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# Examining the Interaction Effect of Control of Corruption and Income Level on Environmental Quality in Africa

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**Abstract:** The effects of corruption and income on environmental degradation is well established in the literature. However, little attention has been given to how the control of corruption affects the environmental quality at different levels of income. This study examines the interaction effect of the control of corruption and income on environmental quality in Africa over the period from 1996 to 2017. Using a Method of Moments Quantile Regression (MMQR) with fixed effects, the results revealed that both the control of corruption and income level increase $CO_2$ emissions while their interaction term reduces $CO_2$ emissions. This implies that the interaction effect of the control of corruption and income level mitigates carbon emissions. Particularly, the marginal effect of the control of corruption on $CO_2$ emissions decreases as income level increases. Furthermore, renewable energy consumption has a negative and significant effect on $CO_2$ emissions. The effect of foreign direct investment on $CO_2$ emissions is positive and significant, which validates the pollution haven hypothesis. These results are heterogeneous across the quantile distribution of $CO_2$ emissions. Based on these findings, our study suggests the need for the government and policymakers to stimulate income levels as a prerequisite for achieving sound and effective environmental policies in Africa.

**Keywords:** environmental quality; corruption; income level; renewable energy; Africa

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## 1. Introduction

Concerns about environmental sustainability are closely linked to the global stance against the vexed issue of global warming and climate change. The general consensus is that the rapid economic and social progress achieved in the past three decades, driven largely by fossil fuels, along with rapid growth in the human population is unsustainable. These concerns are exacerbated by the economic expansion with significant environmental disruptions, which occur at the national and international levels, exposing the entire world to danger [1]. Arguably, the increased attention given to the environmental question is also in accepting the fact that environmental sustainability remains one of the compelling cardinal targets of the United Nations Sustainable Development Goals (SDGs). Therefore, there exists the need for a proper interrogation of the environmental questions at all levels of governance, especially in Africa.

Based on the increasingly negative impact of climate change in Africa, the issue of environmental sustainability has become a top policy issue in recent times. The continent is most vulnerable to the effects of climate change under all climate scenarios above 1.5 °C, which is the global target. Even though, by comparison, Africa has a lesser contribution to global warming and other significant climate changes, the continent has been facing existential exponential collateral and environmental damages, leading to systemic risks in its economies, infrastructure investments, public health, water and food systems, agriculture, and livelihoods. All of these threaten to undo Africa's modest development gains and, therefore, slip into higher levels of extreme poverty [2]. To actively tackle the menace of environmental degradation and achieve a sustainable environment, the sub-Saharan African countries have signed and ratified the Paris Agreement and other related climate action consensuses towards reducing greenhouse gas and building alternative energy resources.

In addition to the over-dependence on fossil fuel energy to drive economic expansion, the African continent also faces the challenge of corruption in its efforts to achieve environmental sustainability. Corruption can be seen as the abuse of power, by the persons entrusted with it, for personal gains [3,4]. There are many forms of corruption, but the most common and worrisome form of corruption is financial corruption, which takes the form of bribes, kickbacks, inappropriate gifts, double-dealing, and other forms of dishonest financial dealings with Transparency International. The extant literature suggests that corruption influences the quality of the environment in two ways. First, it affects the environment by distorting the flow of investments and economic activities that may lead to improvement in the quality of the environment [3–5]. Second, corruption can destabilize the stringency of environmental laws and regulations, thereby exerting a negative influence on the environment [6–8].

While several studies [3,4,6,9] confirm that corruption aggravates $CO_2$ emissions and degrades the environment, little attention has been given to the effects of control of corruption on the quality of the environment. Meanwhile, unabated corruption may lead to the diversion or misappropriation of resources meant for promoting sustainable material consumption and combating environmental degradation. For instance, [10] found corruption in Tunisia to have been associated negatively with environmental quality measured by $CO_2$ emissions. Moreover, [11] divulged that the lower the corruption, the more energy efficiency there is for all income group economies. Since the control of corruption is expensive (requiring the setting up of agencies, procurement of modern equipment and gadgets, as well as personnel costs), countries with high levels of income are likely to achieve higher successes in the control of corruption.

Furthermore, as a continent of developing countries, Africa is seen as a haven for polluting industries due to the weak environmental laws, consistent with the pollution haven hypothesis which postulates that; developing economies keep their domestic environmental regulations laxer, thus offering the highly polluting multinational corporations the opportunity to move in their investments in form of foreign direct investment (FDI) [12–14]. The argument in support of FDI is that it enhances the transfer of technological innovation and consequently, provides the basis for the implementation of greener and cleaner modes of production [13]. In contrast, the economic literature argues that the FDI-induced environmental consequences due to increased $CO_2$ emissions outweigh the economic benefits associated with FDI inflows. To balance up, there is, therefore, a need for the African countries to quickly align to the global trend of increasing the share of renewable energy in the total energy mix. Renewable energy consumption is crucial in reducing $CO_2$ emissions and achieving green growth. In this regard, most African countries have started diversifying their energy portfolios by increasing the share of renewables in their total energy mix [1,15–18]. Empirically, several studies have confirmed the effect of renewable energy on reducing environmental degradation [19,20].

