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The impacts of economic growth, corruption, energy consumption and trade openness upon CO2 emissions: West African countries case

Received 4 January 2023
Revised 28 February 2023
Accepted 22 March 2023

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Abstract

Purpose – This research paper aims to handle the effects of economic growth, corruption, energy consumption as well as trade openness on CO2 emissions for a sample of West African countries during the period 1980 and 2018.
Design/methodology/approach – The current work uses the pooled mean group (PMG)-autoregressive distributed lag (ARDL) panel model to estimate the dynamics among the different variables used in the short and long terms.
Findings – The findings demonstrate that all variables have long-term effects. These results suggest that gross domestic product (GDP) per capita exhibits a positive and prominent effect on CO2 emissions. Corruption displays a negative and outstanding effect on long-term CO2 emissions. In contrast, energy consumption in West African countries and trade openness create environmental degradation. Contrarily to long-term results, short-term results demonstrate that economic growth, corruption and trade openness do not influence the environmental quality.
Originality/value – Empirical findings provide useful information to explore deeper and better the link between the used variables. They stand for a theoretical basis as well as an enlightening guideline for policymakers to set strategies founded on the analyzed links.

Keywords West African countries, CO2 emissions, Economic growth, Energy consumption, PMG
Paper type Research paper

1. Introduction

Recent years have been marked by changes in scientific and technological fields for human civilization, which yielded an increase in the exploitation of natural resources as well as an economic development in addiction to certain negative impacts on the environment. Indeed, the entire planet, and the African continent in particular, consists of a large amount of natural resources that have long been untapped and have been the source of multiple conflicts between countries.

Literature on environmental quality has focused upon the analysis of the link between economic growth, corruption, energy use and carbon dioxide (CO2) emissions over time

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Arab Gulf Journal of Scientific Research
Emerald Publishing Limited
e-ISSN: 2536-0051
p-ISSN: 1985-9899
DOI 10.1108/AGJSR-01-2023-0005

(Wang, Danish Zhang, & Wang, 2018; Rahman, Saidi, & Ben Mbarek, 2020; Sultana, Rahman, Khanam, & Kabir, 2022).

It is noteworthy that research in this field has centered around verifying the Environmental Kuznets Curve (EKC) hypothesis between economic growth and elements related to environmental degradation (Grossman & Kreuger, 1995; Liang & Yang, 2019).

Within this framework, EKC seeks to enhance the environmental quality of poor countries that are mainly in gradual development and whose individuals' standard of living is improving.

Authors, such as Akadiri, Saint Akadiri, and Gungor (2019) and Ntarmah, Kong, Obeng, and Gyedu (2022), conducted empirical research tackling the link associating economic growth with environmental quality.

The environmental Kuznets curve was introduced by, Sharma (2011), Apergis (2015), Ntarmah *et al.* (2022). Environmental researchers, such as Balsalobre-lorente (2018), asserted that the mentioned relationship is a key point that is worth investigating.

Prior studies assessed this link through the use of several econometric techniques and inferred that growth is a significant determinant of CO2 emissions (Dogan & Inglesi-Lotz, 2020; Khan & Ozturk, 2021).

However, over the recent years, the role of corruption as well as the link between growth and CO2 emissions has whetted the interest of numerous researchers. Corruption affects CO2 emissions, which contributes to a great extent to pollution (Wang *et al.*, 2018, 2020). However, corruption can introduce a bias not only in the process of implementing environmental policies but also in the process of applying and monitoring environmental laws.

Furthermore, theoretical and empirical analyses have emphasized that corruption is a significant factor begetting environmental degradation through decreasing the stringency of environmental regulations (Damania, Fredriksson, & List, 2003, Paunov, 2016).

In 2018, the African continent remained the worst ranked region in terms of perceived corruption index (CPI), with a score of 32 against 43 globally, at a scale of 100. CPI statistics between 2004 and 2018 also indicated that, on average, 4 to 5 African countries are classified among the 10 countries regarded to be the most corrupt on the globe.

