SSRG International Journal of Economics and Management Studies
ISSN: 2393 – 9125 / https://doi:10.14445/23939125/IJEMS-V9I10P101

Volume 9 Issue 10, 1-8, October 2022

Original Article

Income, Financial Development and Environmental Pollution in ECOWAS: Evidence from Quantile Regression Approach

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Received: 25 August 2022 Revised: 03 October 2022 Accepted: 14 October 2022 Published: 26 October 2022

Abstract *- This study investigates the effect of income, financial development, and trade on carbon dioxide emissions and covers the annual sample period from 1990 to 2021 in ECOWAS. Preliminary test results indicate non-normality in the data, evidence of slope heterogeneity, and cross-sectional dependence and verify the long-run cointegration relationship among variables. This situation allows us to use a panel quantile regression method to achieve the objectives because it is useful to outliers and provides more reliable estimates for climate policies than FMOLS and DOLS. The findings indicate that financial development exerts a negative and significant effect on CO2 emissions at lower and higher quantiles in lower and higher emissions countries but not significantly at middle quantiles. We also find a positive and significant effect of trade on CO2 emissions for all quantiles except for the 50th and 90th. Furthermore, this study examines the validity of the EKC hypothesis. The result indicates the inverted U-shaped only with the two last higher quantiles (80th and 90th quantiles) in high emissions countries. Contrarily to the quantile regression method, the FMOLS and DOLS approaches validate the EKC hypothesis without considering the heterogeneity, data outliers, and non-normality in data.*

Keywords *- Carbon dioxide emissions, Financial development, Quantile regression, Trade.*

JEL Classification Codes*: C21, F64, O44, Q56.*

1. Introduction

The last two decades were marked by one of the most serious environmental problems: the increase in the concentration of carbon dioxide (CO2) has caused global warming and climate change, which pose a threat to environmental sustainability (Shayanmehr et al., 2020a; Bölük and Mert, 2014). Many studies on this topic examine the effect of economic development on environmental degradation (Adedoyin et al., 2020; Amin et al., 2020). These studies mainly rely on Grossman and Krueger (1995) Environment Kuznets Curve (EKC) hypothesis. That relationship is found to be an inverted U-shaped or a U-shape depending on the characteristics of an economy (Pandey et al., 2020). An inverted U-shape means that environmental pollution increases with income per capita, but this relationship decreases when economies grow and new technologies to build cleaner energy sources are established (Stern, 2004; Shahbaz and Sinha, 2019).

According to Abbasi and Riaz (2016), fossil fuels account for 75% of greenhouse gas emissions and 90% of carbon dioxide emissions, making them the biggest contributors to the climate crisis. Between the end of the 17th century and today, the concentration of carbon dioxide in the atmosphere has thus increased by 40%. If, however, carbon dioxide is the main gas emitted (76% of emissions), methane (CH4), nitrous oxide (N2O), and fluorinated gases also have a significant warming power and represent respectively 16%, 6 % and 2% of emissions (Bernoux and Paustian, 2015). Scientists have grouped greenhouse gases (CO2, CH4, N2O, and three fluorinated gases) into a "carbon dioxide equivalent" category. Since

1970, more than three-quarters of the global greenhouse gas emissions have been attributed to the CO2 emitted by the combustion of fossil fuels (industry, heating, transport, etc.). The rest is mainly linked to land use change and, in particular, to deforestation. Countries with economies in transition, middle-income countries with upper slice, have an emissions profile close to that of the richest countries (Bernoux and Paustian, 2015).

A worrying report from the European Commission's Joint Research Center (JRC) on the dangers of global warming leads countries to adopt the Kyoto (1997) and Paris (2015) climate agreements to reduce greenhouse gases emissions (Shayanmehr et al., 2020b; Olivier et al., 2012). The countries of the European Union, based on the Paris climate agreement, as one of the largest emitters of greenhouse gases and major consumers of Energy in the world (Höhne et al., 2017), pledge to hold the increase in global average temperature to 2°C and reduce greenhouse gas emissions by at least 40% by 2030 compared to 1990 levels (Radmehr et al., 2021).

