Military Expenditure, Governance, and Environmental Degradation in Sub-Saharan Africa

Forthcoming: Environmental Processes

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Abstract

This article examines how good governance counteracts the effects of military expenditure on carbon emissions in forty African countries. The Generalized Method of Moments (GMM) is used to analyze time series data from 2010-2020. Military expenditure per capita is used to measure military expenditure per penetration, while CO_2 emissions per capita are used as an indicator of environmental degradation. The following findings are established. First, from the non-interactive regressions, we find suggestive evidence that arms expenditure increases CO_2 emissions. All indicators of good governance contribute to the increase of CO_2 emissions. Second, with interactive regressions, we find that improved governance has a negative effect on CO_2 emissions per capita. Third, the results are robust to a sensitivity check, considering the synergy effects of governance. This paper provides policy recommendations on low-carbon economies, military expenditure and governance that could help to ensure environmental sustainability by reducing CO_2 emissions. In addition, the study findings can provide guidance to other developing countries seeking to implement effective approaches to environmental sustainability while strengthening climate change mitigation and adaptation measures.

Keywords: climate change; Emission reduction; Environmental degradation; Sustainability; Econometric analysis

1. Introduction

Climate change is now recognized as a global challenge (Benzie and Persson 2019; Tsakiris and Loucks 2023; Loucks 2023; Hjorth and Madani 2023; Cunha 2023; Sabitha et al. 2023; El-Nashar and Elyamany 2023a, 2023b). According to the narrative, projections show that the next decade will be characterized by environmental crises with enormous consequences on biodiversity loss and ecosystem collapse. Carbon emissions due to human activities such as fossil fuel combustion and deforestation (Were et al. 2021; Jaafar et al. 2020; Raihan et al. 2021a) characterize the problems associated with environmental degradation (Bibi et al. 2021; He et al. 2021). The negative consequences of climate change are being felt with heightened intensity worldwide with catastrophic consequences affecting all segments of society (Masson-Delmotte et al. 2018; Begum et al. 2020; Raihan et al. 2022a). Environmental recoveries could still be recorded both in developed and emerging economies (Liu et al. 2022), but developing countries are among the hardest hit by the negative consequences of climate change (Helgeson et al. 2013). As the level of environmental deterioration has reached an alarming point, recent studies on the relationship between military expenditure, good governance and environmental degradation have become more important (Bakhsh et al. 2017). For this reason, the question arises as to whether good governance is decisive in the relationship between military expenditure and carbon emissions.

In recent decades, environmentalists have shown great apprehension about the ecological sustainability and expansion of military activities. In modern societies, armies are part of the most important institutions and use cutting-edge weapons, produced by large, advanced military production industries, and massive infrastructures (Ahmed et al. 2020a). Several empirical studies have investigated the impact of military expenditure on carbon emissions (Gokmenoglu et al. 2020; Bildirici 2017a; 2017b; 2018; Erdogan et al. 2022; Qayyum 2021; Ben Afia and Harbi 2018). Military activities involve the use of fossil fuels which are major sources of greenhouse gas emissions (Bargaoui and Nouri 2017; Santana 2002). Emissions also arise from the production and maintenance of military equipment, the construction and maintenance of military infrastructure, and defense-related research and development activities (Jorgenson et al. 2010; Pellow 2007). Militarization depletes the ecosystem by depleting natural resources and contaminating it via using toxic and radioactive substances (Singer et Keating 1999). Military expenditure impacts the environment through the rising mobility of military staff and large military equipment, which demands high energy consumption (Clark et al. 2010). Likewise, military experiments, training and exercises require huge quantity of oil for instance, in ships, rockets and planes. Such activities increase the emission of pollutants into the atmosphere (Solarin et al. 2018; Jorgenson et al. 2010).

To limit the impact of arms expenditure on carbon emissions, good governance has a role to play. In the literature, there is a link between good governance and military expenditure. The provision of defense services, which is generally a government responsibility, is prone to corruption because regulations give power to officials responsible for authorizing contracts. Consequently, limited competition between suppliers encourages rent-seeking and dishonest behavior by officials (Ades and di Tella 1999; Mbaku 2000). Good governance can help reduce excessive military expenditure and ensure that military expenditure is used responsibly and effectively (Bradford and Stoner 2014; Hewitt 1992, 1993; Hudson and Jones 2008; d'Agostino et al. 2012). In countries with weak governance, military expenditure tends to be higher and less transparent (Waller 1996). Corruption in these countries increases military expenditure (Ali et al. 2019; Gupta et al. 2001; Hudson and Jones 2008). Governments can use military expenditure to maintain power, suppress political dissent and limit civic participation. In such cases, military expenditure is often used to purchase expensive weapons and equipment rather than to support the armed forces and infrastructure needed to protect the country. In countries with strong governance, military expenditure is often more transparent and better managed (Hudson and Jones 2008).

In the light of the literature, military expenditure contributes directly to environmental degradation through increased carbon emissions (Qayyum 2021; Zandi et al. 2019; Ben Afia and Harbi 2018; Gokmenoglu 2020; Isiksal 2021). In our study, we postulate that political governance characterized by the robust process of electing and replacing political leaders, can make military expenditure more transparent and reduce carbon emissions, given that political leaders are often elected based on their commitment to improving human and environmental conditions for the well-being of the community. Moreover, when public policies are designed and implemented transparently to facilitate the provision of public services, such as military expenditure to limit CO_2 emissions (i.e., economic governance), these policies should also be consistent with respect by the State and citizens of institutions governing their interactions (i.e., institutional governance). We therefore consider that good governance is an effective way of counteracting the positive effect of military expenditure on the environment.