This finding reveals the institutional failures that could not only slow down growth and income levels in these economies (Wang, Zhu, & Yang, 2020), but also may degrade their natural capital. The latter constitutes the basis of any sustainable development process (Perrings, 1994).

In an environment marked by corruption, the governmental authorities favor their private interest as they adopt environmental regulations that lead to strong environmental degradation (Omri, Nguyen, & Rault, 2014; Abid, 2016). These measures encourage firms to comply with the strict environmental regulations of developed countries. Their objective of profit maximization leads them to relocate their productive activities to countries with lax environmental regulations. The reciprocal impacts of corruption and environmental quality have constituted a hot area of empirical research such as those conducted by Akhbari and Nejati (2019).

Accordingly, the environmental degradation cannot be caused uniquely by corruption. Other factors, such as energy consumption, can also play a chief role in the degradation of the environment. So far, most scientific research have corroborated the existing link between the phenomenon of global warming and the CO2 emissions because it is intricately related to the increased consumption of energy.

This assumption is confirmed by, Rahman *et al.* (2020) who were concerned with investigating the relationships governing three eminent factors: CO2 emissions, economic growth and energy consumption.

In this regard, Ma, Dai, and Wen (2019) revealed that trade openness acts as a leading agent in terms of economic growth, which is, in turn, linked to energy consumption and preservation of the environmental quality.

Therefore, trade openness contributes to economic development as it facilitates the provision of environmentally friendly products and helps remove the constraints related to the adoption of modern technologies and mainly environmental services (Ahmad, Jiang, Majeed, & Umar, 2020).

Research on environmental quality postulates that trade openness plays a crucial role in reducing CO2 emissions and climate change (Yazdani & Pirpour, 2020; Abid, Mehmood, Tariq, & Haq, 2022).

It is noteworthy that our sample relies on West African countries, as members of the West African Economic and Monetary Union (UEMOA), with data from 1990-2018. This study period is limited for reasons of data availability.

These countries are Ivory Coast, Ghana, Senegal, Mali, Burkina Faso, Gambia, Sierra Leone and Niger. For reasons of data availability, the study shall focus on nine countries.

The contributions of this study are twofold: first, the debate on the right balance between environmental protection and economic growth is likely to gain momentum, especially with the observed climate change, which is becoming a priority for West Africa. These countries had a GDP of $737.689 billion in 2020, which represents 31.11% of Africa's total GDP. This refers basically to the fact that these West African countries have adopted a common strategy for the year 2030, with the objective of strengthening their cooperation in adaptation policies to the effects and elaborating development trajectories with low greenhouse gas emissions and the ambition to increase the share of renewable energy to 48% of the energy mix in 2030. These policies were approved by the Paris agreements (Climate Change Conference [COP21]) in 2015.

Secondly, we can consider this study as original in terms of exploring the effect of corruption on the quality of the environment as it is considered as a brake for development in Africa, which unfortunately remains the region most affected by this institutional problem (Transparency International, 2018). Therefore, alignment between environmental rights and anti-corruption programs can help build understanding and support for environmental rights and broaden those advocating for stronger enforcement to achieve more inclusive economic growth.

Additionally, the particularity of our selected sample lies in the fact that it is characterized by the use of fossil energies coming essentially from the export of crude oil (6.5 % of the world's total resources in 2020), which entails the degradation of the quality of the environment as well as the use of the variable commercial openness which in turn begets an increase of the emission of CO2. In this respect, we find that an empirical study on a sample of West African countries seems to be necessary to approve this observation.

The main objective of the current paper is to assess the impact of economic growth, corruption and energy consumption on the quality of the environment. The remaining of this paper is structured as follows: the second section is dedicated to a literature review that summarizes the main works addressing economic growth, corruption and environmental quality. Section 3 introduces the used data and the employed econometric models. In section 4, a descriptive analysis of data is elaborated along with a discussion of the obtained results. Section 5 synthesizes the main conclusions and provides new perspectives for future research.