Given the position of the literature that the environment is always susceptible to continuous destruction when corruption becomes common in government and its agency structures, it becomes apparent that to reduce environmental degradation, institutions that relate to the process of environmental policymaking play an important role. Furthermore, the fight against corruption requires huge funding. Given the level of income in the African continent, it is still not empirically clear whether the fight against corruption can lead to effective environmental protection and sustainability in the continent.

Therefore, the main objective of the study is to examine the impact of the interaction of the control of corruption and income levels on environmental quality in Africa. The current study contributes to the literature by examining the determinants of environmental quality, measured by the level of $CO_2$ emissions in Africa. We show that the control of corruption is a significant determinant of $CO_2$ emissions in Africa, even when interacting with the level of income to account for the relevance of income in addressing the environmental question and achieving sustainable development. Our results also show that for developing countries, such as African countries, renewable energy consumption and foreign direct investment have a significant influence on the quality of the environment.

The rest of the study is organized as follows. Section 2 deals with a brief literature review. Section 3 focuses on the methodology. Section 4 presents the empirical results, and Section 5 concludes the paper and makes policy recommendations.

## 2. Literature Review

Theoretically, the relationship between economic growth and environmental degradation is better captured with the famous environmental Kuznets curve (EKC) hypothesis, which hypothesizes an inverse relationship between a country's level of pollution and its real GDP. However, the validity of the EKC hypothesis remains a disputable fact across countries, perhaps due to variation in the time frame, methodology, and country peculiarities [19,21–25]. In the case of Africa, several studies have presented conflicting submissions regarding the true nature of the relationship between $CO_2$ emissions (often used as a proxy for environmental pollution) and real income level, thus generating a crisis that does not support sound and formidable policy prescription and, consequently, opening the door for further studies [23,26]. Similarly, the study [27] validated the EKC for Nigeria by taking into account the role of international trade. Thus, the validity of the EKC remains a subject of heated debate in Nigeria.

The extant literature is active on the nexus between corruption and environmental sustainability [3–5,28,29]. The popular opinion is that corruption may stimulate environmental degradation in direct and indirect ways [5]. For instance, [3] applied a dynamic ARDL simulation technique to study the effects of social and economic factors on the environmental quality in Nigeria. While economic growth increased environmental degradation in Nigeria, corruption and internal conflict reduced environmental degradation through a decrease in investments and growth. The authors of [5] used system GMM on provincial panel data in China's industry from 2005 to 2015 to establish that corruption influences $CO_2$ emission through the distortion of environmental policy and by lowering the monitoring levels. Moreover, [9] used a panel quantile regression method to study how corruption affects $CO_2$ emissions and economic growth in Africa. The results revealed the following: (i) a higher level of corruption in Africa; (ii) corruption is negatively related to $CO_2$ emissions in lower emission countries; (iii) in higher emission countries, corruption is not a significant enough factor to explain changes in $CO_2$ emissions; and (iv) corruption is positively affected by $CO_2$ emissions. This positive effect supersedes the negative effect, and hence, the total effect of corruption is positive. Similarly, [4] studied the environmental sustainability impact of corruption using panel data on 16 southern African countries. Applying system GMM and DH Granger causality, the study divulged that corruption causes environmental quality in southern African countries. Wang et al. (2018), in a study, evaluated the nexus between economic growth and carbon emissions within the context of the environmental Kuznets curve hypothesis, covering the period from 1996 to 2017 for the BRICS countries. The results of the study showed that corruption control could reduce carbon emissions. Furthermore, Sinha et al. (2019), in their study involving BRICS and the Next Eleven countries, asserted that corruption dampens environmental quality. Likewise, [10] examined Tunisia's case of the effects of corruption on $CO_2$ emissions and energy consumption. Applying the ARDL modeling technique, the study presented that corruption is related negatively to environmental quality, which is perhaps measured by $CO_2$ emissions, while its effect on energy consumption is negative and statistically significant.

Regarding the nexus between FDI and $CO_2$ emission, [30] in a study on 55 Asia-Pacific countries observed that developing countries, such as most of the African countries, adopted convenient environmental regulations for various reasons, including the fact that economic growth is the major objective of these countries and not the quality of the environment. The study established that FDI causes a rise in $CO_2$ emissions and contributes to environmental deterioration. Corroboration of this assertion was the study of [31], which showed that FDI brings beneficial environmental impacts to developed countries, while it brings negative impacts to the environmental quality of poor or developing nations. The authors of [32], using green technology, FDI, and environmental regulation, found that environmental regulation has a significant effect on green technology innovation and that FDI causes green technology innovation to decrease. Ref. [33] applied PMG and the DH causality test to study the effect of ICGT and inflows of foreign direct investment on environmental degradation in some Asia-Pacific countries. The study found that foreign investment and ICT have a long-running negative impact on the environment. The authors of [12] examined the effect of foreign direct investment on $CO_2$ emissions in Pakistan from 1971 to 2014, within the context of the Pollution Haven Hypothesis. Using the ARDL and the ECM models, the results of the study confirmed the increasing effects of FDI on $CO_2$ emissions, thereby upholding the Pollution Haven Hypothesis. Applying the non-linear approach, [34] explored the relationship between foreign direct investment and environmental degradation in high-income, middle-income, and low-income countries. The results suggested that the environmental Kuznets curve exists, and foreign direct investment increases environmental degradation, also supporting the existence of the Pollution Haven Hypothesis. The authors of [30] in a study on the effect of inward FDI on environmental quality in China showed an inverse U-shape relationship between inward FDI and carbon emissions for the aggregate samples, while the provincial divisions presented heterogeneous results. These findings are confirmed by the studies of [13] which suggested that the entry of FDI into Latin American countries increases $CO_2$ emissions and consequently dampens the environmental quality.

