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Abstract

This work aims firstly to determine the contribution of military spending to environmental degradation in Africa. In a second step, he looks for the transmission mechanism of such an impact. To do this, we used the estimation methods of GMMs in the system and structural VARs. The study showed a positive and significant impact of military spending on indicators of the selected environment (carbon dioxide, nitrous oxide and methane). Thus, military spending contributes to environmental degradation in Africa despite the fact that no country in Africa is a producer of weapons. Controlling military spending is therefore a major challenge for the protection of the environment in Africa. In addition, economic growth plays an important role in the transmission of military expenditure shocks.

Key words: economic growth, military spending, environmental degradation, Africa.

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1. Introduction

War has always occupied an important place in the history of human civilization. It has justified the development of the arms industry and the increase of the share of military expenditure in the state budget. It has also partly justified the backwardness of most African countries.

It is for this reason that programming and planning approaches for development in Africa have always taken into account subregional dynamics. However, governments and international partners accuse a systematic lag behind on the activities of armed groups on both sides of the border.

Thus, the failure to achieve lasting peace condemns the continent to incessant episodes of violence (Khazri, 2011). Among the contemporary vectors of armed violence on the continent are: the constant fragility in the aftermath of the 2012 crisis in the Central African Republic; the spread of the conflict with Boko Haram from Nigeria to Chad, Cameroon and Niger; persistent insecurity in the Great Lakes region; abuses by groups such as the Lord's Resistance Army (LRA) in the Democratic Republic of Congo, Central African Republic, Sudan and South Sudan, linked to the illegal exploitation of natural resources; the anticipated tensions following other recent elections in the continent; and maritime insecurity in the Gulf of Guinea (piracy, armed robbery, illegal, unreported and unregulated fishing, trafficking in arms, drugs and human beings, smuggling, etc.).

In addition to this, the African continent experienced between 1 January and 30 September 2016 no less than 1,426 incidents of violence related in one way or another to terrorist activities. During this period, sixteen different African countries were affected by terrorist activities which cumulatively caused about 8,120 deaths. Terrorist organizations on the continent are: Boko Haram, al-Shabaab, al-Qaeda in the Islamic Maghreb (AQIM) and ISIS (Cummings, 2017).

Following all these tensions and conflicts, the military expenditure of the countries of CEMAC subregion, for example, has experienced an extraordinary boom. They were based on the 2016 WDI and in billions of FCFA: 101.5 in 2002 and 209.64 in 2015 for Cameroon; 7.445 in 2002 and 25.549 in 2010 for the CAR; 23.9 in 2002 and 130.7 in 2015 for Chad; 31,908 in 2002 and 454, 92 in 2015 for the DRC; 49.28 in 2002 and 108.16 in 2010 for the Republic of Congo; 66 in 2002 and 100.77 in 2015 for Gabon.

Before the Vietnam War characterized by the use of multiple herbicides; shelling to destroy forests; BLU 82 gravitational bomb, the consequences of the war on the environment were not

taken into account. Indeed, until the beginning of the 20th century, fighting, fighting techniques and armaments did not significantly affect the coherence of nature (Guillard, 2006: 15). However, taking into account the defense environment really begins when the environmental damage by war and military operations have become blatant and long-lasting (see irreversible). Thus, it is the First World War that appears to be founding in this area, "the first conflict to produce lasting damage and extended to the environment" (Guillard, 2006: 16); it was followed by the Second World War, which brought other more violent types of environmental damage.

On the other hand, the assessment and economic integration of weapons damage to the environment in weapon programs appears later, but is not as recent as it may seem. In reality, it is justified, according to Vadrot (2005), by the need to control costs and price drift in armaments and is a means of achieving this.

Therefore, it is undeniable that the issues of disarmament, development and environmental protection are closely linked and constitute one of the major problems facing the international community today. It should also be noted that the success of development and environmental efforts is compromised by increased military spending (Guillard, 2006).