2. Literature review

An extensive corpus of literature investigates the link between CO2 emissions, economic growth and other variables using various methodologies for different time periods (Kraft & Kraft, 1978). In addition, referring to Grossman and Kreuger (1995) and Churchill, Inekwe,

Ivanovski, and Smyth (2019), literature on economic growth and environmental quality occurs with the EKC hypothesis.

Alaganthiran and Anaba (2022) demonstrated that economic growth stands for one of the eminent agents affecting the increase of carbon gas emissions in many Sub-Saharan African countries over the period 2000–2020 using panel linear regression econometric method.

Akinlo (2008) proved that there exist three types of causality relationships in some African countries between carbon emissions and GDP with vector error correction model (VECM) econometric approach.

Eleazar's (2015) study highlighted a neutral effect existing between energy use and economic performance in many countries such as South Africa and Togo with an ARDL model.

Aye and Edoja (2017) investigated and analyzed the relation between CO2 emissions and economic growth of 31 developing countries. Using the dynamic panel approach, they indicated that there is a negative relation between these two variables. In selected Sub-saharan African countries, Esso and Keho (2016) try to examine the long-run and causal relationships among energy consumption, CO2 emissions and economic growth for the period 1971–2010 through the use of the Granger causality tests. In the same nations, Sun *et al.* (2020) attempted to quantify the link between environmental quality, economic growth, energy consumption and trade liberalization through the use of panel cointegration approach. Authors argued that there is a long-run causality between CO2 emissions and used variables.

However, recent research works on economic growth reinforced that energy consumption, CO2 emissions and oil prices correspond to fundamental elements of the economic growth. This was inferred departing from the study of not only a sample of European countries by using Granger causality (Ahmed & Azam, 2016) but also 119 nations in the world relying on testing an ARDL model (Ntanos *et al.*, 2018). Authors argued that these variables have an effect on economic growth.

Recently, Leitão and Balogh (2020) have assessed not only the link between economic growth and corruption but also the relationship between corruption and the emissions of CO2.

Using fixed effects panel and generalized method of moment (GMM) approach, their empirical findings were suggestive that corruption has an effect on not only economic growth but also the quality of air and climate change.

Likewise, recent research carried out by Leitão (2021) tackled the relationships between CO2 emissions, economic growth, renewable energy, corruption and trade openness using time series approach, quantile regressions and cointegration models for the period 1970–2016.

Their empirical findings disclosed that economic growth and the corruption index exert a positive influence on the degradation of the quality of environment. Yet, international trade and renewable energy are contributive to the reduction of climate change as well as the improvement of environmental quality.

Research on the relationship between CO2 emissions and corruption revealed that there exists a negative relation between corruption and CO2 emissions in Brazil, Russia, India, China, and South Africa (BRICS) countries. This was corroborated relying on the fully modify ordinary least square (FMOLS) for long run regression and the dynamic ordinary least squares (DOLS) (Balsalobre-Lorente, Driha, Bekun, & Osundina, 2019).

Sekrafi and Sghaier (2018) adopted the ARDL model, in an attempt to assess the link between corruption and economic growth on one-side and corruption and CO2 emissions on the other side. Their findings were indicative that while income per capita exhibits a negative influence on CO2 emissions, a squared income per capita impacts positively CO2 emissions.

Other researchers corroborated the relationship between corruption and CO2 emissions (Zhang & Chiu, 2020). These studies proved that corruption can increase CO2 emissions.

In the United States (US) context, Dincer *et al.* (2018) tried to assess the relation between corruption, trust and CO2 emissions by using panel data. Results confirmed that corruption and trust display positively CO2 emissions. However, a negative relationship exists between the lagged variable of stringency, squared income per capita and CO2 emissions. Grounded on Wang *et al.* (2018), the outcome of a partial least squares (PLS) regression disclosed that economic growth, corruption and urban population influence positively pollution in BRICS countries.

Relying on dynamic panel data from 1985 to 2011, Arminen and Menegaki (2019) confirmed the bidirectional association between CO2 emissions and energy consumption. These authors assumed that there exists a link between corruption, energy consumption and climate change.