In this context, we analyze the role that good governance can play in the impact of military expenditure on the environment, and therefore, on carbon emissions. First, we show that higher military expenditure is associated with environmental degradation, and therefore, higher carbon emissions. Second, we highlight that good governance can play a direct role in limiting carbon emissions. As a result, we observe the interaction between good governance and military expenditure and show that good governance remains an instrument capable of limiting the positive environmental effects of military activities. This result is important for political decision-makers because it lets them know that even if military activities are not always conducive to safeguarding the environment, good governance remains a good instrument, especially in a context where one of the African Union objectives by 2043 is to silence arms. The use of arms is a destabilizing factor in many African countries, especially in sub-Saharan Africa. In recent decades, Africa has been the scene of numerous political instabilities, civil wars, coups d' état and political crises.

Several questions have not been resolved in the documents that have focused on the relationship between military expenditure and emissions. For example, most of the existing documents on the impact of military expenditure on emissions have not taken indirect effects into account. To this end, the role that good governance can play in the link between military expenditure and carbon emissions has not been empirically studied. Regarding the African continent, which is the field of application of our study, the few studies on the relationship between military expenditure and carbon emissions are limited to country analyses (Kwakwa 2022; Saba 2023). Kwakwa (2022) considers only current expenditure and excludes capital expenditure. This failure to take account of capital expenditure on armaments limits the scope of the results. The aim of this paper is to complement the existing literature on the relationship between military expenditure and emissions by examining the relationship between military expenditure and emissions in the United States.

This research contributes to the recent literature and policymaking in Africa in several directions. First, there are few studies on the link between military expenditure and carbon emissions. Our study contributes to the literature on carbon emissions. Second, we use data from the World Bank's good governance indicators to analyze the indirect effect of military expenditure on carbon emissions. Third, the most recent data are used to analyze the effects of explanatory factors of dynamic environmental degradation. Fourth, we use the generalized method of moments, which gives much more robust results. Finally, the conclusions of the study provide decision-makers with information that will guide and inform decision-making in the field of environmental degradation, the promotion of good governance and the optimization of public expenditure, including military spending. To this end, policy recommendation is formulated to serve as a reference framework for the establishment of common environmental protection policies.

In the light of the above, the corresponding research question of this study is: how does good governance affect the relationship between military expenditure and carbon emissions in Africa? The rest of the study is organized as follows. The intuition and theoretical foundations of the study are discussed in Section 2. Section 3 covers the data and methodology, while the empirical results are presented in Section 4. Section 5 concludes with future research directions.

2. Review of the Literature

2.1 Theoretical Literature

Consistently with Traoré et al. (2023), from a theoretical premise, the governance system can considerably affect the quality of the environment, especially when it concerns the relevance of governance in influencing how financial and human resources are allocated to fighting the scourge. Moreover, with a favorable institutional environment, bureaucracy that is connected with the implementation of effective policies in the fight against environmental degradation is more apparent (Salman et al. 2019). Following the narrative, transactions costs linked to military expenditure that can negatively influence the environment can be reduced with good governance policies in place. As argued by Traoré et al. (2023), the good governance indicators of the World Bank employed within the remit of the present study have been theoretically documented to influence environmental quality (Asongu and Odhiambo 2021a; 2021b), while military expenditure obviously influence the environment because it is associated with production and transportation processes that engender CO_2 emissions employed in this study as the outcome variable (Isiksal 2021; Wang et al. 2021; Gokmenoglu et al. 2021; Erdogan et al. 2022). To put these in perspective with an example, corruption-control which is a dimension of governance affects CO_2 emissions (Hosseini and Kaneko 2013), in the light of the documented role of corruption in environmental pollution (Abid 2016; Leitao 2016; Wang et al. 2018).

Consistently with Ofori et al. (2023), there are several theoretical frameworks motivating the nexus between environmental governance and CO_2 emissions. For instance, according to Shahbaz et al. (2019), the nexus between globalization-driven military expenditure and environmental degradation can be observed from two perspectives, notably, the scale and compositions channels or impacts. According to the former, environmental governance boosts economic growth externalities such as military expenditure and CO_2 emissions, not least, because the military expenditure and environmental governance are linked to energy intensive activities and the high exploitation of raw material that negatively affects the environment, among others. Concerning the composition effect, it is essentially linked to environmental quality regarding the commodity types that are produced by nations. Accordingly, countries characterized with poor environmental regulations are likely to produce more commodities that are polluting whereas wealthier nations with better environmental policies do specialize in commodities that are cleaner. In essence, according to the narrative, pollution companies tend to migrate from developed to developing countries.

Conversely, the pollution haven hypothesis maintains that environmental governance is a factor that influences pollution such that firms in more developed countries are more likely to relocate to less developed countries where environmental policies are less stringent. This is essentially because the corresponding carbon intensity can engender unfavorable environmental consequences (McGuire 1982). On the contrary, according to the pollution halo hypothesis, environmental governance can reduce environmental pollution. Within the remit of this hypothesis, environmental governance can enhance shocks that are environmentally-friendly (Zarsky 1999).

The corresponding conceptual framework is shown below in Figure 1. It shows that military expenditure affects CO_2 emissions (Isiksal 2021; Wang et al. 2021; Gokmenoglu et al. 2021; Erdogan et al. 2022) and governance influences that relationship, as documented in this section.

