UrbanPop & Ecolog. Footprint (UP*EFP)
PARAMETER	**Coefficient (p-value)**	**Coefficient (p-value)**
C	-0.9782 (0.3694)	-33.4290 (0.2568)
EFP(-1)	1.7482*** (0.0022)	
UP*EFP(-1)		1.1005*** (0.0000)
UP	0.0090* (0.0506)	
RL	-0.2324* (0.0829)	-9.8777* (0.0877)
AP	-3.0E-09 (0.4773)	-5.1E-08** (0.0105)
UP*RL	-0.0055 (0.5971)	
PCY	-0.0070 (0.8190)	-0.7779 (0.7400)
NV	0.0090** (0.0207)	0.6450 (0.1124)
EN	-1.5E-05 (0.6501)	-0.0010* (0.0622)
TO	-0.0020* (0.0779)	-0.0734* (0.0703)
RQ	0.0148* (0.0514)	0.6026 (0.2283)
AR(1)	-2.5746 (0.0100)	-2.434 (0.015)
AR(2)	1.3360 (0.1815)	1.363 (0.173)
Hansen J.	35.086 (0.2395)	32.9673 (0.4196)
Obs.	799	799

**** => 1%; **=> 5%; * =>10% significance level*

Source: Authors' Compilation (2024)

Table 3 highlights several important relationships among the environmental variables. The lagged ecological footprint, which is the proxy for environmental quality exhibits a significant positive effect, at 1% significance level, of the past levels on current outcomes. The level of ecological footprint in the previous year positively influences the level of ecological footprint in the current period. A unit increase in a previous level of ecological footprint propelled the variable to rise by 1.7 unit in the current period within the SSA countries. The effect is greater in the current period than the previous. This finding aligns with the theory on path dependence, which suggests that past level of environmental quality can influence future outcomes. The significant positive impact of urban population on ecology footprint, at 10% significance level, suggests that for every 10% increase in the urban population, there is an increase of approximately 0.09 increase in ecological footprint across SSA. The result attests to increase in urban population contributing to environmental degradation in the SSA, in tandem with Adams and Klobodu (2017) for 38 African countries. Theoretically, urban expansion degrades environmental quality due to pollution. As illustrated in Figure 1, the finding confirms the segment of the analytical framework where weak or nil roles of regulatory institution exist. Surge in urban population without effective enforcement of regulation makes economic activities exacerbate pollution.

Rule of law creates significant negative effect on ecological footprint, at 10% significance level, in support of Castiglione *et al*. (2015) for 33 high-income countries. The negative direction of the effect conforms with the a 'priori sign. A 10% increase in rule of law percentile rank decreases ecological footprint in SSA by approximately 2.32 global hectares. This outcome is desirable in the way it improves environmental quality. It underscores effective legal frameworks in the enforcement of environmental legislation. Intensified enforcement of environment legislation could lead to greater achievement of environmental goals and cleaner environment as discussed in the analytical framework presented in Figure 1. Stronger legal institutions are often associated with better environmental protection and management. Industrial value-added and trade openness are significant at 5% and 10% significance level, respectively, but with different signs. Industrial value-added exhibits positive sign implying increasing effect on ecological footprint, but trade openness leads to a reduction in ecological footprint with the endogenous negative sign. Increase in ecological footprint deteriorates environmental quality while a decrease in it leads to improvement in environmental quality. An increase of 100% in value addition by the industrial sector to GDP degrades environmental quality with an increase of 0.9 global hectares in SSA. Conversely, a similar 100% increase in trade openness improves environmental quality due to a reduction in ecological footprint by 0.2 global hectares. The finding aligns with Yasin *et al.* (2021) and Muhammad and Long (2021) for low-income and high-income countries but negates Muhammad and Long (2021) for lower-middle-income countries. The S-GMM shows a positive coefficient (0.0148) on regulatory quality at the 5% level of significance. Regulatory quality increases ecological footprint and thereby degrades the environment in contrast to theoretical expectation. The finding is in tandem with Feng *et al.* (2020) for China and Hassan *et al.* (2020) for Pakistan, but in negation of Muhammad and Long (2021), Yasin *et al.* (2021), and Tang *et al.* (2023). The quality of regulation in SSA is poor or weak to improve environmental quality.