They found that corruption is not a statistically significant variable, which is not fine-tuned with the Kuznets curve hypotheses.

In the same line, researchers attempted to assess the impacts of a set of variables (i.e. economic growth, energy consumption, foreign direct investment, financial development and corruption index, and urban population) on CO2 emissions. They also proved empirically that corruption has a positive effect upon CO2 emissions. Furthermore, their results confirmed that a foreign direct investment exerts a negative impact upon CO2 emissions in the Philippines and Malaysia, where the urban population positively influences CO2 emissions.

Akhbari and Nejati (2019) research demonstrated that corruption negatively affects the carbon emissions in both developed and developing countries for 2003–2016. Investing a fixed effect panel, they asserted that the result of corruption reveals inconclusive effects. Indeed, when corruption index is uniquely used, authors found that it negatively affects carbon emissions, but, it can show an opposite result when it is multiplied by human development index. In this respect, Akhbari and Nejati (2019) reported a negative influence.

According to Zhang and Chiu (2020) and using a panel regression model, an empirical study on CO2 emissions untertaken in 111 risks countries for the period 1985–2014 revealed that there is a U-curve among CO2 emissions and economic risk. As for financial and political risks, there exists a positive effect on CO2 emissions. Performing a study on Asian countries throughout the period 1984–2017, Lee, Shan, Lee, and Low (2020) used panel regression methods to empirically corroborate that corruption positively affects CO2 emissions. These authors also assumed that there exists a positive relation between CO2 emissions, energy consumption and economic growth. However, population and foreign direct investment negatively impact CO2 emissions.

In this respect, Ike, Usman, and Sarkodie (2020) examined the linkage among energy consumption, income per capita, trade openness, democracy and oil production using panel FMOLS and DOLS method. They argued that environmental damage is positively affected by oil production, democracy and energy consumption.

Recently, Rahman, Zaman, and Górecki (2021) adopted DOLS and FMOLS models to assess the influence of economic growth, energy consumption and globalization on CO2 emissions in BRICS nations over the years 1989–2019. In this regard, their findings indicated that while energy use impacts positively CO2 emissions, the globalization index (KOF) negatively affects CO2 emissions. Similarly, in an attempt to assess the determinants of economic factors and air quality, Kahia, Omri, and Jarraya (2021) who relied on data for the period 1990–2016 in Saudi Arabia and applied the simultaneous equation model, found out that squared income per capita and income per capita are fine-tuned with the EKC hypotheses. In the same direction and using an ARDL approach, Arnaut and Lidman (2021) handled Green land's experiment and proved that square income per capita and income per capita have a positive as well as a negative effect on CO2 emissions. Energy consumption has a positive effect on carbon emissions and a negative effect on urbanization. In South Asia, Tariq *et al.* (2022) examined the effect of green energy consumption, economic growth and

trade on greenhouse gas emissions from 1981 to 2018. Using FMOLS and DOLS models, they proved that trade openness, economic growth increase greenhouse gas emissions.

In five West African context, Adewuyi and Awodumi (2017) used a simultaneous equation model and confirmed that there exists a significant relationship between GDP, biomass energy consumption and CO2 emissions during 1980–2010. As for the selected West African countries with similar income status, Adu and Denkyirah (2019) tried to test the relationship between environmental quality and economic growth by employing a data from 1970 to 2013. The results proved that economic growth in the short-run increases CO2 emissions rather than reduce CO2 emissions in the long-run. Osadume and University (2021) handled the effect of economic growth upon carbon emissions for the period 1980–2019 by using panel econometric methods. They proved an important positive effect of economic growth on carbon emissions in short and long periods on six West African countries.

Recently, in a specimen of West African countries, Radoine, Bajja, Chenal, and Ahmed (2022) adopted Driscoll-Kraay (DK) method of panel regression and argued that urbanization, manufacturing value-added, financial development and foreign direct investment influence positively environmental degradation over the period 1991–2018.

In our research work, we shall focus on this region through covering more West African countries, and examining effects of energy use, economic growth and corruption relying on the ARDL-pooled mean group (PMG).