Concerning the role of renewable energy use and environmental sustainability, the authors of [35], in a study on the nexus between renewable energy use and environmental protection of the Next Eleven developing economies, showed an inverse relationship between renewable energy and $CO_2$ emission. The authors of [36] confirmed the results for 25 selected African countries by establishing that renewable energy consumption decreases $CO_2$ emissions. Similarly, the studies [20,23] indicated that renewable energy consumption has a significant effect in reducing $CO_2$ emissions.

The review of the empirical literature shows that there are few studies and supporting data evaluating the consequences of corruption on environmental sustainability in the emerging economies of Africa, generally regarded as the most corrupt continent on the globe. Moreover, there are few or no studies focusing on the control of corruption's effect on the environment in Africa. Our study is the first, to the best of our knowledge, that focuses on the interactive effects of the control of corruption and income level on the environmental quality in Africa. This is particularly important because the fight against corruption is expensive, and therefore, countries with higher income levels may likely attain higher levels of environmental quality traceable to the pursuit of the control of corruption than countries with lower income levels. In addition, our study uses robust econometric procedures (Method of Moments Quantile Regression (MMQR) with fixed effects) to show how the interaction term with other control variables affects environmental quality across the quantile distribution. Finally, we used the Driscoll–Kraay standard errors based on the estimations of fixed-effects OLS and GLS random effect to control for serial correlation and cross-sectional dependence.

## 3. Materials and Methods

### *3.1. Data and Description*

In this study, environmental quality was proxied by the level of per capita carbon dioxide ($CO_2$) emissions in metric tons. The control of corruption (CC) was measured as −2.5 for weak governance and +2.5 for strong governance. Per capita GDP (GDP) which is proxied for the level of income was measured at constant 2015 US Dollars divided by the total population. Renewable energy (REN) measured the percentage of renewables in total final energy consumption, while foreign direct investment (FDI) was measured as the direct investment equity inflows in current US Dollars. Furthermore, all variables used in this study were downloaded from the website of the World Bank via World Development Indicators (WDI), except the control of corruption which was downloaded from the Worldwide Governance Indicators. We selected the period of the study, i.e., 1996 to 2017, based on the data availability. The variables, their measurements, and sources are summarized in Table 1 below. The list of investigated countries are presented in Table A1 in the Appendix A.

**Table 1.** Description/measurement of variables and sources.

| Variable | Description/Measurement | Source |
|---|---|---|
| Carbon dioxide emissions ($\ln CO_2$) | $CO_2$ emissions (metric tons per capita). | World Development Indicators (WDI) |
| Control of Corruption ($CC$) | −2.5 for weak governance and +2.5 for strong governance. | Worldwide Governance Indicators (WGI) |
| Economic Growth ($\ln GDP$) | Real GDP (constant 2015 US Dollars) per capita. | World Development Indicators (WDI) |
| Renewable Energy Consumption ($REC$) | Percentage of renewables in total final energy consumption. | World Development Indicators (WDI) |
| Foreign Direct Investment ($\ln FDI$) | Direct investment inflows measured in current USD. | World Development Indicators (WDI) |

Source: Authors' computation.

### *3.2. Empirical Modelling*

To achieve the objective of this study, we applied econometric methodological techniques. Based on the empirical works of [37,38], the functional model of the environmental quality with some modifications was specified as:

$$CO_2 = f(CC,\ GDP,\ CC * GDP,\ REN,\ FDI) \quad (1)$$

where $CO_2$ is the country's carbon dioxide emission, CC denotes the control of corruption, GDP is a real gross domestic product, REN is the renewable energy consumption, FDI represents foreign direct investment, and $CC * GDP$ is the interaction term of the control of corruption, and level of income. The econometric model of the functional relationship in Equation (1) was given as follows:

$$\ln CO_{2it} = \alpha_i + \rho_1 CC_{it} + \rho_2 \ln GDP_{it} + \rho_3 (CC_{it} \times \ln GDP_{it}) + \rho_4 \ln REN_{it} + \rho_5 lnFDI_{it} + \varepsilon_{it} \quad (2)$$

where ln represented the natural logarithms of the variables, except the control of corruption. Each country was represented by a time period. The main contribution of our paper was the argument that the level at which control of corruption influences environmental quality may be dependent on the level of income of a country; hence, we took the interaction term of the control of corruption and income level, i.e., $CC * \ln GDP$. The variables, $REN$ and $\ln FDI$ were included in the model as control variables. $\alpha$ was the intercept, while $\varepsilon$ was the residual term with zero mean and constant variance, $\sigma^2$, $\varepsilon_t \sim iid(0, \sigma^2)$.