In a context of sustainable development, this study aims to prevent military spending from having unbearable environmental and budgetary consequences for future generations in Africa, knowing that an armament remains warlike or even deadly.

2. Environment and military spending

The environmental consequences of armed conflicts, often secondary to the urgency of peace and the safeguarding of human lives, are nonetheless systematic, harmful and sometimes irreversible. Indeed, "environmental degradation is still more deadly than armed conflict, and each of these phenomena is both the cause and the effect of violent conflict" (UNDP, 2005: 164).

For Guillard (2006), there is significant damage from physical clashes on the environment. The spectacular example provided by the history of the 20th century is probably that of the bombings of Hiroshima and Nagasaki in 1945. Less impressive a priori, there are also non-nuclear bombings, more "classic", but which destroy enough environment for them to be listed. In addition to the power of the bombs in question, which remains important, the repeated effect of such weapons has a heavy impact on the environment. In Africa in general, arable land and forests also suffer from armed conflict, but on a voluntary and planned basis. Thus, it is not

uncommon for ethnic groups to resort to a "modern scorched earth policy" in order to exert pressure on enemy populations. Crops are destroyed, burned, and drought-prone climates do not allow the environment to recover quickly, leading to famine (Vadrot, 2005: 55-56).

War can't be so deadly if the prowess of contemporary chemistry does not offer the opportunity to sterilize entire areas or to poison fresh and natural water supplies. Vietnam's forests still remember Agent Orange, whose some 72 million liters (UNEP, 2009, p.15) have devastated more than three million hectares of forest in less than a decade.

Chemical pollution also affects water, air and soil. Indeed, the destruction of potentially polluting factories via contaminant spills greatly affects soil and air quality at the local scale (UNDP, 2005: 125). It should be remembered that the chemical consequences of conflicts on the environment often cross borders, especially through atmospheric currents and water flows. The fires of oil wells during the Gulf War and the emissions of pollutants gas such as sulfur dioxide caused an exceptional air pollution.

3. Methodology and data

The empirical approach aims to determine the effect of military spending on the environment in Africa. In this section, we first present the estimation technique used (3.1). Next, we explain the mechanism of transmission of the shock of military expenditures to the environment (3.2). And finally, the data will be described (3.3).

3.1. Methodology for estimating the impact of military spending on the environment

This paper seeks to examine the role of military spending on the evolution of CO2, nitrous oxide (NO2) and methane (CH4) emissions. To do this, we considered the countries of Africa.

The first step is to test the existence of a KEC (Kuznets Environmental Curve) for African countries using the econometric specification of the log-linear model. The next step is to augment the model with new variables, namely military expenditures as a variable of interest, trade openness and population density as control variables to detect their effects on the quality of the environment.

The aim is to improve the basic specification of the model by including control variables that can directly or indirectly influence CO2 emissions (metric tons per capita), nitrous oxide (NO2 in CO2 equivalent) and methane (CH4 in CO2 equivalent) of an economy.

$$\ln(CO_2)_{it} = \alpha_0 + \alpha_1 \ln(PIB)_{it} + \alpha_2 (\ln PIB)^2_{it} + \alpha_3 (\ln PIB)^3_{it} + \alpha_4 \ln(DEPM)_{it} + \alpha_5 X_{it} + \varepsilon_{it} \quad (1)$$

$$\ln(CH_4)_{it} = \alpha_0 + \alpha_1 \ln(PIB)_{it} + \alpha_2 (\ln PIB)^2_{it} + \alpha_3 (\ln PIB)^3_{it} + \alpha_4 \ln(DEPM)_{it} + \alpha_5 X_{it} + + \varepsilon_{it} \quad (2)$$

$$\ln(NO_2)_{it} = \alpha_0 + \alpha_1 \ln(PIB)_{it} + \alpha_2 (\ln PIB)^2_{it} + \alpha_3 (\ln PIB)^3_{it} + \alpha_4 \ln(DEPM)_{it} + \alpha_5 X_{it} + \varepsilon_{it} \quad (3)$$

Where the variable GDP is the income it captures the impact of the level of development on the environment. DEPM is the military expenditure in local currency unit (% of GDP), X_{it} is the vector of control variables. The term α_0 represents the unobserved specific effect, ε_t is the error term, α_1, α_2, α_3, α_4 and α_5 are the coefficients to be estimated, t = 1980, ..., 2016 denotes the periods and i = 1, ..., 54 countries of the African continent.