3. Data presentation and methodology

3.1 Data

Structure of data is a panel of 9 West Africa countries, namely Ivory Coast, Burkina Faso, Gambi, Ghana, Niger, Mali, Senegal, Togo and Sierra Leone for the period 1990–2018. All variables were afforded by the World Bank, World Development Indicators (WDI, 2021), International Country Risk Guide and International Energy Agency. The invested data series are depicted in Table 1.

Table 2 exhibits informative statistics about the used series with regard to a panel of 09 West African nations over the period 1990–2018. All the used variables are changed into natural logarithm, as stated earlier in the data source, except for corruption.

Table 1.
Data description, measurement and sources

Variable	Description/Transformation	Source
CO2	Carbon dioxide emissions correspond to the fossil fuel combustion and cement manufacturing CO_2 components are carbon dioxide resulting from the consumption of solid, gaseous fuels and liquid, as well as gas flaring. They are measured by Kilotonnes (KT)	World Development Indicators, (2021)
Corruption	control corruption Index	International Country Risk Guide (2020)
GDP per capita	GDP per capita stands for a gross domestic product divided on population and measured by constant 2010 US $	World Development Indicators, (2021)
EC	Total energy consumption represented by Kilotonnes of Oil equivalent (KTOE)	International Energy Agency (IEA) (2020)
TR	The total export and import divided by GDP	World Development Indicators (2021)

Source(s): Author's Work

	CO2	COR	EC	GDP	TR
Mean	3006.743	2.249361	1332.748	655.2059	58.67294
Median	1710.000	2.000000	590.8282	570.9100	56.64975
Maximum	16110.00	4.000000	7430.916	2361.090	131.4854
Minimum	150.0000	0.000000	67.45819	138.6987	26.09894
Std. Dev	3329.872	0.711296	1517.414	425.4203	19.24060
Skewness	1.732118	0.014505	1.670502	1.609847	0.766674
Kurtosis	5.815809	3.439964	5.519609	5.921094	3.407461
Jarque-Bera	216.7357	2.114206	190.4292	205.5290	27.37436
Probability	0.000000	0.347461	0.000000	0.000000	0.000001
Sum	784760.0	587.0833	347847.3	171008.7	15313.64
Sum Sq. Dev	2.88E+09	131.5450	5.99E+08	47055427	96252.17
Observations	261	261	261	261	261

Source(s): Author's Work

Table 2. Descriptive statistics of variables

3.2 Methodology

In this research paper, balanced panel data of 9 West African countries were invested using the ARDL-PMG regression. The different steps of the used methodology are described in what follows.

(1) Cross-sectional dependence (CD) and panel heterogeneity

Resting upon Pesaran (2007), CD between all variables may occur. Therefore, the result of the panel data can yield biased and unreliable results. With reference to previous literature, it is proven that panel data models need to provide a significant CD on the error. The basic objective for the cross-correlation of errors is accounted for in terms of multiple reasons: the omitted common effects, unobserved components as well as spatial effects (Pesaran, 2004). In order to verify the CD among variables and to further develop our empirical analysis, we resorted to Breusch and Pagan (1980) and Pesaran (2004) CD tests.

(2) Stationarity

Subsequently, the second step lies in confirming stationarity after studying the CD in the panel data modeling. Numerous unit root tests were addressed in the previous literature, namely first generation and second generation tests. The first generation tests, the most widely used of which are the Levin and Lin (1992, 1993), Im, Pesaran and Shin (IPS) (1997, 2003) and Maddala and Wu (MW) (1999) tests, were inspired from the Dickey and Fuller (1979) tests.

The most widely used second generation tests are the augmented cross-sectional IPS test (CIPS) and cross augmented Dickey-Fuller(CADF) test, taking into account heterogeneous panels (Pesaran, 2007). The second generation tests attempt to validate the independence hypothesis by postulating interdependence between individuals.