### *3.3. Method of Moments Quantile Regression (MMQR)*

Quantile regression analysis became important in the empirical modeling because of the shortcomings of the conditional mean regression approach. Basically, a conditional mean regression estimator uses a conditional mean, which is located in the middle of a distribution. This means that the conditional mean-based estimator only describes the incomplete distribution. To provide information on how the independent variables affect the entire conditional distribution, a quantile regression analysis is suggested by different scholars [39–42]. Applying a quantile regression in this paper, we followed the recent Method of Moments Quantile Regression (MMQR) with fixed effects, developed recently by the authors of [43]. This method allowed differencing out individual effects in the panel as it is usually performed in the estimation of the conditional mean and provides information on the effect of independent variables on the dependent variable using the entire conditional distribution. Moreover, the method controlled for heterogeneity, and as such, detected asymmetry associated with the series explored. Therefore, in a simple term, the MMQR can be specified as follows:

$$Y_{it} = \alpha_i + X_{it}^{'}\beta + \sigma\left(\delta_i + Z_{it}^{'}\gamma\right)U_{it} \tag{3}$$

where $(\alpha,\ \beta',\ \delta,\ \gamma')'$ are unknown parameters, $(\alpha_i, \delta_i), i = 1, \ldots, n$ of course, capture the individual $i$ fixed effects, and $Z'$ is defined as a $k$-vector of known differentiable transformations of the components of $X_{it}$ with element $l$ given by $Z_l = Z_l(X_{it})$ where $l = 1, \ldots, k$. The probability, $P\{\delta_i + Z_{it}^{'}\gamma > 0\} = 1$, and $U_{it}$ represented an unobservable random variable that was palpably independent of $X_{it}$.

To satisfy the moment conditions, ref. [43] suggested that the density function, $F_U(\bullet)$ should be bounded away from 0, and hence, normalized, i.e., $E(U_{it}) = 0$ and $E(|U_{it}|) = 1$. Therefore, Equation (3) becomes:

$$Q_Y(\tau|X_{it}) = (\alpha_i + \delta_i q(\tau)) + X_{it}^{'}\beta + Z_{it}^{'}\gamma q(\tau) \tag{4}$$

where $q(\tau) = F_U^{-1}(\tau)$, and hence, $P(U < q(\tau)) = \tau$. The scaler parameter was given by $\alpha_i(\tau) \equiv \alpha_i + \delta_i q(\tau)$ and is indicative of the quantile-$\tau$ fixed effect for an individual, $i$. Unlike the ordinary least squares-fixed effects, the distributional effect of MMQR allowed varying impacts across the quantiles of the conditional distribution of $Y$, i.e., the dependent variable.

## 4. Results and Discussion

### *4.1. Preliminary Analysis*

We begin the analysis by presenting the descriptive statistics of the variables explored in this study. From the descriptive statistics table (Table 2), it is clear that the mean of all the variables was large, except for the ln$CO_2$ emissions and CC. This suggested that the variables are not normally distributed, as can be seen by the Jarque–Bera statistics and their respective p-values. The standard deviation of the variables suggested that all of the variables were not too volatile, except renewable energy, which is highly volatile. Furthermore, the variables had positive kurtosis, which by approximations are close to the value of 3. The skewness of ln$CO_2$ and lnGDP were all positive while CC, REN, and lnFDI were negative, and they were all close to zero.

The correlation matrix of the variables provides that ln$CO_2$ had a negative and significant correlation with CC and REN. The correlation between ln$CO_2$ and lnGDP was positive and was also positive also with lnFDI. CC had a negative correlation with REN and lnFDI, while the correlation between CC and REN was positive. The correlation between lnGDP and REN was negative, while the correlation with lnFDP was positive. Moreover, REN had a negative correlation with lnFDI. These correlations were all statistically significant as shown via their respective probability values.

In Table 3, we present the results of the cross-sectional dependence. The results showed that in all the variables, the null hypothesis of no cross-sectional dependence was rejected. This implied that there is a cross-sectional dependence in all of the variables. Table 4 reports the results of the panel unit root tests. In this section, two-panel unit root tests were performed. First, the traditional unit root test proposed by [44] was applied while the second-panel unit root test applied was based on the second-generation unit root test advanced by [45], which controlled for cross-sectional dependence. The tests were conducted with the trend and intercept and the results were as follows: Based on the traditional panel unit root test of [44], the variables were stationary at levels, except for lnGDP, which was only stationary at the first difference. However, when cross-sectional dependence was controlled for, the results based on [44] showed that at levels, only $lnCO_2$, lnGDP, and lnFDI were stationary while CC and REN were only stationary at their first differences.

