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RESEARCH ARTICLE

Institutions' quality and environmental pollution in Africa

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Abstract

This paper tests the pollution emissions and institutional quality nexus in Africa. Specifically, we analyze the effect of the political regime and the quality of political governance on CO_2 emissions. To control for endogeneity, we apply the system generalized method of moments on a dynamic panel of African countries over the period 1996–2020. The key finding suggests that better institutions have a negative and significant effect on pollution in Africa. The findings also validate the environmental Kuznets curve hypothesis. Moreover, the results support the pollution haven hypothesis. Finally, if digitalization significantly curbs pollution, then industrialization, natural resources, as well as the intensive use of energy, are considered as positive predictors. All the sensitivity and robustness tests globally validate the strength of the negative association between the good quality of institutions and the level of polluting emissions in Africa. The results call for some policy recommendations in environmental regulation for African economies.

Keywords: CO_2 emissions; environmental Kuznets curve; institutions' quality; pollution haven; waves of democracy

JEL classification: Q00; Q01; Q50; Q56; E02

1. Introduction

The agreement reached at the climate change conference held in Paris (COP 21) at the end of 2015 is historically unprecedented. It stresses the urgency for countries of the world to set up actions to protect the environment. For example, it explicitly foresees limiting the increase in temperature below 2° degrees Celsius and even bringing it down to 1.5° degrees Celsius. It is a flexible agreement, because it accounts for the needs and capacities of each country, with a periodic review of ambitions. More specifically, the agreement recommends a progressive and gradual reduction of greenhouse gas (GHG) emissions across the world. Moreover, this agreement also shows that no real development plan can be conceived without integrating environmental concerns, thus reinforcing the problem of sustainable development (that is, the need to reconcile economic development with environmental protection).

In Africa, the situation is paradoxical. This continent contributes little to global pollution but suffers more than others from the multiple effects of environmental degradation. These effects are the result of the relocation of most polluting industries, bringing about increases in water and air pollution. This paper aims to test the link between pollutant emissions and institutional quality in Africa, through the political regime and governance.

On a factual level, the trend in global pollution has increased globally over time. Between 1990 and 2020, almost all regions of the world experienced sustained growth in carbon dioxide (CO_2) emissions (WDI, 2023). Globally, CO_2 emissions increased from 21,284,043 to 33,566,428 kilotons, an increase of 57.71 per cent over the period under review. This global allocation is unevenly distributed, with regions such as Asia dominating over time. As an illustration, the global growth rate between 1990 and 2020 is 292.71 per cent in South Asia and 240.29 per cent in East Asia and the Pacific. Regions such as Europe & Central Asia and North America made commendable progress, with overall growth rates of −29.19 per cent and −8.10 per cent respectively. However, this performance is not sufficient to curb the strong growth momentum observed worldwide.

The situation in Africa is paradoxical. Illustrated by a low global contribution (the weight of Sub-Saharan Africa (SSA) has increased from 1.89 per cent in 1990 to 2.27 per cent in 2020, while that of North Africa has evolved from 4.04 to 7.20 per cent), it is however materialized by an equally exceptional growth. In North Africa and the Middle East, CO_2 emissions grew by 180.92 per cent, and that of SSA by 89.36 per cent. These trends show that the issue of pollution must now be addressed with urgency in Africa, given its multiple potential negative consequences.

At the institutional level, there are contrasting developments in Africa. The index of the quality of policies and institutions for environmental sustainability (1 = low, …, 6 = high) has decreased in North Africa, ranging from 3.00 in 2005 to 2.50 in 2020. At the same time, it appears to have increased in SSA, from 3.05 to 3.26. Furthermore, the evolution of the political environment shows that since the democratic transition of the 1990s, the number of autocratic regimes has declined, with this decline being offset by a positive increase in democratic regimes, symbolically translated into what Huntington (1991) calls democratic waves.

According to Marshall and Elzinga-Marshall (2017), from independence to the 1990s, the number of autocratic regimes in Africa increased from five to 30, with the number of autocratic regimes falling to ten in the early 1990s and to just over five since the 2000s. In contrast, the number of democratic regimes has increased from three in 1990 to about 20 in 2018 (note that between 1960 and 1990, the number of democratic regimes fluctuated around five). However, these trends are skewed by the number of anocracies, which jumped between 1990 and 2010, and then stabilized around 20 since the second half of the 2010s. This favorable evolution of the number of democracies in Africa, coupled with the decrease in the number of dictatorial regimes, calls for an empirical examination of its potential effects on polluting emissions.

This paper contributes to the existing literature on several points:

– First, it considers not only the overall effect of institutions on the level of pollution, but also the differential effect of the characteristics of democratic and governance institutions on pollution levels. In doing so, we characterize the different institutions according to their quality and we assess the expected effects. This approach is more refined in that it allows us to

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design appropriate economic policies according to the characteristics of the institutions.

- Second, we integrate sub-regional heterogeneity to detect specificities and design policies specific to each sub-region and to design country-specific policy treatments as needed. In other words, making global policies from average information would be a difficult challenge given the heterogeneities across countries and regions in Africa.
- Third, we analyze whether the natural vulnerability of countries to their geographical conditions influences their environmental policies. Thus, we try to prove whether invariant factors that depend on natural predispositions explain the level of pollution.
- Fourth, we consider the inertial effect of CO_2, i.e., the length of its memory effect. As pollution is a global public good through the environment it affects, we contribute by characterizing a framework that would enable us to design dynamic policies, with the severity/depth of the tools used being proportional to the hysteresis of the phenomenon. In other words, the intensity of policies and reforms should be proportioned or scaled as the self-sustaining effect of pollution diminishes or increases over time.
- Fifth, we use a set of institutional indicators and pollution variables to understand holistically the nature of the relationship between the quality of institutions and pollution. This allows us to anticipate both the adverse effects of institutions and the direction they need to take to ensure their regulatory function in the economy.
- Finally, we build original instruments to control for potential endogeneity between institutional indicators and pollution. To do so, we draw on the work of Huntington (1991) and Persson and Tabellini (2009), who respectively developed the theories of 'waves of democracy' and 'democratic capital abroad'. These theoretical frameworks enabled us to calculate empirically robust instruments ('democracy abroad' and 'governance abroad'), to effectively calibrate the external instrumentation strategy implemented at the end of this paper (see section 7).

Using instrumental variables techniques to control for endogeneity, and after several sensitivity and robustness tests, we establish a negative and significant association between the good quality of institutions and the level of pollution emissions in Africa.

Following this introduction (section 1), the rest of the paper is organized into seven additional sections. Section 2 presents some literature underpinnings. Section 3 addresses the empirical strategy. Section 4 presents and discusses the main findings. In section 5, we run some sensitivity tests. Section 6 is devoted to robustness analyses. Section 7 provides an analytical framework for further controlling endogeneity using original, theoretically sound external instruments of our design. Section 8 concludes with some recommendations.

2. Literature underpinnings

Theoretically, one of the fundamental debates on environmental pollution pits two rival schools of thought. For the post-Keynesians, notably Oates and Baumol (1975), the consequences of free trade are the vicious circle favoring pollution. Based on a two-country model, one poor with a 'weak' regulation and another rich with a 'strong' regulation, the post-Keynesian school shows that the polluting industries are moving from the rich country to the poor country: this refers to the environmental dumping hypothesis. On the other hand, according to the Heckscher–Ohlin–Samuelson model, firms' relocation depends on the availability of production factors, but not on institutional laxity. For example, firms that specialize in products requiring a high level of capital (or labor) will settle in countries that are strongly endowed with this factor. Thus, one can have an opposite effect to that envisaged by Oates and Baumol (1975).