3.2. Isolation of the roles of economic growth in the transmission of military expenditure shocks to the environment.

Several approaches are often used to analyse the transmission channel and the role of a variable in the propagation of a shock in a VAR system. To determine the role of economic growth (GDP) in the spread of military spending shocks to the quality of the environment in Africa, we will use the technique adopted by Bachmann and Sims (2011). Suppose, for example, a third order VAR model with the following variables: military spending, economic growth and a greenhouse gas (CO2, NO2 or CH4). The identification of the hypothesis of the periodicity of the budget variable can be given by:

$$\begin{pmatrix} 1 & 0 & 0 \\ a_{2,1} & 1 & a_{2,3} \\ a_{3,1} & a_{3,2} & 1 \end{pmatrix} \begin{bmatrix} lnDEPM_t \\ lnGDP_t \\ lnGAS_t \end{bmatrix} = \sum_{j=1}^{p} A_j \begin{bmatrix} lnDEPM_{t-j} \\ lnGDP_{t-j} \\ lnGAS_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{bmatrix} \quad (4)$$

Let's determine how economic growth affects the transmission of military spending shocks GAS (this variable represents the greenhouse gas retained in this study). Indeed, if the lnGDP variable reacts immediately to a shock on the lnDEPM variable ($a_{2,1} \neq 0$)and the CO2 immediately reacts to a shock on the lnGDP variable ($a_{3,2} \neq 0$), then,$a_{2,1} \times a_{3,2}$, measures the channel of the lNGDP variable of the impact of military expenditures (lnDEPM) on the greenhouse gas. This is of course the indirect impact of military spending. Conversely, $a_{3,1}$is

the direct impact of the effect of military spending on the environmental quality indicators selected.

Moreover, the variable GDP can function as a shock propagation mechanism of the military spending, whether it has a direct impact or not. Indeed, if the lnGDP variable responds to the shock of the lnDEPM variable at any horizon, and if the delayed value coefficients of the lnGDP variable are globally significant in the relevant gas equation, then the dynamic response of the lnGDP variable to a shock of the military expenditure variable will have an effect on the dynamic response of the greenhouse gas effect at this same shock of the variable military expenditures.

Our goal is to statistically isolate the direct effect (in a dynamic sense) of shocks from military spending on the environment from the indirect effect of this shock shifting through economic growth. We more explicitly construct a hypothetical greenhouse gas response function to military expenditure shocks, assuming the fixed economic growth variable over all periods. The comparison of this hypothetical response with the real impulse response obtained by imposing no constraint on the variable economic growth allows us to evaluate the influence of this last variable in the transmission of shocks from military spending to greenhouse gas.

In order to determine the hypothetical response function, we must first impose more restrictions on the structure of the contemporary shock matrix we call A_0. Since the delay assumption that military spending do not react in a period to the lnGDP variable and Gas is sufficient to identify $a_{2,1}$ and $a_{3,1}$, an additional restriction is necessary for the identification of $a_{3,2}$ and $a_{2,3}$. We start by imposing $a_{2,3} = 0$, which then results to an identification of the system under a Choleski decomposition with the lNGDP variable placed in second position and the Gas in third position. $\varepsilon_{2,t}$ and $\varepsilon_{3,t}$ being respectively the shock of the lNGDP variable and that of the Gas, we use the shock of the lnGDP variable to cancel the response of this variable to a military expenditure shock. In a second step, we neutralize the effect of economic growth in the transmission of the shock of military expenditures by fixing $a_{2,1} = 0$. In other words, we answer the following question: while on average, the response of the environment to a military expenditure shock is composed of a direct effect and an indirect effect (through the lnGDP variable) of on the one hand, and military spending shocks and lnGDP are correlated on the other hand, how would the environment react in a hypothetical situation where the shocks of the lNGDP variable in the same structural economy completely offset the effects of military spending shocks on the lnGDP variable. This eliminates the indirect effect and isolates the