**Table 2.** Summary descriptive statistics.

| Variable | $lnCO_2$ | CC | lnGDP | REN | lnFDI |
|---|---|---|---|---|---|
| Mean | −0.853041 | 0.638209 | 6.902804 | 63.38086 | 19.49870 |
| Median | −1.089915 | 0.600000 | 6.672230 | 77.37345 | 19.72185 |
| Maximum | 2.238980 | 2.130000 | 9.573770 | 98.34290 | 23.17240 |
| Minimum | −4.115810 | −1.220000 | 4.630820 | 0.059000 | 11.56060 |
| Std.Dev. | 1.425835 | 0.601351 | 1.057960 | 30.09306 | 1.893661 |
| Skewness | 0.306323 | −0.186970 | 0.357867 | −0.923091 | −0.794093 |
| Kurtosis | 2.277278 | 2.860812 | 2.265845 | 2.415076 | 4.085796 |
| Jarque-Bera | 27.97715 | 4.961850 | 32.76421 | 116.8914 | 115.3568 |
| Probability | 0.000001 | 0.083666 | 0.000000 | 0.000000 | 0.000000 |
| Observations | 748 | 748 | 748 | 748 | 748 |
| **CorrelationMatrix** | | | | | |
| **Variable** | **$lnCO_2$** | **CC** | **lnGDP** | **REN** | **lnFDI** |
| $lnCO_2$ | 1.000000 | | | | |
| | —— | | | | |
| CC | −0.210956 | 1.000000 | | | |
| | (0.0000) | —— | | | |
| lnGDP | 0.888235 | −0.278047 | 1.000000 | | |
| | (0.0000) | (0.0000) | —— | | |
| REN | −0.823869 | 0.397265 | −0.722741 | 1.000000 | |
| | (0.0000) | (0.0000) | (0.0000) | —— | |
| lnFDI | 0.387732 | −0.114827 | 0.506662 | −0.366585 | 1.000000 |
| | (0.0000) | (0.0017) | (0.0000) | (0.0000) | —— |

**Table 3.** Cross-sectional Dependence Test.

| Variables | Breusch and Pagan LM Test | Pesaran CD Test | Pesaran LM |
|---|---|---|---|
| $lnCO_2$ | 4852.05 *** | 30.826 *** | 128.105 *** |
| *p*-value | (0.0000) | (0.0000) | (0.0000) |
| CC | 2411.60 *** | −1.1039 | 55.248 *** |
| *p*-value | (0.0000) | (0.2696) | (0.0000) |
| lnGDP | 8721.35 *** | 91.125 *** | 243.62 *** |
| *p*-value | (0.0000) | (0.0000) | (0.0000) |
| REN | 4297.15 *** | 39.980 *** | 111.539 *** |
| *p*-value | (0.0000) | (0.0000) | (0.0000) |
| lnFDI | 4129.8 *** | 59.6977 *** | 106.54 *** |
| *p*-value | (0.0000) | (0.0000) | (0.0000) |

Note: *** reflects the statistical significance of values at a 1% level.

Having found the stationarity properties of the series, the study further tested the cointegrating properties of the series. As shown in Table 5, the Pedroni residual-based cointegration was applied. As we can see, the null hypothesis of no cointegration was rejected, suggesting that there was a valid cointegration among the variables employed. This was displayed by the statistical significance of the Panel PP-Statistic and Group PP-Statistic.

**Table 4.** Panel unit root results.

| | Im et al. (2003) [44] | | Pesaran (2007) [45] | |
|---|---|---|---|---|
| **Variables** | **Trend & Intercept Model** | | **Trend & Intercept Model** | |
| | I(0) | I(1) | I(0) | I(1) |
| $lnCO_2$ | −3.6243 *** | −13.513 *** | −2.447 *** | −3.734 *** |
| CC | −4.0836 *** | −13.847 *** | −2.025 | −4.426 *** |
| lnGDP | −0.9446 | −10.943 *** | −2.949 *** | −4.294 *** |
| REN | −2.7280 *** | −13.389 *** | −2.225 | −4.329 *** |
| lnFDI | −7.355 *** | −15.488 *** | −3.660 *** | −5.372 *** |

Note: Computed by the author. *** reflects the statistical significance of values at a 1% level. The lag length selected is 1.

**Table 5.** Pedroni residual co-integration test.

| Alternative Hypothesis: common AR coefficients (within-dimension) | | | | |
|---|---|---|---|---|
| | Statistic | *p*-value | Weighted Statistic | *p*-value |
| Panel v-Statistic | −1.45514 | 0.9272 | −2.1001 | 0.9821 |
| Panel rho-Statistic | 3.3328 | 0.9996 | 3.6174 | 0.9999 |
| Panel PP-Statistic | −2.6946 *** | 0.0035 | −1.8646 ** | 0.0311 |
| Panel ADF-Statistic | 1.1505 | 0.8750 | −0.4518 | 0.3257 |
| Alternative Hypothesis: individual AR coefficients (between-dimension) | | | | |
| | Statistic | *p*-value | | |
| Group rho-Statistic | 5.5214 | 1.0000 | | |
| Group PP-Statistic | −3.2611 *** | 0.0006 | | |
| Group ADF-Statistic | −0.7904 | 0.2146 | | |

Note: *** and ** denote the statistical significance of values at 1% & 5% levels.

### *4.2. Results of MMQR and Discussion*

In estimating the data for this study, we started by estimating the model without the interaction term. Results as presented in Table 6 were based on the MMQR estimation technique advanced by [43]. These results suggested that the control of corruption had a positive and significant effect on $CO_2$ emissions across the quantiles. Similarly, income level was positively related to $CO_2$ emissions, and this relationship was statistically significant across the quantiles. This meant that without the interaction term, both the control of corruption and income level exerted a positive and significant effect on $CO_2$ emissions. However, with the interaction term of the control of corruption and income level, the effect became negative and statistically significant across the conditional distribution of the quantile of $CO_2$ emissions as presented in Table 7. The plausible explanations for these results could be that at the low level of income of the country, the crusade against corruption may not translate into reducing $CO_2$ emissions. This is because fighting against corruption requires high level of income to improve environmental quality. Although increasing the level of income alone would stimulate $CO_2$ emissions through an increase in economic activity, which is accompanied by high-intensity of energy consumption and other factors that could trigger an upward trend of $CO_2$ emissions, such as a rising level of urbanization, population, investment, etc. Therefore, our finding was consistent with the earlier findings of [3,46,47].