Empirically, two main hypotheses are generally discussed, namely the environmental Kuznets curve (EKC) hypothesis and the pollution haven hypothesis. The EKC hypothesis was tested for the first time by Grossman and Krueger (1995) who succeeded in demonstrating that, initially, environmental quality deteriorates with increasing income. From a certain level of wealth, economic growth would be accompanied by an improvement in environmental quality; that is, society has the means and the will to reduce the level of pollution. Recent work on the existence of an EKC has led to controversial results (Mania, 2020; Filippidis *et al.*, 2021; Ongan *et al.*, 2021; Li *et al.*, 2022).

As for the pollution haven hypothesis, it highlights the effect of differences in legislation on environmental degradation (Suri and Chapman, 1998; Cole, 2004; Stern, 2004). Indeed, international trade is responsible, everything being equal, for environmental damages caused by relocations (Suri and Chapman, 1998) to countries with soft regulations. This effect results from a pollution transfer from industrialized to developing countries. Recent works attempt to confirm this result with more robust and sophisticated empirical tools (Li *et al.*, 2022; Ma and Shi, 2022). Studies on environmental degradation are also related to the population effect and institutional quality (Cole, 2007), identified in this paper as among the main determinants.

The role of institutions in the development of modern economies is undeniable. Institutions define the development framework by modeling the behavior of individuals in the society, who are required to consider them as rules of the game, whether formal or informal (North, 1990). Otherwise, institutions are questioned through the prism of their measurement and performance in several areas of the economy (Rodrik *et al.*, 2004). Existing literature on the institutions–environmental nexus has been conflicting. More generally, institutions play an important role in environmental performance (Andersson, 2018). Bernauer and Koubi (2009) show that the political institutions measured by the level of democracy and the political system have an impact on the environment. Interesting results are also determined by isolating the effects of corruption and the informal economy, and the effects of regulatory quality (Gani, 2013).

Also, institutional arrangements are key to adaptation as the latter rarely occurs in an institutional vacuum. The literature also highlights that the community adapts to the effects of climate change depending on the nature of institutions, be they public or private (Mubaya and Mafongoya, 2017). However, government efficiency coupled with economic growth harms the environment, while the index of institutions has a positive effect on the environment in SSA (Yameogo *et al.*, 2021). Conversely, factors such as control of corruption, regulatory quality, and economic activities must play a major and significant role in the sustainability process. Economic globalization and institutions have negative and positive impacts on the environment (Cole, 2007). In addition, factors such as the rule of law, regulatory quality, and control of corruption are the governance dimensions that contribute to environmental quality in the long run (Simionescu *et al.*, 2022). In general, environmental protection is a central issue for policymakers.

3. Empirical strategy

3.1 The model

This paper adopts an extension of the basic model of Grossman and Krueger (1995), which examines the relationship between the level of development and pollution indicators. In its canonical form, the model establishes an empirical and non-linear logarithmic relationship between a pollution indicator and GDP per capita (Stern, 2004). Beyond the squared term that captures the nonlinear relation between pollution and GDP per capita (EKC hypothesis), Grossman and Krueger (1995) include a cubic term to test N-shape EKC (Stern, 2004). This 'recoupling' effect captures the resumption (overlapping effect) of pollution with the increase in per capita income after a certain threshold. Depending on the objective of the research, the basic specification of the model can be improved through the inclusion of several variables. However the focus of this paper is on the role of institutions, captured by two groups of variables, namely the political regime (PR) and the six governance indicators (Gov) of the World Bank.

Adopting a panel data specification and including additional control variables, the estimated model is given as follows:

$$\begin{aligned}\text{Log}(\text{Poll}_{it}) = \gamma_0 + \gamma_1 \text{Log}(y_{it}) + \gamma_2 (\text{Log} y_{it})^2 + \gamma_3 \text{PR}_{it} \\ + \gamma_4 \text{Gov}_{it} + \gamma_5 X_{it} + \mu_i + \varphi_t + \varepsilon_{it}.\end{aligned}$$

Poll is the indicator of environmental degradation (CO_2 metric tons per capita); $\boldsymbol{y}$ is real per capita income; PR is the political regime; Gov captures governance indicators; $\boldsymbol{X}$ is a set of control variables such as the level of industrialization, natural resource rents, energy intensity, digitalization, and trade openness; μ_i is the country's fixed effects; φ_t is the time fixed effects and ε is the error term.

3.2 Variables and data

This paper uses three main types of variables (environmental, economic and institutional). The dependent variable is the log of CO_2 emissions. The emissions related to CO_2 are those stemming from the burning of fossil fuels and the manufacturing of cement. They include CO_2 produced during the consumption of solid, liquid, and gas fuels, and gas flaring, respectively. CO_2 emissions are considered in recent studies as a relevant measure of environmental quality (Marques and Caetano, 2022; Nchofoung and Asongu, 2022). Other pollution variables such as methane, nitrous oxide, fine particulate matter ($PM_{2.5}$), GHGs, and environmental footprint are reserved for robustness.

The GDP per capita is one of the key predictor variables of our model. According to the World Bank (WDI, 2023), GDP per capita is calculated as gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes, and minus any subsidies not included in the value of the products. The calculation supposes no deductions for the depreciation of fabricated assets or the depletion and degradation of natural resources. Data are in constant 2010 US$.

Institutional indicators are considered as variables of interest in this paper. They are relative to the political regime (Polity2) and the World Bank's six indicators of governance, namely: voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. The variable Polity2 ranges from −10 (autocratic regime) to +10 (democratic regime), and the governance indicators are between −2.5 (very bad quality) and +2.5 (very good quality). We expect a negative sign for the coefficients associated with institutions. Also, we generate a governance index by simple averaging, given the similarity of the dimensionality of the six indicators. This homogeneity in their basic characteristics guarantees the robustness of the index obtained. For robustness purposes, we will use some political risk indicators of the International Country Risk Guide (ICRG).

Additional control variables were included to ensure model parsimony and to further control for variables' omission bias. For this purpose, we consider industrialization, measured as industrial value added as a proportion of GDP. Following Cherniwchan (2012), this variable captures the pace of structural transformation of the economy, whether this transformation is polluting or not. Also, the consideration of natural resources in the explanation of the dynamics of polluting emissions makes it possible to determine whether the rent which results from it can set up anti-pollution measures, but in particular to see if the exploitation of natural capital with regard to the equipment used is harmful to the environment.

The third variable is energy intensity, which is the ratio of a country's energy consumption to its GDP. In other words, concerning the environment, the amount of energy needed to produce a unit of product can be harmful to the environment (Li *et al.*, 2022) if the mix does not promote renewable energy. In this context, a significant weight of non-renewable energies in the energy mix would be a determining factor in polluting emissions. The fourth additional control variable is digitalization, measured as the rate of internet penetration per 100 people. Following Avom *et al.* (2020) and Evans and Mesagan (2022) among others, this variable allows us to understand how digitization influences pollution by reducing transactions and factor movements. One would expect a negative sign.

Finally, trade openness (ratio of exports and imports to GDP) is considered to test the pollution haven hypothesis. It affects the level of pollution through three channels materialized by three effects (Grossman and Krueger, 1995; Copeland and Taylor, 2005). The first is the *scale effect*, due to a positive association between income and pollution levels. The second effect is described as a *composition effect*, arising from the contribution of the respective sectors of the economy to pollution. The last effect, the *technical effect*, explains the level of pollution by the polluting quality or not of the production equipment. These three effects make the relationship between trade openness and pollution ambiguous.