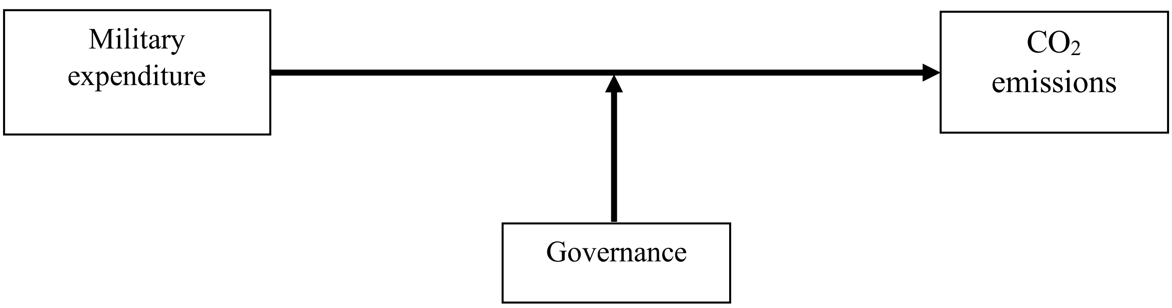

Figure 1: Conceptual framework

2.2 Empirical Literature

Much research has focused on the impact of military activities on the environment (Ahmed et al. 2020; Ben Afia and Hardi 2018; Bildirici 2016; 2017a; 2017b; Clark and Jorgenson 2012; Gould 2007). Military activities contribute to greenhouse gas emissions (Jorgenson and Clark 2012; Bradford and Stoner 2017). Hooks and Smith (2005) show that military activities degrade the environment and degrade the ecosystem in time. Jorgenson et al. (2010) show that the militarization of high technology and the number of soldiers have significant impacts on the environment. The geopolitics and national interests that are driving the expansion of militarism are leading to the development of high-tech weapons and vehicles that consume large quantities of fossil fuels and emit large quantities of carbon dioxide. As a result, the scaling up of national armies, both in terms of soldiers and technology, increases their demands and their impact on the environment.

For a large military power such as the United States of America, Solarin et al. (2018) confirm that military expenditure has a dire effect on environmental quality. This positive effect of military expenditure on emissions in the United States may be due to the large volume of fossil fuels associated with the military sector in the country. In fact, the military sector remains the largest consumer of oil on the planet in the USA (Hynes 2011). Most of the Pentagon's energy needs are met by fossil fuels. Considering biocapacity as an indicator of environmental protection for a set of 142 countries, Bradford and Stoner (2014) show that military expenditure has a negative effect on biocapacity and that countries with higher military expenditure have, on average, lower biocapacity per capita than countries with lower military expenditure. The negative impact of military expenditure on biocapacity is independent of purely economic effects, such as GDP per capita and GDP per capita squared.

Reuveny et al. (2010) showed that there is a correlation between militarization and environmental degradation as measured by CO_2 and NOx emissions, the index on environmental stress and desertification. The results showed that militarization has a critical influence on environmental deterioration. The results are sensitive to the level of development of the countries and the nature of the conflicts which can be internal or external. These results are in line with those found by Jorgenson and Clark (2009) who showed that military expenditure has a positive influence on the ecological footprint of developed and underdeveloped countries. The effect of military expenditure on environmental degradation can be indirect and pass through the income channel (Ben Afia and Harbi 2018). On a panel of

120 countries covering the period 1980-2015, Ben Afia and Harbi (2018) show that military expenditure has a positive indirect effect on per capita emissions.

Considering the impact of governance on greenhouse gas emissions, a volume of papers empirically reported a positive effect (Samimi et al. 2012; Halkos and Tzeremes 2013; Tamazian and Bhaskara Rao 2010; Lameira et al. 2016; Zhang et al. 2016). Likewise, Abid (2016) sustains that institutional quality plays a key role in dampening greenhouse gas emissions via a direct or an indirect mitigation of carbon emissions. Consequently, states characterized by democratic norms promote environmental quality via the implementation of robust and effective environmental regulatory systems. Such regulatory efficacy can be explained by the rising consciousness of individuals and organizations involved in environmental issues (Almeida and García Sánchez 2017). Lastly, the variable of corruption, also adopted as a proxy for good governance, can influence both directly and indirectly, environmental quality by stimulating institutional performance, rent-seeking attitudes and weakening barriers (Zhang et al. 2016).

3. Data and Methodology

3.1. Data

Our study covers 40 African countries from 2010 to 2020, depending on data availability (Supplementary Material (SM); Table SM1). The periodicity is motivated by data availability constraints at the time of the study. We rely on the following variables.

3.1.1 Variable Dependency: Carbon Emissions

Our dependent variable is carbon emissions defined as those emanating from fossil fuels and cement manufacturing. These encompass carbon emissions produced during the usage of fossil fuel. Carbon dioxide (CO_2) is a significant constituent of emissions responsible for global warming and vulnerability to climate change. The choice of the CO_2 emission variable is consistent with recent literature (Raihan 2023; Shah 2022; Raihan 2022; Danish 2019; Farooq 2022).

3.1.2 Variable of Interest: Arms Expenditure and Good Governance

The variable good governance is obtained from the World Bank's World Governance Indicators database. Governance represents the traditions and institutions through which are exercised in a country. It includes the process of selecting, vetting, and replacing governments, state's ability to effectively design and implement policies, as well as ensuring conformity to the rules influencing both the economic and the social interactions within society. These good governance variables capture several facets of governance. The dimensions of good governance considered are: (i) voice and accountability; (ii) political stability and absence of violence/terrorism; (iii) government effectiveness; (iv) regulatory quality; (v) rule of law; and (vi) control of corruption. These variables on good governance are used in the empirical literature (Omri 2021; Hashmi et al. 2022). To account for synergistic effects, we have developed a synthetic index that integrates all six dimensions. This index is constructed using the principal component method.

Furthermore, in this study, we drive a composite index of governance drawn from the main analysis component as indicated in SM (Table SM2). This composite index of governance integrates: (i) political governance (which consist of political stability and, voice and accountability), (ii) economic governance (covering government effectiveness as well as regulatory quality) and lastly, institutional governance (implying the rule of law and the control of corruption). These six metrics of governance are all sourced from the World Bank's World Governance Indicators (WGI).