In addition to the above discussion, the negative effect of the interaction term of the control of corruption and income level in Table 7 summarily suggested that a certain level of income is required for the control of corruption policies to reduce $CO_2$ emissions, and consequently, improve the quality of the environment. From Tables 5 and 6, the control of corruption exerted a positive and significant effect across the conditional quantiles of $CO_2$ emissions. This possibly implies that at a lower level of income, a country may not be able to implement effective policies to control corruption, as fighting corruption requires putting institutions in proper place, such as setting up of agencies, procurement of modern equipment, gadgets personnel costs, etc. However, when the control of corruption interacts with the income level, their effect on $CO_2$ emissions becomes negative and significant across the quantiles. The plausible explanation for this result is that as income is rising, countries tend to prioritize environmental cleanliness. In other words, at low-income levels, countries would be more concerned about increasing economic growth at the expense of the environment. This low-income level comes with insufficient tools to effectively control corruption. However, as income level increases, there is a change in policies from business as usual to more effective policies to control corruption and fight pollution. This paradigm shift is enhanced by the deployment of technologies that improve environmental quality. Moreover, with the high level of income, awareness of a sustainable environment and concerns for the urgent need to combat environmental pollution increase as governments and other stakeholders ensure that stringent environmental policies, as well as laws and regulations, stand tall, leading to a decline in corruption and progressive increase in environmental quality.

**Table 6.** Result of MMQR.

| | Location | Scale | Quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Parameters** | **Parameters** | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** |
| *CC* | 0.1165 | 0.0140 | 0.0944 | 0.101 ** | 0.107 *** | 0.111 *** | 0.117 *** | 0.121 *** | 0.127 *** | 0.132 *** | 0.139 ** |
| | (0.0772) | (0.0244) | (0.0574) | (0.0461) | (0.0376) | (0.0327) | (0.0306) | (0.0323) | (0.0377) | (0.0447) | (0.0579) |
| ln *GDP* | 0.1187 ** | 0.0083 | 0.106 *** | 0.109 *** | 0.113 *** | 0.116 *** | 0.119 *** | 0.122 *** | 0.125 *** | 0.128 *** | 0.132 *** |
| | (0.0479) | (0.0147) | (0.0367) | (0.0295) | (0.0241) | (0.0209) | (0.0196) | (0.0207) | (0.0241) | (0.0286) | (0.0370) |
| *REN* | −0.0251 *** | 0.0014 | −0.0273 *** | −0.0267 *** | −0.0261 *** | −0.0256 *** | −0.0251 *** | −0.0246 *** | −0.0241 *** | −0.0236 *** | −0.0229 *** |
| | (0.0044) | (0.0016) | (0.00296) | (0.00238) | (0.00194) | (0.00169) | (0.00158) | (0.00167) | (0.00195) | (0.00231) | (0.00299) |
| ln *FDI* | 0.0222 * | −0.0078 | 0.0345 *** | 0.0309 *** | 0.0277 *** | 0.0250 *** | 0.0220 *** | 0.0194 *** | 0.0164 ** | 0.0137 | 0.00953 |
| | (0.01126) | (0.0049) | (0.0115) | (0.00921) | (0.00754) | (0.00655) | (0.00613) | (0.00648) | (0.00755) | (0.00895) | (0.0116) |
| *No. of Obs.* | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 |

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

**Table 7.** Result of MMQR.

| | Location | Scale | Quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Parameters** | **Parameters** | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** |
| *CC* | 0.6399 | 0.1379 * | 0.414 | 0.486 ** | 0.539 *** | 0.600 *** | 0.644 *** | 0.688 *** | 0.741 *** | 0.789 *** | 0.859 *** |
| | (0.429) | (0.075) | (0.299) | (0.235) | (0.194) | (0.161) | (0.152) | (0.158) | (0.184) | (0.217) | (0.278) |
| ln *GDP* | 0.1824 ** | 0.0232 | 0.144 *** | 0.156 *** | 0.165 *** | 0.176 *** | 0.183 *** | 0.190 *** | 0.199 *** | 0.207 *** | 0.219 *** |
| | (0.0651) | (0.0199) | (0.0506) | (0.0397) | (0.0328) | (0.0273) | (0.0258) | (0.0268) | (0.0311) | (0.0368) | (0.0470) |
| *CC* × ln *GDP* | −0.0808 | −0.0198 | −0.0485 | −0.0587 * | −0.0664 ** | −0.0751 *** | −0.0814 *** | −0.0877 *** | −0.0954 *** | −0.102 *** | −0.112 *** |
| | (0.0639) | (0.0119) | (0.0433) | (0.0340) | (0.0281) | (0.0233) | (0.0220) | (0.0229) | (0.0266) | (0.0314) | (0.0402) |
| *REN* | −0.0247 *** | 0.0014 | −0.0269 *** | −0.0262 *** | −0.0257 *** | −0.0251 *** | −0.0246 *** | −0.0242 *** | −0.0237 *** | −0.0232 *** | −0.0225 *** |
| | (0.0043) | (0.0015) | (0.00314) | (0.00247) | (0.00204) | (0.00169) | (0.00160) | (0.00166) | (0.00193) | (0.00228) | (0.00292) |
| ln *FDI* | 0.0226 ** | −0.0082 * | 0.0361 *** | 0.0319 *** | 0.0287 *** | 0.0250 *** | 0.0224 *** | 0.0198 *** | 0.0166 ** | 0.0138 | 0.00958 |
| | (0.0105) | (0.0048) | (0.0123) | (0.00968) | (0.00800) | (0.00666) | (0.00628) | (0.00654) | (0.00757) | (0.00896) | (0.0115) |
| *No. of Obs.* | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 | 748 |