Countries are reluctant to reduce environmental pollution, leading to a drop in production and, in turn, in their income. ECOWAS has also experienced remarkable economic growth, as evidenced by its GDP reaching a level of US$565 billion in 2017, at a growth rate of 3.7% compared to previous years. Economic growth in the community peaked at 3.9% in 2019 before the Coronavirus outbreak (UNCTAD, 2018). Total ECOWAS greenhouse gas emissions in 2014 were 994.70 million metric tons equivalent (MCO2e) and increased in 2019 to 1.04 billion metric tons. Compared to developed and emerging countries, Africa's emissions are low. Africa emits only 4% of greenhouse gases (GHG); however, it is subject to more shocks than other continents because it is exposed to the effects of climate variability change. Knowing that the increase in temperature in West Africa is 1.5 times greater than the global level, countries have embarked on a fight against recurrent droughts, the great variability of seasons and rainfall, frequent floods and coastal erosion, etc. (CILSS, 2015). At a 2°C increase, ECOWAS will suffer the highest agricultural losses in the world, between 2 and 4% of its GDP (Boko et al., 2007). According to a report by the World Bank (2012), average losses in the event of drought are estimated at US$70 million in Niger, and flood damage can range from US$12 to 25 million, depending on the ECOWAS countries.

Despite the existence of a vast number of studies, the findings are conflicting regarding the validity of the EKC hypothesis. The EKC hypothesis was supported by many findings (Sinha and Shahbaz, 2018; Dong et al., 2018; Aboagye, 2017; Al-Mulali et al., 2015; Panayotou, 1993; Beckerman, 1992) while Martinez-Alier (1995) assumes the opposite. Other researchers pointed out not to ignore the pollution created by the process of importing goods in the calculation of national emissions. A group of studies considers trade openness to harm CO2 emission (Liu et al., 2018; Apergis et al., 2018; Zhang et al., 2017; Saidi and Mbarek, 2017; Al-Mulali et al., 2015), while other studies (Fang et al., 2019; Rasoulinezhad and Saboori, 2018; Gozgor and Can, 2016, 2017; Tiba et al., 2015) found the opposite effects. Some studies introduce financial development as an important determinant of changes in carbon emissions (Amin et al., 2020; Shahbaz et al., 2020; Gokmenoglu and Sadeghieh, 2019). Some researches lead to the findings that financial development mitigates environmental pollution by using new environmental technologies (Shoaib et al., 2020: Pata, 2018; Shahbaz et al., 2020; Shahzad et al., 2014; Zhang, 2011; Tamazian and Rao, 2010) while others consider financial development allows people to have a new device that can increase emissions (Wang et al., 2019; Tang and Tan, 2014; Islam et al., 2013; Sadorsky, 2011). Based on the literature, we examine the effect of financial development, trade openness, and GDP per capita on CO2 emissions in ECOWAS countries. Is there a positive association between trade openness, financial development, and GDP per capita on CO2 emissions?

The motivations of this paper are threefold. The first is to verify the EKC hypothesis in ECOWAS countries, considering financial development and trade as control variables. The second is based on the econometric techniques used. The empirical analysis is based on Pesaran and Yamagata (2008) slope homogeneity test followed by Breusch-Pagan (1980), Frees (1995), Friedman (1937) cross-sectional tests, then second generation unit root test and Westerlund (2007), Pedroni (1999, 2004) and Kao (1999) cointegration tests for long-run analysis. Since the preliminary analysis confirms the non-normality, cross-section dependence, and slope heterogeneity, we employ a panel quantile regression. Lastly, the quantile regression helps understand the factors that cause carbon emissions and explain the conditional distribution of exogenous variables (Chang et al., 2020).

Moreover, this approach is efficient and stronger than OLS results because of outliers and the non-normality of the error term (Sim and Zhou, 2015). The rest of this paper is as follows. Section 2 presents the data and methodology, Section 3 discusses empirical results and discussion, and Section 4 concludes the paper.

2. Model, Data, and Methodology

This section is based on the model used, the data, and the different methodologies adopted in this paper.