3.1.3 Control Variables

We consider the potential drivers of carbon emissions, in line with the afore-mentioned analysis**.** Firstly, demographic variables are considered. Second, the study accounts for the effect of information and communication technologies, namely internet penetration. Third, the effects of foreign direct investment are taken into account. Finally, the study also controls for a time-fixed effect and the lagged value of the carbon emission variable, to account for any persistence. Table SM2 provides a more detailed description of the variables. The use of these control variables is based on empirical literature (Voumik 2023; Sultana et al. 2023; Nguyen et al. 2020; Zhang and Zhou 2019; Essandoh et al. 2020)

To study the impact of military expenditure on environmental protection and examine the role that good governance can play, we use a balanced panel of 40 African countries from 2010-2020. Descriptive statistics are provided in Table SM3, while their pairwise correlations are shown in Table SM4.

3.1.4 Pairwise Correlation

Preliminary correlations (Figure 2) suggest a consistent trend towards a link between arms expenditure, good governance and CO_2 emissions. It appears that over the period 2010-2020, arms expenditure is positively correlated with CO_2 emissions. This apparent correlation will be assessed more rigorously in the following sections by means of appropriate econometric analyses.

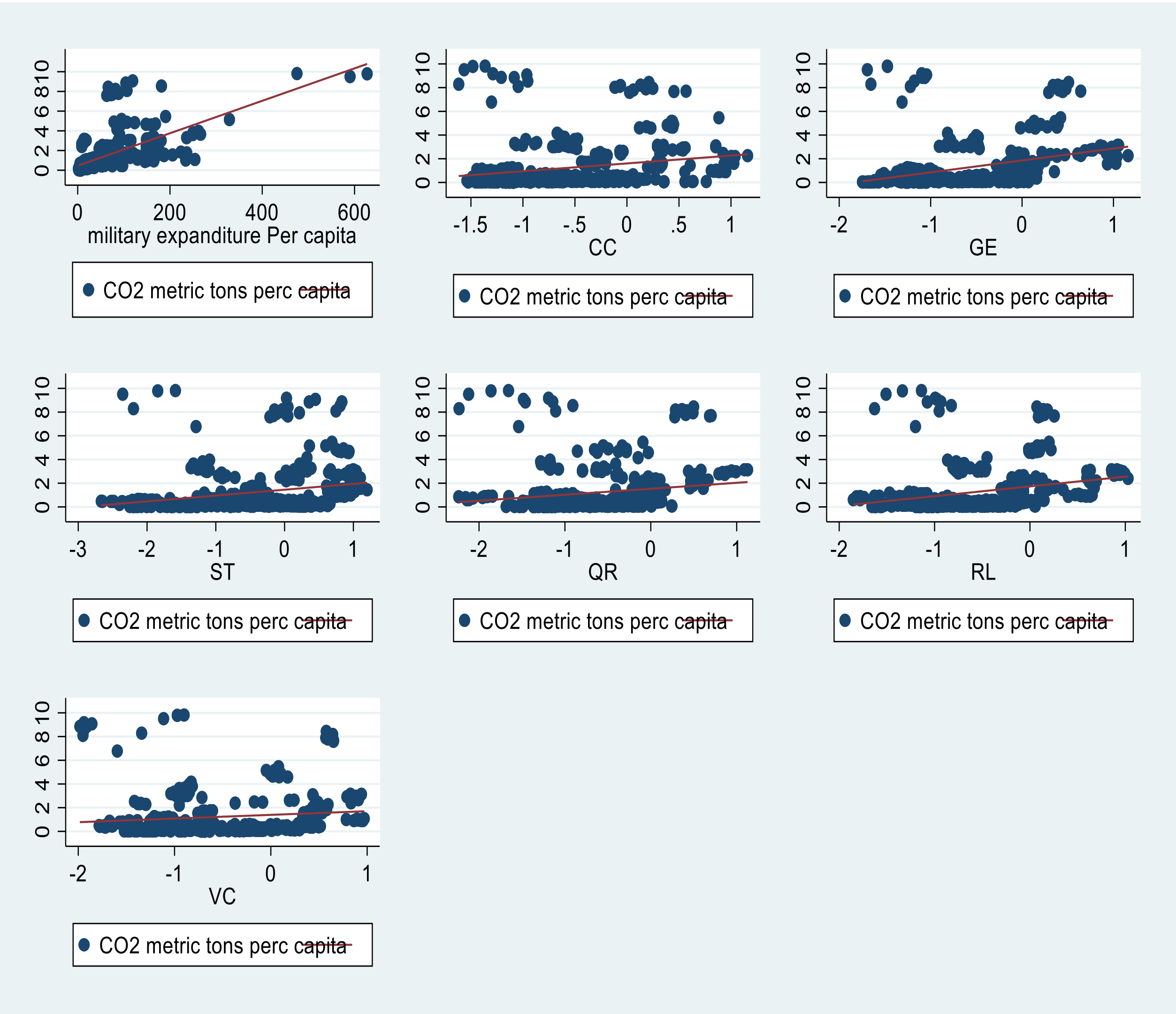

Figure 2: Carbon emissions (CO2) in kiloton (kt) and military expenditure (per capita) followed by the various dimensions of governance. Note: The vertical axes of the graphs are CO2 emissions (metric tons per capita). CC: corruption-control; GE: government effectiveness; ST: political stability; QR: regulatory quality; RL: rule of law; VC: voice and accountability).