direct effect of the lnDEPM variable on the environment. It is important to emphasize that this decomposition of the real impulse response is purely statistical. This approach is however similar to the methodology used by Bernanke, Gertler and Watson (1997); Sims and Zha (2006) and Killian and Lewis (2011).

3.3. Data

We analyse a panel of 54 African countries over the period 1980-2016 with data from the World Development Indicators (WDI). This study period was chosen because of the lack of data on some indicators for most African countries. The dependent variables are carbon dioxide (CO2 in metric tons per capita), nitrous oxide (NO2 in metric tons of CO2 equivalent) and methane (CH4 in metric tons CO2 equivalent). Our variable of interest is the military spending in local monetary unit (DEPM in% of GDP). Subsequently, we include three control variables namely: (i) population density (DPOP); (ii) official development assistance (AID as a% of GNI) and (iii) trade openness (OUV). This last variable makes it possible to verify the hypothesis of "pollution havens" as developed by Birdsall and Wheeler (1992). Indeed, developing countries attract environmentally damaging activities through less stringent environmental regulation, which reduces production costs and can therefore favor offshoring (Low and Yeats, 1992).

These indicators are taken from the World Development Indicators (2017). The descriptive statistics of the different quantitative variables are summarized in Table 1 while Table 2 lists the different correlations between the variables. The correlation matrices of the variables of the two models suggest a strong correlation between some variables.

Table 1: Descriptive statistics of variables

	Variables	Obs	Mean	Std. Dev.	Min	Max
Dependent variables	lnCO2	1820	-1.101562	1.453323	-4.534475	2.306951
	lnN2O	1749	7.697402	2.067654	1.504578	12.05945
	lnCH4	1749	8.475225	1.866043	2.598034	12.15308
Interest variables	lnGDP	1838	6.97788	1.024402	4.751814	9.920047
	lnGDP2	1838	49.73964	14.9894	22.57974	98.40733
	lnGDP3	1838	362.3744	168.1242	107.2947	976.2053
	lnDEPM	1553	-4.053706	.9994879	-15.19182	-.9261765
Control variables	lnDPOP	1962	-3.73831	.4926886	-7.28284	-2.536045
	lnOUV	1740	-.4378052	.5042448	-2.761397	1.67098
	lnAID	1787	1.793457	1.359896	-7.702086	5.257631

The number of observations is not identical for all the variables because of the missing data.

Table 2: correlation matrix between the variables.

	lnCO2	lnN2O	lnCH4	lnGDP	lnGDP2	lnGDP3	lnDEPM	lnDPOP	lnOUV	lnAID
lnCO2	1.0000	-0.2311	-0.1266	0.8944	0.8911	0.8816	0.0858	-0.3309	0.4208	-0.6716
lnN2O		1.0000	0.9503	-0.2259	-0.2388	-0.2513	0.0620	0.1668	-0.4694	-0.1714
lnCH4			1.0000	-0.1354	-0.1414	-0.1472	0.0808	0.2005	-0.4046	-0.2839
lnGDP				1.0000	0.9968	0.9875	-0.0214	-0.3270	0.4575	-0.7075
lnGDP2					1.0000	0.9970	-0.0233	-0.3314	0.4515	-0.7111
lnGDP3						1.0000	-0.0268	-0.3320	0.4433	-0.7090
lnDEPM							1.0000	0.0981	-0.0432	0.0045
lnDPOP								1.0000	-0.1092	0.2457
lnOUV									1.0000	-0.1026
lnAID										1.0000

It can be seen that indeed Table 2 suggests a positive relationship between the indicators of the chosen environment and military expenditures. This observation is confirmed by Figure 1 below. Indeed, this chart suggests a strong increase of CO2, NO2 and CH4 emissions in almost all African countries as a result of an increased of military spending.