The estimates on the role of rule of law in urbanisation-environmental quality relations (UP*EFP), presented in the right-hand side segment of Table 3, show that the first lag of the interactive variable is significant and positively signed at 1% significance level. This finding is similar to the result on the effect of the first lag on ecological footprint discussed in this section. Rule of law, air pollution, energy consumption, and trade openness are statistically significant and have negative effects on the interactive urban population-ecological footprint variable. RL, EN, and TO are significant at 10% each, leading to decrease in ecological footprint and thereby improving environmental quality by 987.8, 0.1, and 7.5 units of each variable, respectively, given a 100% increase in the interactive variable. Stronger legal institutions are often related with efficient urban processes and better environmental protection and management. The findings are consistent with Chen (2010) and Alola *et al.* (2022). Air pollution exhibits significant negative effect on UP*EFP at 5% significance level. The result implies that as the interaction of urban population and ecological footprint continues to rise, air pollution decreases marginally (the coefficient =0.000000051). This finding depicts the picture of an emerging fresh stage of adoption of production technology that protects the environment because of regulatory enforcement by environmental institution.

The S-GMM is robust without any differencing issues. A unit rise in the previous year's ecological footprint results in a 1.7 unit increase in ecological footprint in the current year. It indicates a strong persistence in the level of ecological footprint over time. The lagged variable captures the important dynamics of the model and it is not under-differenced. Statistically, the significant coefficients attest to the lagged variable is correctly specified within the S-GMM framework, correspond with theoretical assumptions of path dependence, and fall within the predicted range when compared to OLS-FE estimations. The findings confirm the robustness of the model in capturing the underlying dynamics of ecological footprint in SSA, with no evidence of over or under-differencing based on the lagged variable. From the lower segment of Table 3, the p-values of the Hansen J-test under each model are greater than 0.05 and validate the instrumental variables. Similarly, the results of second-order serial correlation in the estimated models (AR2) also support the null hypothesis of no evidence of serial correlation in the models, validating the dynamic panel model specification.

Conclusion and Policy Recommendations

Urban population, air pollution, energy consumption, trade openness, industrialisation, rule of law, and regulatory quality are some of the key variables influencing ecological footprint and, consequently, environmental quality in SSA region. The results of the dataset employed revealed preference for System-GMM estimator due to the lower coefficient of the lagged dependent variable in the first Difference-GMM. Accordingly, the S-GMM revealed the first lag of ecological footprint, urban population, industrialisation, and regulatory quality having significant positive effects on ecological footprint, and consequently degrading environment quality in the region. On the other hand, rule of law and trade openness exerted negative effects on ecological footprint, and thereby improved environmental quality. These findings align with the analytical framework in Figure 1. Rising ecological footprint implies greater pollution, reinforcing an inverse relationship between environmental quality and ecological footprint. Rule of law significantly improves environmental quality while regulatory quality, although significant, is too weak to improve environmental quality, but rather contributes to rising ecological footprint. Policymakers in the SSA region are admonished to place priority on strengthening legal institutions, enforcing environmental regulations, and promoting transparency and accountability in environmental management. Increasing result-oriented expenditure on the judiciary with a view to strengthening legal frameworks across all segments of the society including involvement of the civil society and private sector would increase degree of compliance with environmental law.

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Appendix 1

Table 1: Absolute environmental performance by 46 SSA countries

	Air Quality		**PM2.5 Exposure**		**Adj. CO_2E Growth Rate (2010-2019)**		**Adj. CH_4 Growth Rate (2010-2019)**		**Per capita GHG Emission**	
Country	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**
Angola	141	23.10	115	24.00	87	39.00	65	49.70	62	62.30
Benin	146	22.30	100	29.30	150	8.80	145	23.40	20	87.90
Botswana	164	17.10	158	7.70	146	10.70	1	100.00	94	48.20