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

Furthermore, renewable energy had a negative and significant effect on $CO_2$ emissions across the quantiles in both the baseline model and interaction model. This implies that as the consumption of renewables is increasing, environmental quality is enhanced. The plausible reason for this result is consequent upon the fact that renewable energy is typically clean energy that has no combustible elements to deteriorate the environment. Unlike non-renewable energy, such as oil, coal, natural gas, etc., which are commonly used to generate electricity for industries and residential houses, renewables, such as hydropower, winds, solar, biomass, etc., have no environmental consequences, and their consumption dampens the level of greenhouse gases that are emitted into the atmosphere, thereby reducing climate change, air pollution, global warming, and other environmental challenges. This finding was consistent with [48] for EU countries, [37] for G7 nations, and [47].

In addition, the results revealed that foreign direct investment had a positive relationship with $CO_2$ emissions. The relationship is significant across the quantiles. The plausible economic explanation for the positive effect of FDI is that firms that are engaged in foreign direct investment inflows are always operating in environments that are conducive to making more revenues and profits. In other words, due to the high cost of environmental taxes in developed countries, firms would always like to operate where environmental taxes are not exorbitant or where environmental laws and regulations are not stringent. To this extent, firms would always like to operate in less-developed continents, such as the African continent, where they pay lesser environmental taxes and where environmental quality is not prioritized by the government of the day. In such an environment such as Africa, environmental laws and regulations are not stringent, and as such, the prevalence of corruption through bribery can also facilitate a minimum cost of environmental taxes compared with what such firms would have paid if they were operating in developed countries. Therefore, our finding is consistent with the pollution haven hypothesis firmed for Pakistan by [12], [30] for China, and [13] for the Latin American countries. Furthermore, our findings are related to the major finding of [49] that FDI inflows trigger environmental quality in developed nations because of their strong and effective environmental laws and regulation, while in the developing nations, the effect of FDI inflows is inimical to the environment.

Furthermore, from the estimations, it was clear that the coefficients of renewable and foreign direct investments are reducing across the quantile distribution of $CO_2$ emissions. In other words, the coefficients of the lower quantiles are higher but decrease across the quantiles. This implies that countries with a lower level of environmental degradation tend to experience a higher impact of renewable energy consumption and inflows of foreign investment. The finding was consistent with [37]. Although, in the case of the interaction term, the coefficients were increasing across the quantiles, suggesting that higher emission countries tend to experience the effect of the interaction term due to effective policies and commitment of the government to mitigate environmental degradation as recently demonstrated by [1].

### *4.3. Robustness Results*

As we have mentioned in the methodology, one of the limitations of the MMRQ estimator is that it failed to control for the issue of cross-sectional dependence in the series. Therefore, it was very important to check the robustness of our results using some estimation techniques that could control for cross-sectional dependence. In this study, we applied the OLS-FE, GLS-RE, and pooled mean OLS—all with Driscoll–Kraay standard errors which control for cross-sectional dependence as demonstrated by [50]. The results of these techniques are displayed in Table 8 for the model without the interaction term and in Table 9 for the model with the interaction term. We found that the effects of the control of corruption, income level, and foreign direct investment are positive and significant while renewable energy consumption is negative. However, the effect of the interaction of the control of corruption and income turns out to dampen environmental degradation. These results, therefore, confirm the results of the MMQR that even in the presence of cross-sectional dependence, the results invariably survive.

**Table 8.** Results of conditional mean-based regressions for Model I.

| | (1) | (2) | (3) |
|---|---|---|---|
| **VARIABLES** | **OLS-FE** | **GLS-RE** | **Pooled-OLS** |
| $CC$ | 0.116 *** | 0.137 *** | 0.318 *** |
| | (0.0257) | (0.0372) | (0.0381) |
| $\ln GDP$ | 0.119 *** | 0.142 *** | 0.883 *** |
| | (0.0213) | (0.0252) | (0.0242) |
| $REN$ | −0.0251 *** | −0.0282 *** | −0.0207 *** |
| | (0.00182) | (0.00122) | (0.000443) |
| $\ln FDI$ | 0.0222 *** | 0.0139 | −0.0668 *** |
| | (0.00759) | (0.00855) | (0.00777) |
| Constant | −0.587 *** | −0.405 ** | −4.540 *** |
| | (0.192) | (0.159) | (0.221) |
| Observations | 748 | 748 | 748 |
| R-squared | —- | —- | 0.879 |
| Number of groups | 34 | 34 | 34 |

Note: *** $p < 0.01$, ** $p < 0.05$, Driscoll–Kraay standard errors in parentheses.