(3) Cointegration test

After checking the integration order properties of the used data, the econometric theory seeks to examine the presence of a long-run connection between series. As a matter of fact, the Westerlund (2007) panel cointegration procedure is applied since it provides many properties compared to other cointegration approaches. With reference to Persyn and Westerlund (2008), this methodology allows the heterogeneity in the short- and long-term cointegration dynamics. The second property of this methodology lies in its capacity to surmount the issue of CD.

(4) PMG regression

The main merit of the PMG panel cointegration approach, set forward by Pesaran, Shin, and Smith (1999), resides in the fact that PMG estimators take into consideration the time series properties of a group of data sets. Grounded on Pesaran *et al.* (1999), the unique methodology of PMG approach is to account for panel endogeneity, heterogeneity of variables and provide diversified stationary series.

Additionally, the underlying ARDL model authorizes extracting the short and long-term impacts.

Compared to other panel estimation methodologies, the PMG approach provides some other advantages, such as robustness to the outliers and lag orders.

To fulfill the Pesaran *et al.* (1999) PMG estimation, the ARDL (p, q) models are presented as follows:

$$CO2_{it} = \sum_{j=1}^{p} \omega_{ij} CO2_{i,t-j} + \sum_{j=1}^{p-1} \Theta_{ij} \Delta X_{i,t-j} + \gamma_i + \varepsilon_{it}$$

where X expresses the vector independent variables.

4. Results

(1) Results of cross-dependency test

In order to examine the potential correlation between units (countries), both CD tests of Breusch and Pagan (1980), and Pesaran (2004) were undertaken. Results of these tests are outlined in Table 3.

Note that the null assumption of both tests implies the presence of a CD. The findings expose that the null assumption is statistically not accepted by all tests at the different critical thresholds. This result can be accounted for in terms of the possibility of a shock in one of these African countries that can spread to the others.

(2) Unit-root test

This step relies on determining the stochastic properties of the different series of the models: Lev-in-LIN-Chu (LLC) and Breitung (2000), the second generation CIPS and CADF. In fact, the latter takes into account the dependence that has already been specified in the previous estimation step. The findings of the first and second generation stationarity tests are illustrated in Table 4. Based on the results of the LLC unit root test, all variables are I(0) except for TR and CO_2 which are I(1). The Breitung test indicates that GDP, COR and TR are of order I(1), but EC and CO_2 are I(0).

	Breusch-Pagan LM	Pesaran CD
CO_2	694.7875 (0.0000)	25.24403 (0.0000)
EC	681.3245 (0.0000)	24.53458 (0.0000)
GDP	912.2782 (0.0000)	30.17518 (0.0000)
COR	*694.7875 (0.0000)*	25.24403 (0.0000)
TR	200.2479 (0.0000)	5.965291 (0.0000)

Note(s): The cross-sectional dependence test helped in deciding whether to use the first or second generation panel unit root tests

Source(s): Author's Work

Table 3.
Cross-dependency test

Table 4. Unit root results

Variables	LLC		Breitung		CIPS		CADF	
	Level	First difference	Level	First difference	Level	First difference	Level	First difference
CO2	0.090	−7.028*	−2.364*	−7.148*	−2.456**	−4.322*	−2.456**	−4.322*
EC	−2.647*	−3.008*	−1.680**	−6.380*	−2.410**	−3.937*	−2.410**	−3.937*
GDP	−1.871**	−5.856*	−0.294	−8.007*	−2.182***	−3.597*	−2.182***	−3.597*
COR	−4.380*	−7.682*	−1.249	−8.126*	−2.200***	−4.026 *	−2.200***	−4.026*
TR	−0.087	−3.388*	0.442	−4.798*	−1.799	−4.086 *	−1.799	−4.086*

Source(s): Author's Work

In addition, through applying the CIPS and CADF tests, all variables are incorporated at order I(0), except for the TR variable which is integrated at order I(1).

All variables proved to be integrated at order I(0) or I(1), and there is no order I(2).

(3) Cointegration results

The panel cointegration method of Westerlund (2007) was applied to test whether a long-run relationship exists between the different series in the model. Cointegration findings of the Westerlund (2007) test are summarized in Table 5.