Burkina Faso	131	26.10	74	37.20	163	2.20	136	26.30	26	82.80
Burundi	110	30.70	38	51.80	159	4.10	161	15.50	1	100.00
Cameroon	175	13.20	163	6.10	107	29.60	146	23.20	22	86.30
Cape Verde	123	28.00	152	11.70	106	29.70	80	44.90	34	80.10
Central Africa	162	19.00	103	28.50	53	50.40	58	50.30	78	57.00
Chad	137	24.30	82	34.60	131	18.30	176	–	96	47.70
Comoros	79	38.40	43	48.20	149	9.00	151	21.30	10	98.60
Congo, Brazzav.	167	16.70	155	10.10	69	43.80	35	57.60	85	54.20
Congo, DR	135	25.10	70	38.00	66	45.20	169	7.30	1	100.00
Cote d'Ivorie	163	18.20	141	16.60	165	–	129	28.00	14	93.70
Djibouti	158	19.60	161	6.40	7	82.10	119	32.60	33	80.30
Equitorial Guinea	142	22.90	159	7.50	27	58.90	41	55.30	156	19.00
Eriteria	161	19.60	129	21.00	123	23.40	110	36.60	35	77.50
Eswatini	165	16.90	146	14.60	22	62.90	47	53.50	37	77.10
Ethiopia	95	33.70	37	52.20	165	–	134	27.10	23	86.20
Gabon	134	25.70	165	5.80	55	50.30	6	88.00	127	34.80
Gambia	156	20.70	115	24.00	134	17.90	87	42.60	11	96.60
Ghana	171	15.30	160	6.90	145	11.60	174	2.90	17	90.00
Guinea	154	21.00	98	29.60	122	23.50	158	16.30	44	72.60
Guinea Bissau	160	19.40	114	24.20	133	18.10	127	30.50	26	82.80
Kenya	114	30.00	51	42.90	129	18.70	128	29.20	30	81.60
Lesotho	177	11.10	156	8.70	71	43.50	53	51.20	40	73.40
Liberia	121	28.30	77	36.20	158	4.20	159	16.20	1	100.00
Madagascar	96	33.60	42	50.00	165	–	52	52.00	15	91.10
Malawi	89	35.70	33	55.30	117	29.00	171	6.10	1	100.00
Mali	129	26.70	69	38.10	155	5.40	164	13.10	42	73.60
Mauritania	153	21.10	150	12.20	161	2.40	135	26.90	68	61.00
Mauritius	46	50.70	97	29.70	92	35.70	74	47.10	91	52.20
Mozambique	82	37.90	26	59.00	165	–	176	–	21	86.90
Namibia	147	22.20	136	17.90	129	18.70	1	100.00	90	52.60
Niger	127	27.10	56	40.80	155	5.40	173	3.30	29	82.70
Nigeria	174	13.80	153	11.60	89	37.40	69	48.00	38	76.60
Rwanda	136	24.70	71	37.70	165	–	116	33.30	1	100.00
Sao Tome & Princ	128	26.80	124	22.00	83	40.30	147	23.10	1	100.00
Senegal	149	22.10	111	25.20	132	18.20	93	40.30	25	83.10
Seychelles	36	54.80	94	31.20	101	31.50	122	31.90	95	4.80
Sierra Leone	151	21.60	101	29.00	143	12.70	124	31.30	1	10.00
South Africa	147	22.20	148	13.10	39	54.60	72	47.60	144	25.10
Tanzania	98	33.20	48	46.40	147	10.60	130	28.00	24	84.80
Togo	154	21.00	112	25.10	137	17.40	139	24.60	16	90.80
Uganda	126	27.40	57	40.80	139	15.40	148	22.40	13	96.10
Zambia	139	23.60	102	28.60	165	–	97	39.70	41	73.90
Zimbabwe	138	23.90	95	30.10	110	29.30	42	55.10	36	77.20

Source: Authors' Compilation (2004) based on Environmental Performance Index (2022)