The data comes from three main sources: the World Bank (WDI, 2023) for environmental and macroeconomic variables, Polity IV of the Centre for Systemic Peace for the democratic regime, and the Worldwide Governance Indicators for governance indicators. Other data sources such as the South Pacific Applied Geoscience Commission, the United Nations Environment Program, the Global Footprint Network, Varieties of Democracy (V-Dem), and the ICRG were used for sensitivity and robustness. The sample covers 50 African countries[1] over the period 1996–2020. The choice

[1]The countries are Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, DR Congo, Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

of this period is constrained by the availability of data on the World Bank's governance indicators.

3.3 Identification strategy and estimation technique

Four main empirical critiques related to heteroscedasticity, simultaneity, omitted variables bias, and cointegration are addressed in the modeling of pollution and its main determinants (Stern, 2004). However, most studies failed to prove the existence of heteroscedasticity. Moreover, the question of cointegration is not a matter of urgency since we use panel data. Following Stern (2004) and Cole (2004), there remains the issue of endogeneity, which requires the use of instrumental variable techniques. In this paper, we use the generalized method of moments (GMM) estimator through a dynamic panel specification to capture the lagged effect of the emission on its current level and to efficiently correct the endogeneity bias. According to Baum *et al.* (2003), this technique is more appropriate in the presence of an unknown form of heteroscedasticity.

One can attest to a bi-directional link between the level of emissions and some of its determinants (GDP per capita, industrialization, etc.), just as some variables can be measured with errors (institutions, etc.). In this context, we could suspect an endogeneity bias. Indeed, in a dynamic panel model, the countries' unobservable specific effects are correlated with the lagged dependent variable, which provides inconsistent estimators under ordinary least squares (OLS). However, as in Nchofoung and Asongu (2022), the GMM estimator becomes consistent under this condition. Using the lagged values of the first difference of the endogenous variable as instruments, Arellano and Bond (1991) developed a consistent estimator, called the difference GMM estimator. However, Blundell and Bond (1998) demonstrated that when the dependent variable is persistent over time, lagged values are very poor instruments. Using additional conditions of moment, they proposed a more robust alternative estimator called the system GMM estimator from a system of two equations, one in level and the other in first difference.

Several other arguments can be used to justify the GMM estimator. First, our specification obeys Roodman's (2009) condition that the number of countries (50) must be much larger than the number of periods (25). Second, the inertial effect of CO_2 is high, as the correlation between the dependent variable and its lagged value is strongly significant; this leads us to retain the lagged CO_2 as an important determinant of current emissions. Third, the GMM estimator is biased when the estimation strategy imposes too many instruments. To overcome this problem, we follow the approach of Arellano and Bover (1995) extended by Roodman (2009), which consists of limiting the number of instruments and maximizing the sample size by using the forward orthogonal deviation technique. Also, since the one-step GMM estimator retains a heteroskedastic error structure, we apply the two-step estimator to correct this bias. Finally, our identification strategy poses problems related to the simultaneity of the variables and to the set of restrictions to be observed. Faced with these problems, the recent literature (see Nchofoung and Asongu, 2022) advises considering all the explanatory variables as a potential source of endogeneity, with time-fixed effects having made it possible to instrument the equations in level and in difference.

For this purpose, the set of equations that generates our system GMM estimator is:

$$\begin{aligned}\text{Log}(\text{Poll}_{it}) = {} & \gamma_0 + \alpha \text{Log}(\text{Poll}_{it-1}) + \gamma_1 \text{Log}(y_{it}) + \gamma_2 (\text{Log} y_{it})^2 + \gamma_3 \text{PR}_{it} \\ & + \gamma_4 \text{Gov}_{it} + \gamma_5 X_{it} + \mu_i + \varphi_t + \varepsilon_{it}\end{aligned}$$

$$\begin{aligned}\text{Log}(\text{Poll}_{it}) - \text{Log}(\text{Poll}_{it-1}) + \alpha[\text{Log}(\text{Poll}_{it-1}) - \text{Log}(\text{Poll}_{it-2})]\\ + \gamma_1[\text{Log}(y_{it}) - \text{Log}(y_{it} - 1)] + \gamma_2[(\text{Log}y_{it})^2 - (\text{Log}y_{it-1})^2]\\ + \gamma_3[\text{PR}_{it} - \text{PR}_{it-1}] + \gamma_4[\text{Gov}_{it} - \text{Gov}_{it-1}] + \gamma_5[X_{it} - X_{it-1}]\\ + (\varphi_t - \varphi_{t-1}) + (\varepsilon_{it} - \varepsilon_{it-1}).\end{aligned}$$

GMM is a generalization of the method of moments (MM) that allows for more moment conditions than there are parameters to estimate. This makes GMM more efficient than MM, as it can use more information to estimate the parameters. In addition to being more efficient than MM, GMM has several other advantages, including: (i) robustness to misspecification: GMM is robust to misspecification of the model's distribution. This means that the estimates will still be consistent even if the model is not exactly specified; (ii) ability to handle overidentifying restrictions: GMM can handle overidentifying restrictions, which are additional restrictions on the parameters of the model. These restrictions can be used to test the validity of the model and to improve the efficiency of the estimates; and (iii) ability to handle non-stationary data: GMM can handle non-stationary variables in mean and variance over time. This makes it a useful tool for analyzing time series data.

3.4 Data main characteristics

The validation of estimates must be preceded by a battery of tests applicable to panel data. These statistics/tests give us a glimpse of the main characteristics of the variables, their level of correlation and collinearity, and above all their cross-sectional dependence and stationarity.

As for the main statistical characteristics of the variables selected for our study, two main trends emerge, based on the proportionality of the first two moments of their distributions (table A1, online appendix). Thus, we observe variables clustered around their means (GDP, manufacturing value added for industrialization, energy intensity and trade openness), characterized by their under-dispersion. The other variables (natural resource rents and institutional indicators) are over-dispersed, with their standard deviations being greater than their means.

Then, before proceeding with the econometric analysis, it is important to consider the level of bilateral correlation between the variables in order to anticipate the expected signs of the different relationships. The correlation matrix (table A2, online appendix) shows that pollutant emissions are positively correlated with real GDP per capita, industrialization, natural resource exploitation, internet connectivity, and trade openness. In general, institutional indicators are negatively correlated with pollution levels. This bivariate analysis tends to reinforce the intuition that better institutions constrain polluting emissions. Indeed, such institutions would be governed by, among other things, a democratic political regime, low levels of corruption, political stability combined with an absence of violence, the rule of law, good regulatory quality, good representativeness of the people (voice and citizenship), and efficient government.

However, the high level of some correlation coefficients could induce a suspicion of multicollinearity. To verify this, we conduct the variance inflation factor (VIF) test. This test reveals that our variables are not strongly correlated with all VIF statistics being below 10 (table A3, online appendix), the threshold at which multicollinearity becomes critical. For this test, we retained several specifications depending on the type

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of governance indicator and according to the average level of governance using an aggregate index.

Finally, we check for the cross-sectional dependence of our series and we implement the related unit root tests. In general, the robustness of the results of a GMM estimation is enhanced in the presence of stationary variables. However, stationarity tests in panel data are conditioned by the presence or absence of cross-sectional dependence between countries (Pesaran, 2015, 2021), which first requires carrying out this test and implementing the unit root test(s) controlling for this dependence. Indeed, by ignoring the cross-sectional dependence between the variables used, most of the unit root tests conclude that the variables are stationary (Banerjee *et al.*, 2004), which is not always the case in reality.

Apart from governance indicators, our results stipulate that the economic structures of the countries in our sample are strongly linked or integrated. In other words, real shocks (GDP), pollution shocks, natural resource price shocks, energy shocks, digital transformation, trade shocks and (non-) democratic waves, could easily be transmitted from one African economy to another, through more or less complex mechanisms. In other words, the dependence is strong for CO_2 emissions, real GDP per capita, natural resources, energy intensity, the level of internet connectivity, trade openness and the political regime, but weak for most governance indicators (table A4, online appendix).