2.1. Model and Data

This study tests the pollution and income relationship based on the well-known Environmental Kuznets Curve (EKC) developed by Grossman and Krueger (1995). Since the original empirical work on the EKC, many researchers have analyzed this relationship using CO2 as a proxy for environmental degradation. From the preceding, the empirical model expresses environmental degradation (proxy with CO2 emissions) as a function of income (proxy with GDP per capita), financial development, and trade (Amin et al., 2020). The model can therefore be expressed as:

$$CO_{2it} = f(GDP_{it}, GDP_{it}^2, FD_{it}, TRA_{it}) \qquad (1)$$

Where CO2 is carbon dioxide emissions, GDP is the gross domestic product, FD is the financial development, and TRA is the trade openness across unit i at t time periods. To confirm the EKC hypothesis, the expected sign of GDP per capita is positive on the carbon emissions. In contrast, the square of GDP per capita is negative (inverted U-shaped relationship). Financial development's effect on pollution is expected to be ambiguous, while trade openness positively affects CO2 emissions.

Annual data span from 1990 to 2021, including 32 observations, representing 14 of 15 countries in ECOWAS (see table 1). These countries are Benin, Burkina Faso, Capo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. Data are expressed in a natural logarithm.

2.2. Methodology

This study's starting point is the cross-section dependence test. In econometric literature, most studies consider the cross-section as an independent. This assumption is not always confirmed. For this reason, Breusch-Pagan (1980), comforted by Frees (1995) and Friedman (1937), tests are used. These tests are preferred to Pesaran's (2004) CD test because the time period is larger than cross-section units. The general form of the Breusch-Pagan (1980) test is as follows:

Table 1. Variable definitions and data sources

Variable	Definition	Source
CO_2	Carbon dioxide emissions (metric tons per capita)	World Development Indicator (2021)
GDP	Economic growth (Real GDP per capita constant USD at 2015 prices)	World Development Indicator (2021)
TRA	Trade is the sum of exports and imports of goods and services (% of GDP)	World Development Indicator (2021)
FD	Financial development, domestic credit to the private sector (% of GDP)	World Development Indicator (2021)

Source: data from WDI (2022)

$$LM_{BP} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2} \quad (2)$$

Where $\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T}\hat{u}_{it}\hat{u}_{jt}}{\left(\sum_{t=1}^{T}\hat{u}_{it}^{2}\right)^{1/2}\left(\sum_{t=1}^{T}\hat{u}_{jt}^{2}\right)^{1/2}}$

is the pairwise correlation, $i = 1, \dots, N$ and

$t = 1, \dots, T$ for $i \neq j$. Breusch and Pagan (1980) suggest an LM test when N is fixed and $T \to \infty$ under the null hypothesis of cross-section independence $H_0: \rho_{ij} = 0$ for $i \neq j$. After the cross-section dependence, the slope homogeneity test (Δ test) proposed by Pesaran and Yamagata (2008) for panels in which both N and T are large is used. It is based on a standardized version of Swamy's test (Swamy, 1970). The test provides two statistics: Δ, and it's an adjusted version $\tilde{\Delta}$ with a null hypothesis of homogenous slope as follow:

$$\tilde{\Delta} = \frac{1}{\sqrt{N}}\left(\frac{\sum_{i=1}^{N}\hat{d}_i - k_2}{\sqrt{2k_2}}\right) \quad (3)$$

Where

$$\tilde{d}_i = \left(\hat{\beta}_{2i} - \tilde{\beta}_{2WFE}\right)' \frac{X_{2i}' M_{1i} X_{2i}}{\tilde{\sigma}_i^2}\left(\hat{\beta}_{2i} - \tilde{\beta}_{2WFE}\right)$$

and $M_{1i} = I_{Ti} - Z_{1i}(Z_{1i}'Z_{1i})^{-1}Z_{1i}'$. Under H_0, $\tilde{\Delta} \sim N(0,1)$. According to the unit root test, there are two generations of tests. The first generation hypothesis that cross-section units are cross-sectionally independent (Im et al., 2003; Levin et al., 2002; Choi, 2001; Breitung, 2000; Hadri, 2000; Maddala and Wu., 1999), while the second generation of panel unit root tests (Pesaran, 2007; Bai and Ng, 2004, 2005; Harris et al., 2005; Moon and Perron, 2004; Chang, 2002) relax this assumption and allow for cross-section dependence. We will only present the Im, Pesaran, and Shin (2003) (IPS) test and Pesaran (2007) cross-sectionally augmented IPS (CIPS) test. The IPS (2003) statistic can be written as follow based on a separate ADF regression for each cross-section:

$$\Delta y_{it} = \alpha_i y_{i,t-1} + \sum_{j=1}^{P_i}\varphi_{ij\Delta y_{i,t-j}} + Z_{it}'\gamma + \varepsilon_{it} \quad (4)$$