Appendix 2

Table 2: Related laws, statutes, and regulations of 25 SSA countries

Country	**Environmental Legislation from Selected SSA Countries**
Burkina Faso	Loi relative au Code de l'Environnement (no. 005/97/ADP, Jan. 30, 1997) Loi relative au Code Forestier (no. 006/97/ADP, Jan. 31, 1997). Decree No. 2001-185/PRES/PM/MEE sets standards for air, water, and soil pollution Law No. 2013- 406/PRES within Burkina Faso's Environmental Code
Cameroon	Loicadre relative A la gestion de l'environnement (no. 9612, Aug. 5, 1996). Law No 2008/001 of the 14 April 2008
Comoros	Loi-cadre relative A l'environnement (no. 94-018, June 12, 1994). Decree of 19 April 2001 Order No. 01/031 /MPE/CAB protecting wild fauna and flora of the Comoros Decree No. 01/32/MPE/CAB of 14/05/2001
Congo, Brazzaville	Loi sur la protection de l'environnement (no. 003/91, Apr. 23, 1991) Decret rendant obligatoires les Etudes d'Impact sur l'Environnement (no. 86/775, 1986)
Congo, DR	Fundamental Principles of Environmental Protection (Loi 11-009) Law No 14/003 of 11 February 2014 on Nature Conservation Environmental Protection Law 2011 Law No. 18/001 of 9 March 2018 amending and supplementing Law No. 007/2002 of 11 July, 2002 on the Mining Code
Cote d'lvoire	Loi portant Code de l'Environnement (no. 96-766, Oct. 3, 1996). Decret determinant les regles et procedures applicables a l'impact environnemental des projets de developpement (no. 96-894, Nov. 8, 1996). Environment Code, Law No. 96-766 of 3 October 1996
Ethiopia	National Environmental Protection Authority Act (1992) Proclamation No. 300/2002 on Environmental Pollution Control specifies ambient air quality standards and allowable emissions
Gabon	Loi relative A la protection et a l'amelioration de l'environnement (no. 16/93, Aug. 26, 1993).
Gambia	National Environment Management Act (no. 13, 1994).
Ghana	The Environmental Protection Agency Act (no. 490, 1994). Procedures and Other Matters Pertaining to EIA (LI no. 1652, Feb. 26, 1999). Environment Protection Agency Act, 1994 (Act 490) National Environment Policy, 2012 National Climate Change Policy, 2013 Right to Information Act, 2019 No. 989
Guinea	Ordonnance portant Code de l'Environnement (no. 045/PRG/87).
Kenya	Physical Planning Act (1996). Environment Management and Coordination Act No. 8 of 1999 (revised 2015) and its regulations National Adaptation Plan 2015-2030 Wildlife Conservation and Management Act No. 47 of 2013 Forest Conservation and Management Act No. 34 of 2016

	Energy Act No. 1 of 2019 Fisheries Management and Coordination Act (FMDA) No. 35 of 2016 Climate Change Act, No. 11 of 2016 Mining Act No. 12 of 2016 Petroleum Act No. 2 of 2019
Madagascar	Loi relative A la Charte de l'Environnement malgache et annexe (no. 90-033, 1991). Decret portant refonte du decret 92-926 du 21 octobre 1992 relatif A la mise en compatibilite des Investissements avec l'environnement. Order No 18177/04 of 27/09/2004
Malawi	Act No. 23 (Aug. 16, 1996).
Mali	Loi relative A la protection de l'environnement et du cadre de vie (no. 9147/ANRM). Decret portant institution de la procedure d'etude d'impact sur l'environnement (no. 99-189, July 5, 1999).
Mauritius	The Environment Protection Act (1991, incorporating 1993 amendments). Environment Protection Act 2002 (No. 19 of 2002)
Namibia	Environmental Assessment Policy Cabinet Resolution (no. 002, Aug. 16, 1994). Environmental Management Act, 2007 (No. 7 of 2007)
Country	**Environmental Legislation from Selected SSA Countries (Continued)**
Nigeria	Federal Environmental Agency Decree (1988). Decree No. 86 (Dec. 10, 1992, supplement to Official Gazette Extraordinary no. 73 vol. 79, part A A979, Dec.31, 1992). Federal Environmental Protection Act (1990, as amended by Decree No. 52, 1992). National Environmental Standards and Regulations Enforcement Agency (NESREA) Act 2007 National Environmental (Wetlands, River Banks & Lake Shores) Regulations, S. I. No. 26, 2009 National Environmental (Sanitation and Wastes Control) Regulations, S. I. No. 28, 2009 National Environmental (Desertification Control and Drought Mitigation) Regulations, S. I. No. 13, 2011 National Environmental (Ozone Layer Protection) Regulations, S. I. No. 65, 2022 National Environmental (Control of Vehicular Emissions from Petrol and Diesel Engines)
Seychelles	The Environment Protection Act (1994). Environment Protection Act 2016 (No. 18 of 2016)
South Africa	Environment Conservation Act (no. 73, 1989). National Environmental Management Act (no. 107, 1998). Regulation 1182 (Regulation Gazette, Sept. 5, 1997). Regulation 1183 (Regulation Gazette, Sept. 5, 1997). National Environment Management Act 107 of 1998. National Environment Management: Air Quality Act 39 of 2004