Under these conditions, the second-generation panel data unit root tests effectively controlling for cross-sectional dependence are indicated. As a reminder, the first-generation tests come up against two identical problems, namely the heterogeneous nature of the unit root and the failure to consider inter-individual independence. We use two tests in this paper, namely the test of Breitung and Das (2005) and the test of Pesaran (2007). The results validate the stationarity of the majority of the pooled series (table A4, online appendix), which does not weaken our empirical strategy (the non-stationary variables are significantly stationary in first difference).

4. Main findings

Overall, the pollution level of the previous year has a positive and highly significant memory effect. *Ceteris paribus* and on average, an increase of one point in the previous level of emission increases its current level, ranging from 0.31 to 0.40 points. This result implies a vicious circle of pollution that is difficult to break (table 1). The results for our institutional variables validate the general intuition. They generally show that the democratization of political regimes is negatively associated with pollutant emissions, illustrating the ability of good democratic institutions to promote pro-environmental policies. The effect remains highly significant for all specifications. Recent studies show that the level of democracy matters in environmental regulation in general (Acheampong *et al.*, 2022; Ahmed *et al.*, 2022; Kim *et al.*, 2022).

As for the institutional governance indicators, the results show that they address pollution when they are of good quality. Thus, by improving the quality of political governance, countries can easily curb the harmful effects of environmental pollution. This result, which is significant for any specification, suffers from an asymmetry in magnitude. In other words, the different institutional dimensions, while exerting a negative effect on the level of pollution, do not have the same magnitude. A more significant result is apparent for control of corruption, government effectiveness, and global governance index. It is less significant for the other indicators. These promising results for Africa

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Table 1. Institutions and pollution in Africa: basic results

	Dependent variable: CO_2 emissions (metric tons per capita, in Log)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged dep. var.	0.391 (0.0263)	0.329 (0.0310)	0.385 (0.0264)	0.315 (0.0307)	0.393 (0.0263)	0.332 (0.0311)	0.393 (0.0263)
ln(GDPPC)	3.708 (0.302)	5.812 (0.553)	3.790 (0.304)	6.128 (0.544)	3.745 (0.303)	5.472 (0.540)	3.720 (0.303)
ln(GDPPC) squared	−11.23 (1.063)	−19.06 (2.067)	−11.45 (1.064)	−19.94 (2.022)	−11.46 (1.073)	−17.81 (2.021)	−11.30 (1.069)
Industrialization		0.0193 (0.00334)		0.0187 (0.00330)		0.0188 (0.00343)	
Natural resource rents		0.00169 (0.00164)		0.00127 (0.00162)		0.00151 (0.00166)	
Energy intensity		0.0223 (0.0104)		0.0223 (0.0101)		0.0189 (0.0104)	
Internet		−0.0036 (0.000943)		−0.0046 (0.000957)		−0.0032 (0.000938)	
Trade openness		0.00328 (0.000720)		0.00330 (0.000711)		0.00334 (0.000726)	
Polity2	−0.0105 (0.00469)	−0.00150 (0.000663)	−0.0114 (0.00467)	−0.000248 (0.000695)	−0.00961 (0.00463)	−0.00149 (0.000671)	−0.00889 (0.00487)
Control of corruption	−0.0426 (0.0059)	−0.164 (0.0587)					
Government effectiveness			−0.0529 (0.0257)	−0.155 (0.0282)			
Political stability …					0.0948 (0.0596)	−0.0340 (0.0617)	
Regulatory quality							0.0349 (0.0546)
Rule of law							
Voice and accountability							
Governance index							
Observations	1,080	1,071	1,079	1,051	1,080	1,051	1,080
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of instruments	43	41	38	42	43	39	40
Number of countries	50	50	50	50	50	50	50
AR1 p-value	0.0006	0.0077	0.0034	0.0057	0.0005	0.0006	0.0008
AR2 p-value	0.4713	0.6008	0.6503	0.4724	0.3494	0.4920	0.5826
Hansen p-value	0.218	0.125	0.312	0.189	0.142	0.225	0.405

Continued.

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Table 1. *Continued.*

	Dependent variable: CO_2 emissions (metric tons per capita, in Log)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DHT for instruments							
(a) In level							
Hansen excluding groups	0.566	0.273	0.676	0.476	0.387	0.561	0.387
Diff(null H = exogenous)	0.313	0.387	0.268	0.313	0.513	0.095	0.673
(b) iv(years, eq(d))							
Hansen excluding groups	0.582	0.441	0.369	0.471	0.804	0.468	0.388
Diff(null H = exogenous)	0.468	0.593	0.791	0.493	0.787	0.491	0.698
	Dependent variable: CO_2 emissions (metric tons per capita, in Log)						
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Lagged dep. var.	0.338 (0.0309)	0.377 (0.0257)	0.331 (0.0308)	0.393 (0.0263)	0.332 (0.0311)	0.394 (0.0264)	0.327 (0.0309)
ln(GDPPC)	5.680 (0.541)	4.067 (0.299)	5.511 (0.535)	3.733 (0.303)	5.541 (0.547)	3.716 (0.303)	5.846 (0.551)
ln(GDPPC) squared	−18.41 (2.015)	−12.36 (1.050)	−17.89 (2.004)	−11.33 (1.067)	−18.12 (2.051)	−11.30 (1.066)	−19.09 (2.052)
Industrialization	0.0175 (0.00339)		0.0189 (0.00333)		0.0192 (0.00336)		0.0183 (0.00334)
Natural resource rents	0.00131 (0.00164)		0.000979 (0.00164)		0.00173 (0.00169)		0.00190 (0.00164)
Energy intensity	0.0198 (0.0102)		0.0149 (0.0102)		0.0193 (0.0104)		0.0231 (0.0103)
Internet	−0.0038 (0.000962)		−0.0042 (0.000950)		−0.0032 (0.000940)		−0.0038 (0.000951)
Trade openness	0.00321 (0.000719)		0.00322 (0.000718)		0.00336 (0.000725)		0.00337 (0.000717)
Polity2	−0.00141 (0.000663)	−0.0298 (0.00535)	−0.00158 (0.000660)	−0.00884 (0.00473)	−0.00146 (0.000669)	−0.00951 (0.00465)	−0.00103 (0.000682)
Control of corruption							
Government effectiveness							
Political stability …							
Regulatory quality	−0.160 (0.0569)						

Continued.

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Table 1. *Continued.*

	Dependent variable: CO_2 emissions (metric tons per capita, in Log)						
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Rule of law		0.381	0.235				
		(0.0557)	(0.0481)				
Voice and accountability				0.0600 (0.0562)	−0.0519 (0.0545)		
Governance index						−0.0587 (0.0085)	−0.242 (0.0145)
Observations	1,051	1,080	1,051	1,080	1,051	1,080	1,050
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of instruments	40	39	38	45	42	44	38
Number of countries	50	50	50	50	50	50	50
AR1 p-value	0.0006	0.0007	0.0084	0.0017	0.0025	0.0036	0.0003
AR2 p-value	0.5824	0.7119	0.7614	0.5835	0.4605	0.6031	0.6937
Hansen p-value	0.43	0.336	0.523	0.414	0.353	0.236	0.617
DHT for instruments							
(a) In level							
Hansen excluding groups	0.558	0.265	0.668	0.468	0.379	0.553	0.379
Diff(null H = exogenous)	0.494	0.561	0.449	0.494	0.694	0.276	0.858
(b) iv(years, eq(d))							
Hansen excluding groups	0.513	0.372	0.328	0.402	0.735	0.391	0.311
Diff(null H = exogenous)	0.371	0.503	0.745	0.403	0.697	0.401	0.608

Note: Standard errors in parentheses.

are put into perspective in several recent seminal works (e.g., Mignamissi and Djeufack, 2022).