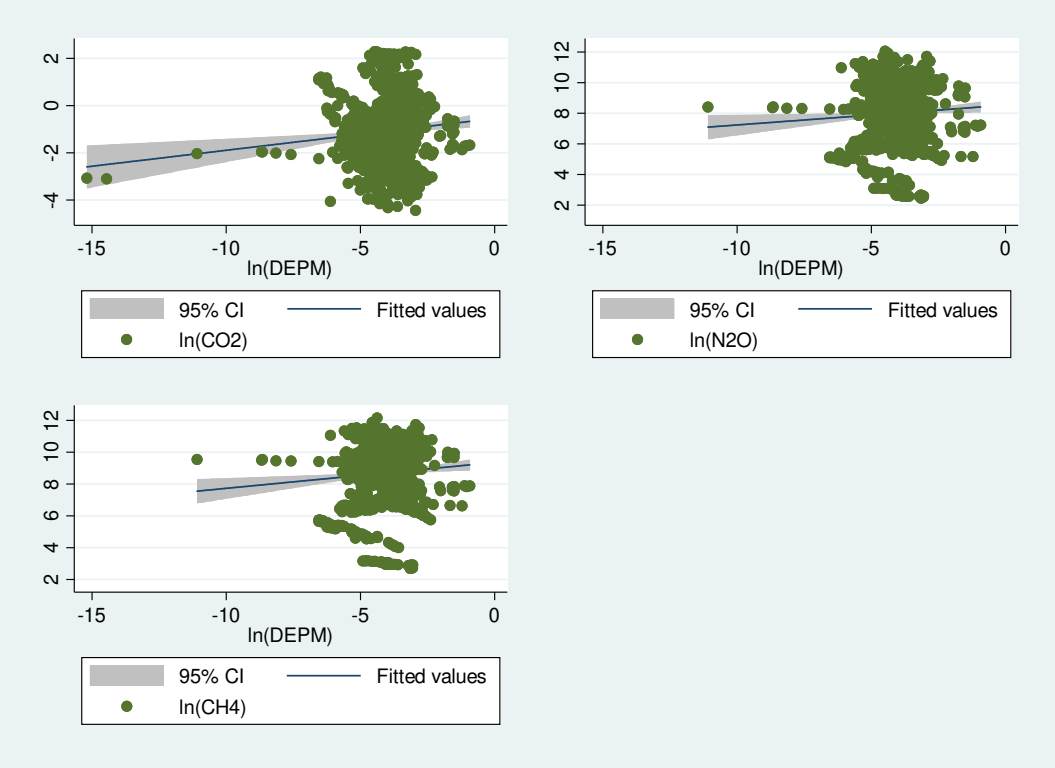

Figure 1: Evolution of environmental indicators according to military expenditure.

To estimate these different equations enabling to determine the impact of military expenditures on the environment on all African countries for the period 1980 to 2016, we opted for the use of GMM in systems (Blundel and Bond, 1998). The choice of this method of analysis is justified by the fact that the future value of our dependent variables is influenced by their past values. This method has enormous advantages for estimating dynamic models compared to traditional methods. This method relies on the orthogonality conditions between the lagged variables and the error term both in first differences and in level. When the dynamic model is expressed in first differences, the instruments are in level and vice versa.

4. Results

In this section we present the results of the estimation of the impact of military expenditures on the environment (4.1). Then, the result of the transmission mechanism of this impact will be discussed in section (4.2).

4.1. Results of the impact of military expenditures on the environment.

Table 3 presents the results of the estimation of the impact of military expenditures on the environment. Three main pieces of information are needed to validate the GMM model with an orthogonal deviation (see Asongu and De Moor, 2017, p.200) namely the validity of the autocorrelation test of Arellano and Bond (1991); Hansen's instrument validity test and Fisher's test for the joint validity of the values of the estimated parameters.