3.2.Methodology

Following the literature, the Generalized Method of Moments (GMM) regression is maintained as accounted for by the following arguments. Firstly, given the main condition on the fact that cross-sections number must exceed the number of periods (Tchamyou 2019a), our study meets this criterion given that we cover a sample of 40 countries over a period of 10 years (i.e., 2010 to 2020). Secondly, the carbon emissions variable considered is persistent given that the correlation coefficients alongside its first lag lie above the 0.800 thresholds considered as the thumb rule (Tchamyou et al. 2019). Thirdly, the GMM technique is compatible with a data structure, which should be in panel data with cross-country variations being accounted in the regressions (Asongu 2018). Lastly, the endogeneity bias regarded as a simultaneity or reverse causality is rigorously treated; meanwhile, we also employ time-invariant variables to solve the problem of omission bias (Boateng et al. 2018). In our study, we adopt the extension by Roodman (2009) of Arellano and Bover (1995) to solve the problem of instrument proliferation (or limit overidentification) and we account for the cross-sectional dependence in our sample (Baltagi et al. 2007). The GMM estimation technique has been employed in the extant literature on CO_2 emissions (Asongu et al. 2017; Troaré et al. 2023).

The following equations in level (Eq. 1) and first difference (Eq. 2) articulate the estimation procedure for the standard GMM system:

$$CO_{it} = \emptyset_0 + \emptyset_1 CO_{it-\tau} + \emptyset_2 Arm_{it} + \emptyset_3 Gov_{it} + \emptyset_4 Inter_{it} + \sum_{k=1}^{3} \delta_k W_{hit-\tau} + \varphi_i + \omega_t + \varepsilon_{it} \quad (1)$$

$$CO_{it} - CO_{it-\tau} = \emptyset_1 (CO_{it-\tau} - CO_{it-2\tau}) + \emptyset_2 (Arm_{it} - Arm_{it-\tau}) + \emptyset_3 (Gov_{it} - Gov_{it-\tau}) + \emptyset_4 (Inter_{it} - Inter_{it-\tau}) + \sum_{k=1}^{3} \delta_k (W_{hit-\tau} - W_{hit-2\tau}) + (\omega_t - \omega_{t-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (2)$$

where CO denotes CO_2 emissions; $\emptyset_0$ is the constant; Arm represents military expenditure; Gov_{it} stands for the composite index enclosing six dimensions of governance quality (namely, political stability, voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption control); *Inter* denotes the interaction between military expenditure and governance; W represents the vector of control variables; τ is the unit coefficient of autoregression given that a lagged year is sufficient to display former information; ω_t is our time-specific constant; φ_i denotes the country-specific effect and ε_{it} represents the error term.

To guarantee the robustness of the estimation strategy adopted, we specify that the GMM observes the identification and exclusion barriers. Previous studies posit for the endogenous nature of all explanatory variables meanwhile time-invariant variables are strictly exogenous (Tchamyou et al. 2019). This strategy of identification was used by Boateng et al. (2018). Nevertheless, it is worth noting that the time-invariant indicators are susceptible not to solving endogeneity at the first difference (Roodman 2009). Thus, to ensure the GMM model validity, we follow four main information criteria. Namely, the Arellano and Bond autocorrelation, the Hansen and Sargan tests as well as the Wald test for model overall validity.

4. Empirical Results

4.1. Presentation of Results

Summary statistics for the variables are presented in Table SM3. The data shows that emissions per capita averaged 1.294 between 2010-2020. Regarding the variables of interest, the data show that the average expenditure on arms is 51.98. The average values for corruption control, government effectiveness, political stability, regulatory quality, rule of law and voice and accountability are -0.563, -0.649, -0.567, -0.618, -0.603 and -0.493, respectively. For variables such as foreign direct investment, internet, and population growth are 43.533, 4.493, 4.493, 10.495 and 2.388 respectively. Table SM4 presents the correlation matrix to illustrate the relationship between the variables under study**.** Following the correlation results, it can be observed that our model is exempted from multicollinearity.

We used a total of four information criteria to assess the validity of the specifications after estimation. Based on these criteria, we find that all models are extremely valid as they pass the corresponding diagnostic tests after estimation. Our estimates thus appear to be reliable given the validity of the AR (2) post-estimation tests. This consequently implies that the residuals are exempted from second-order serial correlation and the Hansen P-value confirms the validity of the instruments. Additionally, this confirms the complete absence of instrument proliferation given that the number of instruments is significantly lower than the number of countries in each specification (Tchamyou2019a).

The following conclusions can be drawn from Table 1. First, according to the non-interactive regressions, military expenditure has a positive and significant impact on CO_2 emissions. In addition, there is also strong empirical evidence that all good governance variables have positive and significant unconditional effects on carbon emissions except for the corruption control variable which has a positive but insignificant effect. Second, we find evidence for the last hypothesis. The relevance and originality of this result lie in the fact that, while military expenditure boosts carbon emissions in Africa, the effect tends to decrease in the presence of governance.

These results can be related to those obtained in the corresponding literature. Thus, the favourable role of governance, which allows military expenditure to negatively influence carbon emissions, is also a form of environmental protection, which is largely consistent with the literature focused on military expenditure, which emphasizes the importance of good governance for improving military expenditure (Dizaji et al. 2016; Gupt et al. 2001; Dunne and Perlo-Freeman 2003; Dunne et al. 2008; Nordhaus et al. 2012) and the importance of military expenditure on the environment (Erdogan et al. 2022; Isiksal 2021; Gokmenoglu 2020; Zandi 2019; Gould 207).