The findings validate the existence of an EKC in Africa. In other words, the level of pollution tends to increase with per capita wealth up to a certain threshold. The relationship remains robust in all specifications. Among the additional control variables, industrialization, natural resource rents, intensive energy use, and trade openness are factors of environmental pollution in Africa (Nchofoung and Asongu, 2022).

Indeed, industrialization is perceived as a polluting factor for African economies. In their structural transformation process, African countries have opted to allocate their resources from low value-added to high value-added sectors. In other words, to the detriment of agriculture, countries are promoting industrialization, sometimes by attracting highly polluting industries. This analysis is partially opposite to that of Mignamissi and Djeufack (2022), illustrating that pollution is an increasing function of industrialization in developing regions.

Furthermore, natural resource rents are an increasing function of their degree of exploitation. If the exploitation of resources is abusive and intensive, it requires the use of heavy means and equipment that are generally polluting, especially in countries that are rich in oil and forests. Moreover, the abundance of natural resources attracts resource-seeking FDI, sometimes in disregard of the major environmental balances. Some recent works discuss the direct or indirect effect of natural resources on environmental variables (Aladejare, 2022; Alfalih and Hadj, 2022).

In correlation with the previous explanation, high energy intensity for production needs is harmful to the environment, especially when the mix is not in favor of renewable energy. This situation is the case in Africa, where the development of renewable energies is rather slow because of the cost of technological delay, which postpones energy transition. There are several empirical works discussing the relationship between energy and environmental pollution (see Li *et al.*, 2019; Apergis and Gangopadhyay, 2020; Li *et al.*, 2022).

As for trade openness, the sign obtained validates the well-known classical hypothesis of the pollution haven, which translates the fact that this variable is a channel of pollution in countries with poor quality institutions, as is the case in our sample. The results obtained show that, on average, African countries are pollution havens, i.e., their pollution is an increasing function of their openness. This result is empirically tested in several recent works, with generally controversial views (Fang *et al.*, 2020; Pata and Caglar, 2021).

Finally, the digitalization of the economy is helping to control the level of pollution. This can be explained by the fact that digitalization reduces the number of transactions and trips, which limits the use of polluting energy and equipment. This experience was felt during the peak of the COVID-19 pandemic which imposed teleworking, especially in developed countries. In addition, digitalization promotes innovation, which facilitates production processes while accelerating the transformation of economies compatible with the preservation of major environmental balances. Several recent works discuss this result and many others related to it (Avom *et al.*, 2020; Evans and Mesagan, 2022).

The relevance of our estimates can be justified, at least empirically. For all baseline specifications, the post-estimation tests first indicate a first-order autocorrelation (justified by the presence of the lagged endogenous variable). Second, they show an absence of second-order autocorrelation (the p-values associated with Arellano and Bond's AR2 statistic are greater than 10 per cent). Finally, they confirm the validity of the instruments used (Hansen's over-identification test shows insignificant p-values).

5. Sensitivity analysis

Three sensitivity tests are performed in this paper: (1) we test the stability of our results to the type and the quality of institutions; (2) we consider the sub-regional heterogeneity of African countries; and (3) we control the results with the Environmental Vulnerability Index to consider the effect of economic policies concerning exposure to certain environmental constraints.

5.1 Sensitivity to institutional characteristics

The institutional variables modeled in this paper are designed on a scale that denotes their good and bad quality. For both the political regime and political governance indicators, it is possible to identify negative values (describing bad quality) and positive values (describing good quality). Thus, distinguishing them according to the identified signs, we control sequentially for the political regime and the overall governance index.

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Table 2. The political regime characteristics on CO_2 emissions

	Dependent variable: CO_2 emissions (metric tons per capita, in log)					
	Autocracy		Anocracy		Democracy	
Governance index	−0.0818 (0.224)	−1.191 (0.552)	0.0934 (0.0493)	−0.270 (0.0690)	−0.0267 (0.0604)	−0.0736 (0.0734)
Control variables	No	Yes	No	Yes	No	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	99	87	915	710	432	353
Instruments/Countries	11/15	14/15	33/42	34/42	25/41	36/41
AR1 p-value	0.000	0.006	0.000	0.006	0.000	0.000
AR2 p-value	0.865	0.575	0.022	0.044	0.386	0.033
Hansen p-value	0.553	0.235	0.466	0.264	0.371	0.566

Note: Standard errors in parentheses.

First, the definition of the political regime is made in a continuum integrating the two most extreme forms, which are autocracy and democracy. To do this, we distinguish, according to the typology proposed by Marshall and Elzinga-Marshall (2017), three categories of political regimes, namely autocracies ($-10 \leq \textit{political score} \leq -6$), anocracies ($-5 \leq \textit{political score} \leq +5$), and democracies ($+6 \leq \textit{political score} \leq +10$). The results obtained from this categorization are reported in table 2 (see also online appendix table A5). Based on the three samples, it appears that countries with democratizing regimes are the ones that best deal with environmental pollution. In anocratic countries, the effect is certainly relevant, but it is weaker and less significant. Finally, autocratic regimes seem to be pollution havens (pollution attractors), although the effect remains insignificant. Moreover, in all the specifications, we detect the existence of a globally significant EKC.

Second, in terms of governance quality, we distinguish two modalities, namely poor governance (negative aggregated index) and good governance (positive aggregated index). The results obtained in table 3, with and without taking into account the additional control variables, broadly validate those previously established (see table A6, online appendix).

First, good quality governance strengthens the quality of institutions, which contributes to reducing ecological dumping. Thus, better quality institutions help to strengthen the pollution halo. Second, the pollution haven hypothesis is globally verified in a weak institutional context, which favors ecological dumping. The results also broadly validate the existence of an EKC.

5.2 Sensitivity to sub-regional heterogeneity

The second sensitivity test focuses on sub-regional samples, that is, the base model is specified for each sub-region. This specification violates the Roodman (2009) condition of proportionality between the number of countries and the number of annual periods. To address this, we use the pooled OLS. This estimator (table 4) globally validates the existence of an EKC in Eastern, Central and Northern Africa (see table A7, online appendix).

The analysis also shows that the improvement of democratic conditions is favorable to the reduction of polluting emissions in all sub-regions, with the effect being

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Table 3. The governance index characteristics on CO_2 emissions

	Dependent variable: CO_2 emissions (metric tons per capita, in log)			
	Negative governance index		Positive governance index	
Polity2	−0.0243 (0.00456)	−0.00203 (0.000619)	−0.0350 (0.272)	−0.00452 (0.001152)
Control variables	No	Yes	No	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	811	801	260	270
Instruments/Countries	22/35	25/35	8/9	9/9
AR1 *p*-value	0.000	0.000	0.000	0.000
AR2 *p*-value	0.352	0.157	0.736	0.239
Hansen *p*-value	0.563	0.661	0.620	0.674

Note: Standard errors in parentheses.

more pronounced in Central, Southern and Western Africa. Also, improving the governance of political institutions appears to be a brake on pollution, although the effect remains insignificant in East Africa (bivariate specification) and West Africa (augmented specification).