These findings are indicative that the statistics of the group-t and panel-t tests are significant, which entails the rejection of the null hypothesis with the absence of cointegration. Therefore, the existence of the long-term cointegration in our model is confirmed.

(4) Long-term and short-term effects

In Table 6, estimates are exhibited using the ARDL-PMG model. The long and short term results are foregrounded. According to our econometric results, we can confirm the validity of our estimation based on the error correction term (ECT) coefficient, which is clearly negative and significant at the different threshold levels. This reinforces the adjustment speed and the presence of a long-term relationship.

The results show that all variables used in our study have long-term effects. These findings can clarify the situation of West African countries in terms of environmental sustainability, and specify possible actions, taking into account the evolution of each selected determinant (energy consumption, corruption, economic growth and trade).

Table 5. Westerlund cointegration test

Statistic	Value	*Z*-value	*p*-value
Gt	−2.776	−2.326	0.010*
Ga	−11.063	−0.500	0.309
Pt	−6.582	−1.367	0.086***
Pa	−10.142	−1.653	0.049**

Source(s): Author's Work

Table 6. Results of ARDL-PMG

Variables	Coefficients	Std.error	*p*-value
Long run			
ECT	−0.280	0.0797611	0.000
GDP	0.210	0.0474191	0.000
COR	−0.059	0.0273492	0.030
EC	0.882	0.043899	0.000
TR	0.152	0.640666	0.017
Short run results			
Δ GDP	0.1223	0.0965394	0.205
ΔCOR	−0.059	0.0257725	0.210
ΔEC	0.348	0.1621146	0.032
ΔTR	0.137	0.1160528	0.235
Constant	−0.027	0.027749	0.329

Source(s): Author's Work

In what follows, we shall characterize the influence of the different variables and compare them to the empirical economic literature. GDP per capita (ln GDP per capita) displays a significant and positive reaction on the acceleration of CO2 level. More precisely, the EKC hypothesis cannot be validated: a 1% increase in GDP per capita tends to contribute to 0.21% of environmental deterioration. This result goes in good agreement with those reported by Mongo, Belaïd, and Ramdani (2021) on a sample of 15 European nations over 23 years.

Furthermore, our results go in good accordance with those of Al-Mulali *et al.*'s (2015) who focused on Vietnam during the period 1981–2011, Boukhelkhal's research (2022) on data of 35 African nations and Osadume and University's (2021) findings from West African countries as well as Muftau, Iyoboyi, and Ademola Abdulsalam (2014) who asserted the long run effect of GDP and environmental quality in West Africa.

Corruption has a negative and significant effect on the level of CO2 emissions in the long-term run. This confirms that the fight against corruption can decrease the levels of polluting emissions and subsequently protects the environment in West Africa in the long run. Corruption automatically leads to inefficiency in the economic management of the country; this is reflected in the failure of economic policies in general and environmental policies in particular that are adopted by public authorities. Indeed, the reduction of the level of corruption enables strategies to rise the production and consumption of green energies in developing countries (Amoah, Asiama, Korle, & Kwablah, 2022; Saadaoui & Chtourou, 2022; Saadaoui, 2022), which certainly allow the improvement of environmental quality.

The results go in good consistency with those of Al-Mulali and Ozturk (2015) for the case of Cambodia during 1996–2012, with those of Ben Jabeur and Sghaier (2018) for the case of Middle East and North Africa (MENA) region, and with the findings of Bae, Li, and Rishi (2017) for the case of 15 post-Soviet Union independent states during 2000–2011. Yet, our findings are considered different from certain other studies. For instance, working on a sample of 33 countries in Asia for the period 2000–2015, Liu, Latif, Danish Latif, and Mahmood (2021) reported that corruption is contributive to pollution in the atmosphere. Likewise, Arminen and Menegaki (2019) highlighted a positive effect of corruption on CO_2 emissions in the case of high-income and upper-middle-income countries over the period 1985–2011. Moreover, conducting a study on a sample of 23 African countries between 1999–2017, Leal and Marques (2021) inferred that there is no effect of corruption on environmental performance.