Table 1: Linkages between military expenditure, governance, and CO_2 emissions

	Dependent variable: CO_2 emissions metric per capita					
	Political governance		Economic governance		Institutional governance	
	Politicalstability	Voice and accountability	Regulationquality	Goverment effectivness	Rule of law	Corruption control
CO_2 (-1)	**0.919*** (0.018)**	**0.933*** (0.016)**	**0.910*** (0.015)**	**0.918*** (0.017)**	**0.940*** (0.011)**	**0.973*** (0.012)**
Militaaryexpenditure	**0.052*** (0.025)**	**0.052*** (0.015)**	**0.047*** (0.013)**	**0.062*** (0.019)**	**0.047*** (0.013)**	**0.053*** (0.009)**
Politicalstability	**0.050** (0.012)**	-	-	-	-	-
Voice and accountability	-	**0.042*** (0.011)**	-	-	-	-
Regulationquality	-	-	**0.053*** (0.008)**	-	-	-
Govermenteffectivness	-	-	-	**0.027** (0.013)**	-	-
Rule of law	-	-	-	-	**-0.028** (0.014)**	-
Corruption control	-	-	-	-	-	0.014 (0.021)
STarm	**-0.0004*** (0.0001)**	-	-	-	-	
VCarm	-	**-0.0005*** (0.0002)**	-	-	-	-
QRarm	-	-	**-0.0005*** (0.00008)**	-	-	-
GEarm	-	-	-	**-0.0005*** (0.0001)**	-	-
RLarm	-	-	-	-	**-0.0003*** (0.0001)**	-
CCarm	-	-	-	-	-	0.0001 (0.0001)
Population growth	**-0.045*** (0.013)**	**-0.052*** (0.010)**	**-0.062*** (0.008)**	**-0.063*** (0.011)**	**-0.061*** (0.008)**	**-0.037*** (0.008)**
Internet	**-0.014** (0.007)**	-0.009 (0.008)	0.004 (0.006)	-0.007 (0.006)	-0.0007 (0.005)	-0.036*** (0.006)
FDI	0.0008 (0.002)	0.002 (0.002)	**0.004** (0.002)**	0.002 (0.002)	**0.006** (0.002)**	0.001 (0.002)
Constant	0.026) (0.064)	0.011 (0.041)	0.008 (0.035)	-0.008 (0.048)	-0.038 (0.040)	0.022 (0.029)
Time Effects (2010-2020)	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	0.050	0.042	0.053	(0.027	-0.028	na
AR (1)	(0.024)	0.024)	(0.023)	(0.024)	(0.027)	(0.023)
AR (2)	**(0.286)**	**0.255)**	**(0.233)**	**(0.273)**	**(0.267)**	**(0.277)**
Sargan OIR	(0.062)	0.036)	(0.046)	(0.022)	(0.045)	(0.001)
Hansen OIR	**(0.394)**	**0.689)**	**(0.400)**	**(0.747)**	**(0.732)**	**(0.284)**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**(0.299)**	**(0.604)**	**(0.343)**	**(0.772)**	**(0.590)**	**(0.579)**
Dif(null, H=exogenous)	**(0.466)**	**(0.613)**	**(0.437)**	**(0.583)**	**(0.676)**	**(0.187)**
(b) IV (years, eq(diff))						
H excluding group	**(0.350)**	**(0.403)**	**(0.439)**	**(0.740)**	**(0.559)**	**(0.129)**
Dif(null, H=exogenous)	**(0.451)**	**(0.855)**	**(0.355)**	**(0.545)**	**(0.738)**	**(0.685)**
Fisher	**13196.11 *** **	**207471.45*** **	**253573.93*** **	**73851.75 *** **	**71105.73 *** **	**413048.27*** **
Instruments	35	35	35	35	35	35
Countries	39	39	39	39	39	39
Observations	395	308	308	308	308	308

Note: *, **, ***: significance levels of 10%, 5% and 1% respectively. CO_2: carbon dioxide emissions; Gov: general governance index by CPA; CCarm: corruption-control interaction with militarily expenditure; GEarm: government effectiveness interaction with militarily expenditure; STarm: political stability interaction with militarily expenditure; QRarm: regulatory quality interaction with militarily expenditure; RL: rule of law interaction with militarily expenditure; VCarm: voice and accountability interaction with militarily expenditure. The mean value of Gov index is -3.19e-09, the mean value of political stability index is -0.567, the mean value of regulatory quality index is -0.618, the mean value of rule of law index is -0.603, the mean value of voice and accountability is -0.493 while the mean value of government effectiveness index is -0.649. na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the OIR and DHT tests.

To assess the overall impact of governance on CO_2 emissions, we calculated the net effects from the estimates. Net effects are calculated according to the literature on interactive effects (Asongu and Odhiambo 2019b). For example, in the first column of Table 1, the net relationship of the effect of political stability and CO_2 emissions is 0.050 (0.050+ [-0.0004×-0.543]). In the calculation of these net effects, the average value of "political stability" is -0.543, the unconditional relationship of "Political stability" is 0.050, and the marginal relationship is -0.0004. For estimates where one of the unconditional or marginal effect variables is not significant, we did not calculate the net effect. Accordingly net effects are not computed in the last column of Table 1.

4.2 Robustness Check

To test the robustness of the results, we clustered the relevant governance variables in Table 1 through principal component analysis. We draw on the work of Tchamyou (2017) and Asongu and Odhiambo (2019c) to reduce the dimensions of the components of a governance category. The principal component analysis groups: (i) in the governance index, we have political stability and voice and accountability; (ii) in the economic governance index, we have government efficiency and regulatory quality; and (iii) in the institutional governance index, we have control of corruption and rule of law. Finally, we constructed a general governance index decomposed from the six governance dimensions.

As an attempt to assess the model validity used in Table 1 following the information criteria, we observe that the models are mostly valid since they conform with all the post-estimation diagnostic tests performed. Our results in Table 2 show that political governance remains relevant for the calculation of net effects. Thus, improved political governance has positive effects on CO_2 emissions. By extension, we have determined the net effect of general governance on CO_2 emissions.