5.3 Sensitivity to environmental vulnerability index

We aim to test whether the exposure of countries to certain environmental constraints influences their tolerance for pollution. For this purpose, we use the Environmental Vulnerability Index (EVI), which attempts to characterize the relative severity of various types of environmental problems. This index is used to focus on expected solutions to negative pressures on the environment. It also measures environmental sustainability. The index is calculated based on several factors, including exposure, sensitivity, and adaptive capacity.

The EVI is a composite index obtained from 50 indicators and can be subdivided into three sub-indices relating to hazards, resistance, and damage. The 50 indicators can also be broken down into climate change, biodiversity, water, agriculture and fisheries, human health aspects, desertification, and exposure to natural disasters. The EVI is a useful tool for policymakers and researchers to assess the environmental vulnerability of countries and to identify areas where interventions are needed to reduce vulnerability. Measured on a scale of 1 (high resilience / low vulnerability) to 7 (low resilience / high vulnerability), five categories of countries are encountered: resilient, at-risk, vulnerable, highly vulnerable and extremely vulnerable countries. The last category of countries is absent in our sample.

Applying pooled OLS to avoid violation of Roodman's (2009) 'large N and small T' condition, we obtain results according to the bivariate and multivariate specifications in table 5 (see also table A8 in the online appendix). These results show that in vulnerable and highly vulnerable countries, environmental degradation is not sensitive to the quality of institutions. On the other hand, in resilient and at-risk countries, good institutional quality contributes significantly to ensuring a healthy environment. The effect is much more dependent on the political regime than on good governance indicators. Everything being equal, democratizing countries gives more freedom of speech, which

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Table 4. Subregional heterogeneity (pooled OLS estimates)

	Dependent variable: CO_2 emissions (metric tons per capita, in log)									
	Eastern Africa		Central Africa		Northern Africa		Southern Africa		Western Africa	
Polity2	−0.0111 (0.00213)	−0.000115 (0.000611)	−0.154 (0.0202)	−0.0732 (0.0247)	0.0168 (0.0125)	−0.00044 (0.00145)	0.871 (0.129)	0.299 (0.0516)	−0.00444 (0.00156)	−0.00117 (0.000508)
Governance index	−0.0134 (0.0310)	−0.0786 (0.0366)	0.505 (0.153)	0.350 (0.150)	−1.173 (0.204)	−0.987 (0.481)	−5.375 (0.502)	−2.247 (0.677)	−0.0267 (0.0156)	−0.0104 (0.0241)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Time FE/Country FE	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Observations	366	351	185	179	120	111	117	101	302	297
R^2	0.935	0.962	0.930	0.980	0.971	0.994	0.812	0.986	0.773	0.814

Note: Robust standard errors in parentheses.

Table 5. Controlling for Environmental Vulnerability Index (pooled OLS estimates)

	Dependent variable: CO_2 emissions (metric tons per capita, in log)							
	Resilient countries		At-risk countries		Vulnerable countries		Highly vulnerable countries	
Polity2	−0.0367 (0.0158)	−0.0129 (0.0077)	−0.016 (0.0019)	−0.0311 (0.0100)	−0.00340 (0.00359)	−0.000281 (0.000650)	−0.3010 (0.229)	−0.167 (0.133)
Governance index	−0.207 (0.108)	−0.409 (0.208)	−0.262 (0.155)	−0.601 (0.143)	−0.1194 (0.2390)	−0.2430 (0.1920)	−0.402 (0.989)	−1.271 (1.230)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
Time FE/ Country FE	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Observations	175	170	315	300	413	398	177	171
R^2	0.938	0.974	0.890	0.932	0.919	0.938	0.414	0.986

Note: Robust standard errors in parentheses.

in turn gives more space to environmental lobbies, whose daily actions help to protect the environment.

6. Robustness analysis

Firstly, we assess the inertial effect (memory effect) of CO_2. Secondly, we check the robustness of the relationship studied using other pollution indicators. Finally, we test the relevance of our results using the ICRG institutional indicators.

6.1 The inertial effect of CO_2 on results

The effects of CO_2 can be persistent, i.e., CO_2 has a hysteresis effect, marked by a long or short memory. Thus, estimating the length of this memory effect or auto-regression effect yields important information on the stability of results and the forecasting of economic policies. Technically, we estimate a set of AR(p)-X panel models, i.e., auto-regressive panel models with exogenous variables of interest and control. This intuition is taken from Acemoglu *et al.* (2019). In each of the specifications concerning lags, we retain two types of models, namely the basic model (which considers only GDP, its square and institutions) and the augmented model (which incorporates the control variables).

The results in table 6 show that the memory effect fades overall after the 4^{th}-order lag. In other words, the CO_2 dynamics have an inertia of four years at most in the basic model. In the model augmented with control variables, this effect is reduced to two years, making explicit the significance of dynamic interactions between past CO_2 values and its other predictors. Furthermore, the EKC hypothesis is preserved, and the good quality of institutions continues to be a powerful predictor of pollution reduction (see table A9 in the online appendix).

6.2 Alternative indicators of pollution

This test is conducted in two sequences, namely the mobilization of certain components of GHGs and fine particles for the first, and the ecological footprint for the second. For

Table 6. CO_2 persistence effect

	Dependent variable: CO_2 emissions (metric tons per capita, in log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lag 1 Dep. var.	0.0363 (0.0281)	0.328 (0.0308)	0.0487 (0.0300)	0.277 (0.0326)	0.0524 (0.0298)	0.276 (0.0332)	0.0768 (0.0266)	0.283 (0.0338)
Lag 2 Dep. var.			−0.0972 (0.0312)	0.139 (0.0352)	−0.0305 (0.0325)	0.138 (0.0357)	−0.00161 (0.0297)	0.147 (0.0366)
Lag 3 Dep. var.					−0.230 (0.0341)	0.00575 (0.0345)	−0.155 (0.0311)	0.0246 (0.0380)
Lag 4 Dep. var.							−0.0956 (0.0291)	−0.0432 (0.0368)
Polity2	−0.0119 (0.00503)	0.00451 (0.00543)	−0.0113 (0.00539)	0.00574 (0.00529)	−0.00645 (0.00556)	0.00571 (0.00530)	−0.0113 (0.00521)	0.00598 (0.00531)
Governance index	0.212 (0.0724)	−0.295 (0.0803)	0.178 (0.0758)	−0.296 (0.0781)	0.0285 (0.0805)	−0.295 (0.0785)	−0.0419 (0.0764)	−0.318 (0.0810)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,075	1,061	1,024	1,011	972	964	921	913
Instruments/ Countries	40/50	45/50	36/50	45/50	38/48	44/48	39/47	41/47
AR1 *p*-value	0.015	0.022	0.014	0.005	0.008	0.009	0.001	0.004
AR2 *p*-value	0.524	0.754	0.403	0.525	0.302	0.545	0.736	0.835
Hansen *p*-value	0.325	0.252	0.309	0.256	0.279	0.508	0.748	0.703

Note: Standard errors in parentheses.

the first sequence, the variables specifically used are methane (metric tons per capita in log), nitrous oxide (in log), fine particulate matter ($PM_{2.5}$), and total GHGs, whose use in this paper allows us to understand the impact of global pollution on global warming (Mignamissi and Djeufack, 2022). Applying the system GMM estimator, the results (table 7) validate the existence of an EKC for nitrous oxide and $PM_{2.5}$. In all these specifications, CO_2 pollution is significantly sensitive to the good quality of institutions (high political score and good level of governance on average) in the sample (see table A10, online appendix).

In the second sequence, it should be noted that the relationship between institutional quality and environmental footprint has rarely been analyzed. Following Uzar (2021), we use the total ecological footprint[2] and its different dimensions (built-up land, carbon, cropland, fishing grounds, forest products, and grazing land). Both are measured

[2]The ecological footprint or environmental footprint is an indicator and a method of environmental assessment that accounts for the pressure exerted by humans on natural resources and the 'ecological services' provided by nature. More specifically, it measures the productive land and water area needed to produce the resources that an individual, population or activity consumes and to absorb the waste generated, taking into account current technology and resource management. This area is expressed in global hectares.