The energy consumption variable exhibits positive and significant effects on CO2 emissions: 1% increase in energy consumption can entail a rise of 0.882% in CO2 emissions. Our finding goes in good conformity with that of Namahoro, Wu, Zhou, and Xue (2021) who indicated that energy intensity increases CO2 emissions in Africa. Indeed, Belaïd and Zrelli's findings (2019) go in good consistency with our finding in the case of Mediterranean countries. Moreover, Ben Jabeur and Sghaier (2018) demonstrated that energy consumption increases the level of CO_2 emission in MENA region. This result indicates that energy consumption in West African countries yields environmental degradation. This result may be accounted for in terms of the dominance of non-renewable energy consumption, which is a basic source of CO2 emissions.

Eventually, trade openness, with an approximate degree of economic openness, tends to raise CO_2 emissions in the long run. It reveals that a 1% increase in trade openness exports and imports contributes to a 0.1526% increase in CO_2 emissions. In this sense, Mongo *et al.* (2021) confirmed this result for some European countries.

In contrast, these findings differ from those obtained by Iorember, Jelilov, Usman, Işık, and Celik (2021) who recorded that trade openness reduces the ecological footprint in the South Africa case. These findings differ in turn from those of Muftau *et al.* (2014) who emphasized that estimated results of both long- and short-runs prove that openness explains significantly CO2 emissions in West Africa from 1970 to 2011. Moreover, Omri and Saadaoui (2022) emphasized that a negative shock in the trade openness raises the polluting emissions in France.

In contrast to the long-term results, the short run ones suggest that corruption, economic growth and trade do not influence environmental quality. Only energy consumption contributes to the rise of polluting emissions in the West African region.

5. Conclusion

The current study tackles the effect of economic growth, corruption, energy consumption and trade on CO2 emissions for 09 West African countries over the period 1990–2018. The main recorded results of this research are: Firstly, the results obtained from both CD tests of Breusch and Pagan (1980) and Pesaran (2004) reveal the existence of a CD. Secondly, the CADF and CIPS panel unit root tests indicate that all variables are incorporated at level I (0), except for the trade openness variable, which is integrated at the first difference. Thirdly, the Westerlund cointegration test suggests that the used data are cointegrated and therefore exhibit a long-run relationship. Proceeding in the same way, results from the ARDL-PMG estimator demonstrate that; (1) there is a positive and significant impact of energy use on carbon dioxide emissions both in the long and short-runs for all panels; (2) only in the long run is there a positive and significant effect of economic growth on carbon emissions; (3) a negative and significant effect of corruption on CO2 emissions and carbon emissions exists uniquely in the long run for all panels; (4) there is a positive and significant impact of trade on CO2 emissions in the long term.

Our empirical findings provide useful information to explore deeper and better the link between the used variables. They stand for a theoretical basis as well as an enlightening guideline for policymakers to set strategies founded on the analyzed links. As part of the pursuit for the dual objective of growth and preservation of the environmental quality, we set forward the following recommendations. It is therefore necessary to.

(1) Enact a common energy transition strategy based on the structured production of hydroelectricity in the coastal countries, the structured production of solar energy and the strengthening of the interconnection network.

(2) Coordinate, modernize and strengthen investments in the energy infrastructures of West African countries. It is a question of solving the problem of power cuts, which negatively influences the activity and the well-being of populations.

(3) Promote a healthy environment and manage natural resources in a sustainable development.

All these measures aim at creating a stable socioeconomic geopolitics. This research work can be powerfully integrated into a healthy environment, where well-oriented natural resources will take an active part in ensuring a sustainable development and the well-being of populations.

At this stage of analysis, we would assert that tackling this area is extremely valuable in terms of opening further fruitful lines of investigation. Indeed, future studies may consider several other variables that may affect environmental degradation, as institutional indicators (e.g. political stability, government effectiveness and democracy). Finally, it is noteworthy that our research is limited to West African countries. Thus, future research can take into account all countries in the African continent.

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