It can be seen that the estimation results allow to accept the presence of the serial correlation of the first order residues (AR (1)) and to accept its absence at the order 2 (AR (2)) for the equation 1. Moreover, equations 2 and 3 accept the serial correlation of order 1 and 2 residues. The Hansen test validates the choice of instruments. The results of the estimated parameters are valid and consistent with economic intuition as evidenced by the Fisher test. In addition, most of the explanatory variables are statistically significant, with positive effects of military spending on the selected environmental indicators.

Table 3: Impact of military expenditure on the environment.

VARIABLES	lnCO2 equation (1)	lnN2O equation (2)	lnCH4 equation (3)
L.lnCO2	0.101***		
	(0.00283)		
lnGDP	-1.818***	-6.798*	14.41***
	(0.521)	(3.751)	(2.835)
lnGDP2	0.461***	1.293**	-1.782***
	(0.0727)	(0.515)	(0.394)
lnGDP3	-0.0236***	-0.0800***	0.0657***
	(0.00332)	(0.0233)	(0.0179)
lnDEPM	0.0976***	0.191***	0.276***
	(0.00873)	(0.0191)	(0.0190)
lnDPOP	-0.255***	0.709***	0.830***
	(0.0114)	(0.0146)	(0.0328)
lnOUV	0.150***	-0.846***	-0.548***
	(0.0206)	(0.0252)	(0.0279)
lnAID	-0.118***	-0.741***	-0.889***
	(0.00626)	(0.0113)	(0.0143)
L.lnN2O		-0.0552***	
		(0.00530)	
L.lnCH4			-0.0595***
			(0.00242)
Constant	-2.971**	24.79***	-21.08***
	(1.245)	(9.004)	(6.623)

Observations	1226	1160	1160
Number of year	35	33	33
AR(1)	1.60e-05	1.01e-05	1.95e-06
AR(2)	0.210	7.77e-05	0.00104
j0	36	36	66
Hansen test of overid	0.141	0.202	0.868
F	42267	15086	11250

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

From this table, it can be seen that the environmental curve takes several forms depending on the variable used to capture the degradation of the environment.

Equations 1 and 2 suggest an inverted N relationship between economic growth and environmental pollution indicators retained by these models. Indeed, $\alpha_1 < 0$; $\alpha_2 > 0$ and $\alpha_3 < 0$, so the relationship between income (GDP) and CO2 emissions and nitrous oxide has a cubic polynomial or inverted N 'shape. In addition, the values taken by these parameters are significant. This result is consistent with that found by Noubissi and Njangang (2017) for Cameroon and by Başar and Temurlenk (2007) for Turkey. On the other hand, the model 3 has a form in " N " because $\alpha_1 > 0$; $\alpha_2 < 0$ and $\alpha_3 > 0$. Similarly, the control and interest variables selected in this study all have a significant influence on the environmental indicators of this study.

Commercial openness has various effects depending on the model. According to these models, it seems not to contribute to the degradation of the environment in Africa on the contrary, it seems to be beneficial for the environment. This can be justified by the fact that in Africa, exports occupy a prominent place in commercial transactions with the outside world. In the same way, imports have been controlled for a long time and limited by the various customs barriers in almost all these countries. In addition, the activities of most households are traditional agricultural activities and the industrial fabric is poorly developed. These models accept essentially the hypothesis of the haven of transmission because the value of its parameter is significant. Model 1, on the other hand, validates the hypothesis of pollution haven. Development Aid (AID) helps to improve the environment regardless of the model. The population density improves the environment for model 1 and degrades the environment for models 2 and 3. This result confirms the results found by Brajer et al. (2007) who show that the increase in population density is associated with an increase in sulfur dioxide emissions in China.