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Table 7. Robustness checks with pollution indicators

	(1)	(2)	(3)	(4)
	Methane	Nitrous oxide	$PM_{2.5}$	Total GHGs
Polity2	−0.00261 (0.000422)	−4.06*e* − 05 (0.000535)	−0.0354 (0.0047)	−0.00147 (0.000349)
Governance index	−0.0571 (0.0534)	−0.0459 (0.0069)	−9.892 (2.930)	−0.3403 (0.0439)
Control variables	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	1,044	992	738	997
Instruments/Countries	43/50	45/45	30/41	36/45
AR1 *p*-value	0.026	0.033	0.025	0.046
AR2 *p*-value	0.835	0.965	1.014	0.836
Hansen *p*-value	0.316	0.223	0.410	0.287

Note: Standard errors in parentheses.

in global hectares and are extracted from the Global Footprint Network database. Using the average governance indicator, we obtain the results reported in table 8. They show that the negative association between good institutional quality and environmental footprint contributes to ecological sustainability in Africa (Uzar, 2021). Furthermore, the EKC hypothesis is globally confirmed (see table A11, online appendix).

6.3 Alternative institutional measures

The measurement of institutions is diverse and varied in the literature. In this robustness test, we use the V-Dem database to measure corruption according to its various sources (public sector corruption, executive corruption, and political corruption). We also use indicators such as government stability, military in politics, law and order, democratic accountability and bureaucracy from the ICRG. The effect of the indicators selected remains consistent with the general intuition (table 9).

A stable government ensures the sustainability of its institutions and therefore takes socio-economic measures that improve the living conditions of its people. Such a government is associated with the implementation of policies that promote sustainable development, which makes it possible to design effective strategies to combat environmental pollution. Moreover, more corruption weakens the functioning of the State through the development of rent-seeking behaviors, which prevents the design of inclusive social policies to the benefit of self-interest. In this context, large foreign polluting firms easily find havens to export their pollution. This result is significant for all measures of corruption, depending on its origin (see online appendix table A12).

Also, the analysis shows that the implementation of a hardline and interventionist regime (with more military) at all levels tends to reduce economic activity and, in general, discourage the action of large polluting firms that do not have a secure guarantee of their property rights. In this context, more military in politics could in the short term slow down polluting activities even if, in the long term, the search for credibility makes military governments relatively conciliatory, which in turn avoids the uprising of

Table 8. Institutions and ecological footprint

	Dependent variable: total ecological footprint and its components						
	Total	Built-up land	Carbon	Cropland	Fishing grounds	Forest products	Grazing land
Polity2	−0.5375 (0.0198)	−0.0095 (0.0246)	−0.0695 (0.0602)	−0.0085 (0.028)	−0.0375 (0.1386)	−0.0395 (0.0429)	0.0035 (0.2302)
Governance index	−0.3505 (0.0477)	−0.1035 (0.0756)	−0.1325 (0.0699)	−0.0835 (0.0725)	−0.0525 (0.0493)	−0.1635 (0.1215)	−0.1865 (0.4477)
Controls and time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,024	1,035	1,020	1,005	1,022	1,028	1,022
Instruments/Countries	28/49	31/49	33/49	29/49	35/49	37/49	38/49
AR1 *p*-value	0.0344	0.0556	0.0258	0.0578	0.0467	0.0323	0.0244
AR2 *p*-value	0.6734	0.5393	0.7132	0.6157	0.6147	0.627	0.6148
Hansen *p*-value	0.7734	0.7933	0.7273	0.8146	0.738	0.772	0.7564

Note: Standard errors in parentheses.

Table 9. Alternative institutional measures and pollution in Africa

	Dependent variable: CO_2 emissions (metric tons per capita, in log)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Polity2	−0.00177 (0.000686)	−0.00162 (0.000684)	−0.00155 (0.000673)	−0.00139 (0.000670)	−0.000511 (0.000783)	0.000211 (0.000828)	−0.000182 (0.000722)	−0.00153 (0.000687)
Public corruption	0.117 (0.0019)							
Executive corruption		0.0335 (0.0075)						
Political corruption			0.0121 (0.0048)					
Military in politics				−0.267 (0.107)				
Gov. stability					−0.152 (0.0287)			
Law and order						−0.0206 (0.0697)		
Dem. accountability							−0.00324 (0.0253)	
Bureaucracy								0.0625 (0.0212)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	956	956	956	956	854	951	879	861
Instruments/ Countries	43/47	45/47	38/47	44/47	39/47	40/47	38/44	35/44
AR1 *p*-value	0.045	0.022	0.044	0.015	0.038	0.029	0.011	0.041
AR2 *p*-value	0.628	0.758	0.807	0.629	0.506	0.649	0.740	0.567
Hansen *p*-value	0.427	0.334	0.521	0.398	0.351	0.700	0.880	0.582

Note: Standard errors in parentheses.

populations that have suffered restrictions since they came to power. The effect would therefore not be monotonous over time.

The variable 'rule of law and order' tends to constrain polluting activities. In a regime that has already adopted environmental legislation, the coercive nature of the legislation and the compliance of the people with it reinforces its effect on environmental protection, which tends to reduce the level of pollution. However, this effect was not significant in our sample.

This tendency to control pollution is further enhanced when the government feels democratically committed, responsible, and accountable. Indeed, most governments are established based on their political, social, economic, and environmental commitments. Thus, their reappointment to power requires that they send signals about their

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accountability. In this context, they tend to promote activities in favor of the environment and impose pacts on firms concerning their social responsibility. However, the results show that democratic accountability in the majority of African states is not sufficient to significantly bend the pollution curve. Finally, a good quality bureaucracy survives successive governments, which allows the continuance of contracts related to environmental balance by avoiding renegotiations according to the system in place.

7. Building a robust instrument for further investigation (IV-2SLS estimates)

The main estimation technique used in this paper is the system GMM. However, since the endogeneity hypothesis could not be proven, several other alternatives are used. According to Baum *et al.* (2003), the IV-2SLS estimator competes with the GMM estimator in the absence of heteroscedasticity. Furthermore, it is considered as a special case of GMM (Baum *et al.*, 2003). The latter also has the advantage of using two instrumentation strategies: an internal instrumentation strategy, which consists of using the lags or differences of the suspected endogenous variable(s), and an external instrumentation strategy, when it is possible to select a robust external instrument. In this paper, we use the second strategy.

Indeed, the quality of institutions as well as GDP or other variables can either be measured with errors or can be circular with the level of pollution. We assume that the democracy index and governance indicators are endogenous. To effectively control for this bias, we use an external instrumentation strategy inspired by Acemoglu *et al.* (2019). In our context, institutional variables relating to the political regime (Polity2) and governance indicators may be subject to measurement errors. Indeed, the assessment of governance or democracy can vary from one measure to another, from one definition to another, from one country to another, or from one individual to another. This situation renders previous empirical strategies powerless to control this bias. It is therefore fundamental to define a robust instrument that is the least possible correlated with the error.