The null hypothesis is defined as $H_0: \alpha_i = 0$ for all i, whereas now the alternative hypothesis is given as:

$$H_1: \begin{cases} \alpha_i = 0 & for \quad i = 1,2,\dots,N_1 \\ \alpha_i < 0 & for \quad i = N_1+1, N_1+2,\dots,N \end{cases} \quad (5)$$

The Pesaran (2007) CIPS test overcomes the problem of heterogeneity and cross-section dependence and can be written as follow:

$$\Delta y_{it} = \gamma_i + \gamma_i w_{i,t-1} + \gamma_i \overline{x}_{t-1} + \sum_{j=0}^{L}\gamma_{ij}\,\Delta\overline{x}_{t-j} + \sum_{j=1}^{L}\gamma_{ij}\Delta x_i \quad (6)$$

Where $\overline{x}_{t-1}$ and $\Delta\overline{x}_{t-j}$ are the average values for each cross-section and lags.

We also use panel cointegration tests such as Pedroni (1999, 2004), Kao (1999), and Westerlund (2007). Despite considering the slope heterogeneity, Westerlund's (2007) test considers the cross-section dependence with the null hypothesis of no cointegration for each test. Finally, we use a panel quantile regression using Powell's (2016) quantile regression considering the non-linearity problem of the specification in the fixed effects variables. Koenker and Bassett (1978) give some ideas of quantile regression. The quantile regression model permits the determination of a covariate's impact on the dependent variable's whole conditional distributions. Contrary to quantile regression, the OLS regression model determines this impact on the conditional average of the dependent variable. Most economic variables commonly have outliers and non-normal distributions in econometric theory (Lin and Xu, 2018). OLS estimations could produce spurious results (Bitler et al., 2006), while quantile regression estimation is robust to outliers and non-normal distribution (Koenker and Bassett, 1978). Thus, the quantile regression estimation is preferred to the OLS estimation. The residuals of the quantile regression model do not need to meet the classical assumptions of OLS, such as zero mean, constant variance, and normal distribution residuals (Lin and Xu, 2018).

The conventional regression analysis only estimates the average effect of covariates on dependent variables and may cause over or under-estimating coefficients. However, quantile regression avoids over and underestimating coefficients and captures all important associations between dependent and independent variables (Zhu et al., 2016). Four main ideas about quantile regression analysis are: (i) due to varying quantiles, it provides a different effect of an independent variable on the dependent variable. (ii) it follows a non-parametric specification or non-normality assumption. (iii) it deals with unobserved heterogeneity for each cross-section and estimates different slope parameters at varying quantiles. (iv) it is robust to outliers and provides efficient estimations (Uddin et al., 2017; Chamberlain, 1994). Powell's (2016) quantile regression estimator of panel data (QRPD) is with nonadditive fixed effects and overcomes the difficulties in estimating a large number of fixed effects in the quantile framework (Albulescu et al., 2019). Powell's (2016) method provides point estimates which can be interpreted in the same way as the ones coming from a cross-section regression (Albulescu et al., 2019), and the model is presented as follows:

$$Y_{it} = D_{it}'\beta(U_{it}^*) \tag{7}$$

Where $D_{it}'\beta(\tau)$ is strictly increasing in τ, $U_{it}^* \sim (0,1)$, Y_{it} represents the CO2 emissions, D_{it} the set of exogenous variables (GDP per capita, square GDP per capita, financial development, and trade openness), β is the parameter of variables and U_{it}^* is the error term which may be a function of fixed and time-varying disturbance terms. The model is linear in parameters, and τ is the τ^{th} quantile of Y_{it} and