Our variable of interest (military spending) contributes to environmental degradation regardless of the indicator chosen. Indeed, the multiplicity of conflicts and terrorist groups on the continent undoubtedly justifies the increase of military expenditures in the budget of African states. Conflicts are always accompanied by a degradation of the natural environment. It is undeniable that issues of disarmament, development and environmental protection are closely linked and constitute one of the major problems facing African countries today. Development can't be sustained at the right pace, nor can the safety of the environment be guaranteed, as the arms race continues to accelerate. It should also be noted that the success of development and environmental efforts in Africa is compromised by the accumulation of weapons, the deliberate or accidental use of which would put the very existence of human beings at risk in danger.

4.2. Role of economic growth in the transmission of military expenditures to environmental degradation

Table 4 gives the coefficients of the impulse responses of the environmental quality indicators (CO2, NO2 and CH4) selected for this study to a military spending shock, with an understanding of the role of economic growth in the 54 countries of the world. Africa. Thus, for each military spending shock, the "real" column gives impulse responses of the environmental indicator concerned to this shock by considering a reaction of economic growth to the shock. On the other hand, the "hypothetical" column gives the responses of the environmental quality indicator to this shock by taking economic growth as zero over the entire period. The assessment of the role of economic growth in the transmission of military expenditure shocks to the environment is made through the comparison of impulse responses. The results of this table show that the influence of economic growth in transmission of unemployed military expenses shocks can be grouped into two categories.

Table 4: Real and hypothetical impulse responses of environmental indicators to shocks to military expenditures in Africa.

	lnCO2 reponses		lnCH4 reponses		lnN2O reponses	
Periods	**Hypothetical**	**Real**	**Hypothetical**	**Real**	**Hypothetical**	**Real**
1	-0.004367	-0.002103	-0.004436	0.114664	-0.003529	-0.003634
2	-0.000256	0.003479	-0.002560	0.074012	-0.002071	-0.001642
3	-0.004351	0.000199	-0.004050	0.088414	-0.003690	-0.002219
4	-0.005116	-0.000277	-0.003739	0.083269	-0.003678	-0.002187
5	-0.006351	-0.001363	-0.003861	0.084967	-0.003875	-0.002177
6	-0.007310	-0.002271	-0.003752	0.084258	-0.003915	-0.002196
7	-0.008217	-0.003165	-0.003679	0.084378	-0.003938	-0.002185
8	-0.009064	-0.004016	-0.003579	0.084208	-0.003941	-0.002185
9	-0.009865	-0.004832	-0.003484	0.084136	-0.003937	-0.002179
10	-0.010628	-0.005612	-0.003387	0.084030	-0.003929	-0.002174

In the first category, economic growth plays a relatively small role in spreading shocks from military spending to environmental degradation. Looking at the results in Table 4, it appears that in this category we have the shock of military spending on nitrate (N2O) emissions. Indeed, for this shock, we can notice that the impulse and real responses have small differences implying that economic growth plays a minimal role in the transmission of the shock of military spending on nitrate emissions in Africa.

Finally, it is in the second category that economic growth plays an important role in the propagation of military expenditure shocks. Indeed, the hypothetical and actual impulse responses of carbon dioxide and methane emissions in Africa indicate relatively large differences.

5. Conclusion and policy implications

The purpose of this paper was to examine the effects of military spending on CO2, NO2 and CH4 emissions in Africa. From the panel data for 54 countries and a period from 1980 to 2016, the GMM method and the structural VAR model were applied. Overall, it appears that the relationship between the main greenhouse gas emissions in this study and GDP is in the form of " inverted N " or " N ". The explanatory variables selected have different effects depending on the models. However, our interest variable helps to degrade the environment regardless of the environmental degradation indicator used. Economic growth plays an important role in spreading shocks from military spending to the environment.

Politically, the leaders of African countries must better control or reduce their military spending. This is possible by acting on the main causes of conflict in Africa, that is, better distributing national wealth and improving the quality of governance. By interacting with these elements, it is possible to reduce conflicts in Africa and consequently military spending.

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