To this end, we draw inspiration from the identification strategy developed by Acemoglu *et al.* (2019), based on the theory of 'waves of democracy' developed by Huntington (1991) and the theory of 'foreign democratic capital' proposed by Persson and Tabellini (2009). For Huntington (1991), the major democratic movements observed throughout history are an apprehension of waves of democracy. These waves are associated with sudden changes in the distribution of power among major powers, which create openings and incentives to introduce radical domestic reforms. Furthermore, Persson and Tabellini (2009) evoke the notion of democratic capital as the historical experience of a nation in terms of democracy and its incidence in neighboring countries. For these authors, democratic capital, understood as a slow accumulation of a stock of civic and social assets, would reduce the exit rates from democracy and increase the exit rates from autocracy. By transposing these two theories, we define the notions of 'waves of governance' and 'foreign governance capital'.

Inspired by the approach recently developed by Acemoglu *et al.* (2019), we model waves of democracy and governance which we consider to be robust instruments of the political regime and governance indicators. Thus, for each country i, we generate an indicator of 'democracy abroad' and 'foreign governance abroad' as a sub-regional average of the performance of democracy and governance indicators of member countries. To

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generate these indices, we use a set of information. For a given country, this information includes its level of democracy or the quality of its governance, its membership in a well-defined regional economic community (REC), and its historical political proximity to the other member States in its community, among others. On this basis, we define 'exogenous' instruments for the level of democracy and all governance indicators in the sense of Acemoglu *et al.* (2019).

To define the sub-regional waves of democracy and governance, we demarcate the African continent according to its main REC. These RECs are the Southern African Development Community, the East African Community, the Economic Community of West African States, the Economic Community of Central African States, and the Arab Maghreb Union. Based on this information, we calculate for each given country i belonging to a REC of n member States, a set of instruments as sub-regional averages of the levels of democracy and governance indices of the remaining $n - 1$ countries.

Noting the desired instrument by K, we obtain for a given country:

$$K_i^{\text{Inst}} = \frac{1}{n} \sum_{j \neq i}^{n} \text{Inst}_j,$$

where i represents the country and Inst the institutional indicator (polity2 or governance indices).

After having defined the different instruments, the system to be estimated is

$$\begin{cases} \text{Log}(\text{Poll}_{it}) = \gamma_0 + \gamma_1 \text{Log}(y_{it}) + \gamma_2 (\text{Logy}_{it})^2 + \gamma_3^{\text{Inst}} \text{Inst}_{it} + \gamma_4 X_{it} + \mu_i + \varphi_t + \varepsilon_{it} \\ \text{Inst}_{it} = \phi_0 + \phi_1 K_{it}^{\text{Inst}} + \phi_2 \text{Log}(\text{Poll}_{it}) + \phi_3 \text{Log}(y_{it}) \\ \qquad + \phi_4 (\text{Log}y_{it})^2 + \phi_5 X_{it} + \theta_i + \lambda_t + \eta_{it} \end{cases}.$$

In addition, the following orthogonality condition should be observed:

$$E(\varepsilon_{it} | y_{it}, X_{it}, K_{it}^{\text{Inst}}, \mu_i, \varphi_t) = 0.$$

This condition states that regional waves are a significant function of the level of democracy and governance, but are not caused by pollution levels at the sub-regional scale, validating the robustness of our identification approach.

Also, several determinants of pollution are thought to have a double causality with it, which requires further control of this bias by instrumenting them. This is the case for GDP, industrialization, energy intensity, and natural resource exploitation. For these variables, we use first-order lags, given the difficulty of choosing instruments that are unanimously accepted.

This identification strategy is validated by the use of specific tests, namely the Kleibergen and Paap (2006) under-identification test, which assesses the level of correlation between the endogenous variable and the chosen instrument. There is also the instrument weakness test developed by Cragg and Donald (1993) and popularized by Stock and Yogo (2005). Finally, there is a test of over-identification of all instruments, or rather of their validity, developed by Hansen (1982).

In the presence of country and time-fixed effects, the results obtained globally validate the previous predictions, namely the presence of an environmental Kuznets curve and significant explanatory power of the good quality of institutions on CO_2 emissions (table 10). Specifically, by instrumenting democracy and governance by their regional

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Table 10. Institutions and pollution in Africa: IV-2SLS estimates

	Dependent variable: CO_2 emissions (metric tons per capita, in log)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Polity2	−0.00261 (0.00116)	−0.00193 (0.000930)	−0.00268 (0.00125)	−0.00243 (0.00121)	−0.00305 (0.00122)	−0.00277 (0.00123)	−0.00253 (0.00120)
Control of corr.	−0.0848 (0.0512)						
Political stability		−0.0658 (0.0349)					
Rule of law			−0.0227 (0.0046)				
Regulatory quality				−0.157 (0.0597)			
Voice and account.					−0.202 (0.0603)		
Gov. effectiveness						−0.0124 (0.0026)	
Governance index							−0.0641 (0.0004)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE/Country FE	No/Yes	No/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Observations	591	591	591	591	591	591	591
R^2	0.989	0.990	0.990	0.990	0.990	0.990	0.990
Kleibergen-Paap	39.857	41.222	38.659	40.258	41.578	39.247	38.451
Cragg-Donald	70.246	75.568	72.249	78.257	75.698	74.123	71.486
Stock-Yogo (10%)	19.93	19.93	19.93	19.93	19.93	19.93	19.93
Hansen *p*-val.	0.1857	0.1174	0.1001	0.1635	0.1246	0.0969	0.0957

Note: Robust standard errors in parentheses.

waves, African countries best control for the level of CO_2 emissions. Moreover, the chosen instruments are robust, with the Stock-Yogo statistic at 10 per cent being lower than the calculated value of Cragg-Donald or Kleibergen-Paap, including the Hansen threshold values which are all above 10 per cent (see table A13, online appendix).

8. Conclusion and policy implications

Although a high level of pollution is not yet prevalent in Africa, it seems relevant and timely to look at the factors that could lead to it in the future. This forward-looking posture allows us to anticipate and design the best economic policies, and also to have the necessary and sufficient time to ensure their implementation. This paper tested the nexus between pollution and institutional quality, through political regime and governance indicators in Africa. We applied the system GMM estimator to a panel of African countries over the period 1996–2020. The study establishes the following key findings:

- The EKC hypothesis is verified in Africa. In other words, the relationship between the level of CO_2 emissions per capita and income per capita is non-linear. The

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level of development is accompanied by environmental degradation up to a certain threshold. Above this threshold, a sufficient level of income contributes to the implementation of anti-pollution measures, which helps to limit polluting emissions.

- The level of pollutant emissions is sensitive to the political regime in Africa. In other words, implementing democratic reforms in the medium and long term strengthens the effectiveness of green policies. These policies promote environmental protection because government credibility is now based on democratic fundamentals.
- Better governance strengthens the action of democratic reforms in addressing environmental pollution. The World Bank's governance indicators are environmental anti-dumping measures in that they significantly curb the level of polluting emissions. In other words, better institutions would make Africa a pollution halo, not a pollution haven.
- The set of sensitivity and robustness tests globally validates the strength and stability of the negative relationship between the good quality of institutions and the level of polluting emissions in Africa. More specifically, the institutional characteristics, the sub-regional heterogeneity of African countries, and the inclusion of the EVI strengthen and consolidate the quality of our results. Moreover, they are robust to a theoretically sound instrumentation strategy by IV-2SLS to further control for endogeneity, but also to the use of several proxies of the dependent variable and the institutional variables of interest.

These results call for some policy recommendations in environmental regulation for African economies including strengthening institutional quality and making them more inclusive; adoption of specialized investment promotion agencies on the attractiveness of green investments; and implementation of incentive mechanisms in favor of companies that have adopted a greening program on their activities. Finally, to further control pollution levels in the long term, African countries should prepare for an energy mix dominated by renewable energies, promote migration to smart cities, and reform the transport system in line with the preservation of environmental balances.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1355770X24000044.

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Conflict of interest. The authors declare none.

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