**Table 9.** Results of conditional mean-based regressions for Model 2.

| | (1) | (2) | (3) |
|---|---|---|---|
| **VARIABLES** | **OLS-FE** | **GLS-RE** | **Pooled-OLS** |
| $CC$ | 0.640 *** | 0.712 *** | 1.111 *** |
| | (0.204) | (0.163) | (0.133) |
| $\ln GDP$ | 0.182 *** | 0.210 *** | 0.940 *** |
| | (0.0319) | (0.0283) | (0.0259) |
| $CC \times \ln GDP$ | −0.0808 *** | −0.0880 *** | −0.109 *** |
| | (0.0280) | (0.0229) | (0.0167) |
| $REN$ | −0.0247 *** | −0.0275 *** | −0.0207 *** |
| | (0.00172) | (0.00142) | (0.000460) |
| $\ln FDI$ | 0.0227 *** | 0.0151 * | −0.0591 *** |
| | (0.00745) | (0.00848) | (0.00783) |
| Constant | −1.057 *** | −0.934 *** | −5.129 *** |
| | (0.300) | (0.275) | (0.271) |
| Observations | 748 | 748 | 748 |
| R-squared | —- | —- | 0.881 |
| Number of groups | 34 | 34 | 34 |

Note: *** $p < 0.01$, * $p < 0.1$, Driscoll–Kraay standard errors in parentheses.

## 5. Conclusions

Given the intensive war against corruption in Africa over the years, there is a high expectation that such a move will help to achieve a structural transformation of the economies in Africa. In this study, we examined not only the effects of the control of corruption on environmental quality but also the extent to which the level of income of a country plays in influencing the impact of control of corruption on environmental quality in Africa. To achieve this objective, we applied the technique of MMQR with fixed effect, which controls for heterogeneity, and also OLS-FE, GLS-FE, and Pooled OLS with Driscoll–Kraay standard errors. These estimations controlled for cross-sectional dependence. Having found evidence in support of the integration of variables explored and their cointegration, the empirical results suggested that the effects of the control of corruption, income level, and foreign direct investment on environmental quality were positively significant, while renewable energy consumption dampened the quality of the environment. However, the effect of the interaction of the control of corruption and income level improved environmental quality in Africa. These results, therefore, suggested that income level plays a vital role in how the control of corruption crusade reduces environmental degradation. Moreover, the positive effect of inflows of foreign direct investment suggested that Africa is a dumping ground where high-intensive carbon-emitting firms operate because of environmental laws and regulations that are not stringent.

Following the results of this study, there are many policy recommendations. These recommendations will help the policymakers to draft environmental policies to achieve low-carbon economies in Africa. As shown by the results, income level forms the basis upon which the war against corruption can mitigate environmental degradation. Therefore, there is a need to stimulate income levels to influence an effective control of corruption. This can be achieved by stimulating consumption and investment in clean energy. Moreover, stimulating consumption and investment requires government and stakeholders to create an enabling environment to attract inflows of foreign investment in addition to domestic investment. Moreover, since renewable energy reduces $CO_2$ emissions, government policies need to target investment in the clean energy sector rather than in fossil fuels. To achieve this, subsidies, carbon tax, tax holidays, environmental taxes, etc. are suggested as operational instruments. The implication of this study further displays the need to strengthen the laws and regulations concerning the environment in Africa. In other words, since the African continent is a dumping ground for many highly carbon-intensive industries, there is a need to strengthen and implement effective environmental laws and regulations in Africa. Such environmental taxes should include taxes on pollution, taxes on resources, taxes on transport, and taxes on other activities that contribute to the upward trend of $CO_2$ emissions in Africa. Furthermore, a growing income level was found as one of the channels through which Africa increases the level of $CO_2$ and greenhouse gases. Therefore, to achieve the environmental sustainability target, there is a need for Africa to shift from carbon-intensive-led growth to a green growth path. This can be achieved by promoting a cleaner environment through clean energy consumption.

Finally, this study may have some practical limitations. Africa's economies are quite different from other continental economies such as Asia and South America. Therefore, the policy recommendations in this study might have a limited application in these countries. Therefore, we suggest that a similar study could be carried out in the continents mentioned to find out how their levels of income interact with the control of corruption to achieve environmental quality. Better still, future studies could use the World Bank classifications of countries' income levels and compare how income levels influence the impact of the control of corruption on environmental degradation in these categories of countries.

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## Appendix A Aix A

**Table A1.** List of Countries.

| |
|---|
| -Algeria; |
| -Angola; |
| -Botswana; |
| -Burkina Faso; |
| -Cameroon; |
| -Congo; |

**Table A1.** *Cont.*

| |
|---|
| -Congo DR;<br>-Cote d'Ivoire;<br>-Egypt;<br>-Ethiopia;<br>-Gabon;<br>-Gambia;<br>-Ghana;<br>-Guinea;<br>-Guinea-Bissau;<br>-Kenya;<br>-Libya;<br>-Madagascar;<br>-Malawi;<br>-Mali;<br>-Morocco;<br>-Mozambique;<br>-Namibia;<br>-Nigeria;<br>-Senegal;<br>-Sierra Leone;<br>-South Africa;<br>-Sudan;<br>-Tanzania;<br>-Togo;<br>-Tunisia;<br>-Uganda;<br>-Zambia;<br>-Zimbabwe. |

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