Table 2: Robustness checks

	Dependent variable CO_2 emission metric per capita			
	Political governance	**Economic governance**	**Institutional governance**	**General governance**
CO_2(-1)	**0.896*** (0.016)**	**0.851*** (0.017)**	**0.851*** (0.017)**	**1.006*** (0.023)**
Militaryexpenditure	**0.001*** (0.0001)**	**0.002*** (.0001))**	**0.002*** (0.0001)**	**0 .0004** (0.0001)**
Political governance	-0.072*** (0.016)	-	-	-
Economic governance		**-.0398*** (0.011)**	**-**	**-**
Institutional governance	-	**-**	**-0.039*** (0.011)**	**-**
General governance	-	**-**		**-0.061*** (0.020)**
Polgovarm	**0.0001*** (0.00007)**			-
Ecogovarm		0.00005 (0.00005)		-
Insgovarm	-	-	0.00005 (0.00005)	-
Govarm	-	-	-	**0.0002*** 0.00007)**
Population growth	**-0.241** (0.021)**	-0.215 (0.018)	**-0.215*** (0.018)**	**-0.187*** (0.026)**
Internet	-0.0002 (0.0006)	**0.0001*** (0.0007)**	0.0001 (0.0007)	**-0.003*** (0.001)**
FDI	-0.0004 (0.0007)	0.0002 (0.0005)	0.0002 (0.0005)	**0.001* (0.001))**
Constant	**0.646*** (0.066)**	**0.595*** 0.056)**	**0.595*** 0.056)**	**0.529*** 0.084)**
Time Effects (2010-2020)	Yes	Yes	Yes	Yes
Net Effects	(-0.072)	na	na	(-0.61)
AR (1)	(0.027)	(0.021)	(0.021)	(0.031)
AR (2)	**(0.187)**	**(0.131)**	**(0.131)**	**(0.259)**
Sargan OIR	(0.000)	(0.000)	(0.000)	(0.000)
Hansen OIR	**(0.309)**	**(0.552)**	**(0.552)**	**(0.706)**
DHT for instruments				
(a)Instruments in levels				
H excluding group	**(0.555)**	**(0.300)**	**(0.300)**	**(0.232)**
Dif(null, H=exogenous)	**(0.218)**	**(0.667)**	**(0.667)**	**(0.870)**
(b) IV (years, eq(diff))				
H excluding group	**(0.542)**	**(0.677)**	**(0.677)**	**(0.495)**
Dif(null, H=exogenous)	**(0.168)**	**(0.329)**	**(0.329)**	**(0.731)**
Fisher	**1.90e+06*** **	**821082.79 *** **	**821082.79*** **	**373074.47 *** **
Instruments	35	**35**	35	31
Countries	39	39	39	39
Observations	323	323	323	323

Note: *, **, ***: significance levels of 10%, 5% and 1% respectively. CO_2: carbon dioxide emissions; Gov: general governance index by CPA; The mean value of Gov index is -3.19e-09, the mean value of political governance index is -4.30e-09, the mean value of economic governance index is 1.97e-09, the mean value of institutional governance index is 1.97e-09, while the mean value of general governance index is -3.19e-09; na: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) and AR(2) tests and; b) the validity of the instruments in the OIR and DHT tests.

5. Conclusions and Policy Implications

This paper contributes to the debate by providing some of the first empirical evidence on the link between arms expenditure and carbon emissions by considering the role of good governance in Africa. Military expenditure is measured by the military expenditure per capita indicator and good governance by the World Bank's six good governance indicators. We draw on a large panel of 40 African countries over the period 2010-2020. The GMM results reveal that the non-interactive regressions military expenditure has a positive and significant effect on CO_2 emissions. For the indirect effect, good governance decreases the positive impact of military expenditure on CO_2 emissions. The estimated results are robust when governance is bundled by means of principal component analysis . The results contribute to the existing literature by highlighting the role that good governance can play in training to reduce carbon emissions caused by military activities and offer policy recommendations for environmental sustainability.

The results of the current study recommended that African authorities put in place a comprehensive environmental management mechanism that reduces the level of carbon emissions. In an environment characterized by weak governance, the study recommends that the authorities rely on the instrument of good governance to act on carbon emissions. From a policy perspective, these findings call for comprehensive reforms to limit Africa's carbon emissions, including promoting stability, which remains a driver of arms expenditure, and addressing poor governance. This last point requires bold measures to improve the transparency of arms expenditure. The results also call for intensified efforts to combat instability in African countries, echoing the African Union's agenda of silencing guns, but also a policy agenda of mitigating natural disasters related to climate change (UN Sustainable Development Goal 17). In this context, the study recommended that African governments establish regulations that enhance emission reduction targets as mentioned in many national development plans as well as sustainable development goals. In addition, the study recommends that the authorities ensure military infrastructure and military investments that contribute to the reduction of carbon emissions. For a sustainable ecological transition, African governments can rely on regulations that range from the introduction of high taxes and pollution rights markets to regulating the massive importation of arms. The findings and corresponding policy implications can be relevant to other developing countries with other development conditions as Africa countries, notably, some Asian and Latin American countries.

Like any scientific study, this study has its limitations. In our study, we considered a panel of 40 African countries, to better understand the specificities of each country, country studies can be carried out in the future and compared to the results of this study with a larger sample. Measuring environmental degradation, our study focused on CO_2 emissions. Within the literature, other measures of degradation also exist. For this reason, further studies could be conducted to consider other measures of environmental emissions such as nitrous oxide (N_2O) and sulfur dioxide (SO_2), methane (CH_4), carbon monoxide (CO), ground-level ozone (O_3), hydrogen sulphone (H_2S) and other short-lived climate forces (SLCF). Recognizing that although carbon emissions are the main causes of environmental pollution, they are not its only cause. Based on this observation, future research can integrate more indicators of environmental pollution, namely soil and water pollution. In the literature on the determinants of carbon emissions, variables related to international trade, financial development, urbanization, industrialization, and agricultural productivity are believed to have effects on carbon emissions. These variables are not considered in our model. In future research, more control variables can be considered. Future research can be conducted by considering military expenditures according to the components of operating expenditures and investment expenditures. Such an analysis would help to better target policies to combat environmental degradation in military activities.