	National Environment Management: Waste Act 59 of 2008 National Environmental Management Act: Integrated Coastal Management Act 24 of 2008 National Environmental Management: Biodiversity Act 10 of 2004 National Environmental Management: Protected Areas, 2003 (No. 57 of 2003) National Water Act 36 of 1999 Mineral and Petroleum Resources Development Act 28 of 2002
Swaziland	Swaziland Environment Authority Act (no. 15, 1992). Environmental Management Act 2002 (Act No. 5 of 2002)
Togo	Loi instituant Code de l'Environnement (no. 8814, Nov. 3, 1988). 118/119 Biodiversity and Forest Assessment
Uganda	The National Environmental Statutes (May 1995). The Environmental Impact Assessment Regulations (1998). The National Forestry and Tree Planting Act, 8/2003 National Environment Act, No. 5 of 2019 The Uganda Wildlife Act, 2019 National Environment (Audit) Regulation, 2020 Petroleum (Waste Management) Regulations S.I. No. 3 of 2019 National Environment (Management of Ozone Depleting Substances & Products) Regulations S.I. No. 48 of 2020 National Environment (Waste Management) Regulations S.I. No. 49 of 2020, 153-2 National Environment (Stds for Discharge of Effluent into Water or Land) Regulations 2020 National Environment (Oil Spill Prevention, Preparedness and Response) Regulations, 2020 National Environment (Environmental and Social Assessment) Regulations S.I. No. 143 of 2020
Zambia	Environmental Protection and Pollution Control Act (no. 12, July 20, 1990). The Environmental Impact Regulations (statutory instrument no. 28, 1997). Environmental Management Act of 2011 (EMA Act) administered by the Zambia Environmental Management Authority (ZEMA), the Energy Regulation Act of 2019 (ER Act) administered
Zimbabwe	Environmental Impact Assessment Policy (1994). Communal Lands Forestry Produce Act (19:07) Environmental Management Act (Chapter 20:27) Parks and Wildlife Management Act (Chapter 20:14) Environmental Management Act of 2011 (EMA Act) administered by the Zambia Environmental Management Authority (ZEMA), the Energy Regulation Act of 2019 (ER Act) administered

Source: Authors' Compilation based on Bekhechi & Merder (2021); The Access Initiative (2023)

Appendix 3

Table 3: Law Enforcement 2022 Ranking of 33 SSA countries

Country	Rule of Law Index		Regulatory Enforcement	
	Rank	**Score**	**Rank**	**Score**
Angola	113	0.43	114	0.42
Benin	88	0.48	83	0.48
Botswana	51	0.59	41	0.60
Burkina Faso	82	0.47	87	0.47
Cameroon	134	0.40	120	0.40
Congo Brazzaville	120	0.46	96	0.46
Congo, DR	137	0.36	134	0.36
Cote d'Ivoire	108	0.50	67	0.50
Ethiopia	123	0.37	129	0.37
Gabon	126	0.47	89	0.47
Gambia	86	0.36	130	0.37
Ghana	58	0.54	54	0.54
Guinea	117	0.36	132	0.36
Kenya	104	0.45	98	0.45
Liberia	112	0.40	122	0.45
Madagascar	111	0.38	125	0.38
Malawi	66	0.47	90	0.47
Mali	114	0.48	78	0.48
Mauritania	131	0.28	138	0.28
Mauritius	45	0.62	36	0.62
Mozambique	122	0.40	119	0.40
Namibia	46	0.59	43	0.59
Niger	109	0.47	86	0.47
Nigeria	118	0.41	116	0.41
Rwanda	42	0.60	40	0.60
Senegal	56	0.56	46	0.57
Sierra Leone	105	0.38	126	0.38
South Africa	54	0.53	56	0.53
Tanzania	98	0.43	105	0.43
Togo	101	0.51	63	0.51
Uganda	128	0.42	111	0.42
Zambia	103	0.43	108	0.43
Zimbabwe	124	0.35	135	0.35

Source: World Justice Project (2024)