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Table SM1: The list of countries

Algeria	Ivory coast	Madagascar	Senegal
Angola	Ethiopia	Malia	Seychelle
Benin	Gabon	Mauritania	Sierra Leone
Botswana	Gambia	Mauritius	South Africa
Burkina	Ghana	Morocco	Sudan
Burundi	Guinea	Mozambique	Tanzania
Cabo Verde	Bissau	Namibia	Togo
Cameroon	Kenya	Niger	Tunisia
Democratic republic of Congo	Lesotho	Nigeria	Zambia
Republic of Congo	Libya	Rwanda	Zimbabwe

Table SM2: List of variables

Variables	**Description**	**Sources**
CO_2 per **c**apita	CO_2 emissions (metric tons per capita)	World Bank (WDI)
Military expenditure %GDP	Military expenditure per capita	Stockholm International Peace Research Institute (SIPRI)
Corruption-control	Control of corruption (governance composite index).	World Bank (WDI)
Government effectiveness	Government effectiveness (Governance Composite Index,)	World Bank (WDI)
Political stability	Political stability and absence of violence/terrorism	World Bank (WDI)
Regulation quality	Regulatory quality (Governance Composite Index);	World Bank (WDI)
Rule of law	Rule of law (governance composite index)	World Bank (WDI)
Voice and accountability	Voice Democratic expression and accountability (EDemocra Composite Governance Index).	World Bank (WDI)
General gouvernance	First principal component of political, economic, and institutional governances	PCA
Political governance	First principal component of political stability and voice and accountability. The process by which those in authority are selected and replaced	PCA
Economic governance	"First principal component of government effectiveness and regulation quality. The capacity of government to formulate and implement policies and to deliver services"	PCA
Institutional governance	"First principal component of rule of law and corruption-control. The respect for citizens and the state of institutions that govern the interactions among them"	PCA
Internet	Internet penetration (per 100 people)	World Bank (WDI)
Foreign Direct Investment	Foreign direct investment inflows (% of GDP)	World Bank (WDI)
Population growth	Population growth rate (annual %)	World Bank (WDI)

Source : Authors' compilation
Source: WDI, World Bank Development Indicators
Source: SIPRI, Stockholm International Peace Research Institute

Table SM3: Summary statistics 2010-2020

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
CO2 per capita	400	1.294	2.001	0.029	9.817
Military expenditure %GDP	400	51.980	80.714	0.580	627.324
Political stability	440	-0.567	0.861	-2.665	1.111
Voice and accountability	440	-0.493	0.683	-1.940	.979
Political governance	440	-4.30e-09	1.278	-2.994	2.716
Regulatory quality	440	-0.618	0.572	-2.347	1.127
Government effectiveness	440	-0.649	0.612	-2.009	1.056
Economic governance	440	1.97e-09	1.367	-3.674	4.112
Rule of law	440	-0.603	0.587	-1.969	.9749
Corruption-control	440	-0.563	0.652	-1.626	1.23
Institutional governance	440	1.97e-09	1.367	-3.674	4.112
General governance	440	-3.19e-09	2.219	-5.181	5.483
Population growth	440	2.347	0.987	-5.280	4.679
Internet	419	22.328	18.842	0.58	84.120
Foreign Direct Investment	433	4.503	6.673	-11.199	57.837

Source: Authors' compilation

Note: obs: observations; Mean: average; SD: standard deviation; Min: minimum; Max: maximum ; CO_2: carbon dioxide emissions; Armpc: military expenditure per capita ; Urban: urbanization; Internet: internet subscription ; Popgr: population growth ; CC: corruption-control ; GE: government effectiveness ; ST: political stability; QR: regulatory quality; RL: rule of law; VC: voice and accountability.

Table SM4: Matrix of correlation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.000														
2	0.6846	1.000													
3	0.174	0.187	1.000												
4	0.107	0.180	0.715	1.000											
5	0.283	0.246	0.890	0.692	1.000										
6	0.192	0.176	0.918	0.734	0.929	1.000									
7	0.033	-0.005	0.800	0.670	0.869	0.883	1.000								
8	0.156	0.064	0.722	0.634	0.711	0.787	0.754	1.000							
9	0.146	0.135	0.795	0.904	0.778	0.841	0.788	0.904	1.000						
10	0.163	0.127	0.874	0.704	0.966	0.937	0.966	0.760	0.810	1.000					
11	0.163	0.127	0.874	0.704	0.966	0.937	0.966	0.760	0.810	1.000	1.000				
12	0.176	0.159	0.932	0.812	0.943	0.970	0.919	0.846	0.917	0.963	0.963	1.000			
13	-0.542	-0.319	-0.368	-0.248	-0.389	-0.374	-0.206	-0.296	-0.301	-0.308	0.308	-0.348	1.000		
14t	0.562	0.357	0.466	0.310	0.542	0.514	0.347	0.366	0.378	0.462	0.462	0.477	-0.532	1.000	
15	-0.017	-0.052	0.024	0.144	-0.021	-0.008	-0.034	0.033	0.098	-0.029	-0.029	0.022	0.016	-0.073	1.000

Source: Authors' compilation

Note: obs: 1: CO_2pc: carbon dioxide emissions; 2: military expenditure per capita; 3: corruption-control; 4: political stability; 5: government effectiveness; 6: rule of law; 7: regulatory quality; 8: voice and accountability; 9: political government index; 10: Economic governance index; 11: Institutional governance index; 12: general governance index; 13: population growth; 14: Internet subscription; 15: Foreign direct investment