$0 < \tau < 1$. The conditional restriction of the quantile regression is based on the following:

$$P(Y_{it} \leq D_{it}'\beta(\tau)|D_i) = \tau \tag{8}$$

Powell's (2016) estimator QRPD is based on both a conditional restriction and an unconditional restriction letting $D_i = (D_{i1}, \dots, D_{iT})$:

$$P(Y_{it} \leq D_{it}'\beta(\tau)|D_i) = P(Y_{is} \leq D_{is}'\beta(\tau)|D_i) \tag{9}$$

$$P\big(Y_{it} \leq D_{it}'\beta(\tau)\big) = \tau \tag{10}$$

Powell's (2016) instrumental variables estimation suggests that $Z_{it} = (Z_{i1}, \dots, Z_{iT})$ and are included in the model using the generalized method of moments (GMM) defined as:

$$\hat{g}(b) = \frac{1}{N}\sum_{i=1}^{N} g_i(b)$$

With

$$g_i(b) = \frac{1}{T}\left\{\sum_{t=1}^{T}\left(Z_{it} - \left(\frac{1}{T}\sum_{t=1}^{T} Z_{it}\right)\right)[1(Y_{it} \leq D_{it}'b)]\right\} \tag{11}$$

The rest of the parameters can be presented as follows:

$$\beta \equiv \left\{b|\tau - \frac{1}{N} < \frac{1}{N}\sum_{i=1}^{N} 1(Y_{it} \leq D_{it}'b) \leq \tau\right\}$$

$\forall\, t$. Then, the parameter is estimated as:

$$\hat{\beta}(\tau) = \arg\min_{b \epsilon g} \hat{g}(b)'\hat{A}\,\hat{g}(b) \tag{12}$$

Where $\hat{A}$ is the weighting matrix (an identity matrix and the two-step GMM estimation can be used).

3. Empirical Results and Discussion

We start our empirical analysis by reporting descriptive statistics. Table 2 displays these statistics providing the minimum, maximum values, mean, median, standard deviation, skewness, kurtosis, Jarque-Bera (JB) p-value, and the number of observations (448) for all variables. The normality of data is tested using the skewness, the kurtosis, and the Jarque-Bera test. Data are normally distributed if the value of skewness (coefficient of asymmetry) is 0 and the kurtosis is lower than 3 (Alharthi et al., 2021; Bruna et al., 2021; Mukherjee et al., 1998). The kurtosis value is greater than 3 for all variables except for GDP per capita (2.442), suggesting the presence of extreme values.

Furthermore, the variables are asymmetrically distributed because no skewness value is close to 0. Moreover, the assumption on the normal distribution of the variable should be rejected because the Jarque-Bera statistical test strongly rejects the null hypothesis of normality. Then, these variables do not perfectly fulfill the normality and no-outlier assumptions.

After descriptive statistics, the slope homogeneity test is realized to check the homogeneity or heterogeneity of the slope. Table 3 reports the Pesaran and Yamagata (2008) slope homogeneity test. As we can see, the null hypothesis (slope coefficients are homogenous) is strongly rejected at 1%. Since heterogeneity is observed across countries according to the variables used and the non-normality distribution of data, the panel quantile regression method is preferred because it considers the sample's heterogeneity and is robust to the non-normality distribution of the dependent variable (Dogan et al., 2020).

Table 4 shows the outcomes from cross-sectional and unit root tests. Breusch-Pagan's LM test and Frees and Friedman's tests confirm the existence of cross-sectional dependency. The rejection of the null hypothesis of slope homogeneity (Δ and $\Delta adj.$) and cross-sectional independence suggest using a second-generation unit root test that considers both issues.

Thus, we test whether the variables used are stationary using the Pesaran (2007) CIPS unit root test. Results are reported in table 4 and indicate that the null hypothesis of the existence of a unit root could not be rejected almost for all variables in level with and without trend. Using the first difference of Pesaran's (2007) CD test, with and without trend, the null hypothesis is rejected for all variables at the 1% level. Variables are $I(1)$. The unit root results confirm that the variables are integrated of order 1, so in this step of the study, we perform a test of cointegration following Westerlund (2007), Kao (1999), and Pedroni (1999, 2004) approaches. Neither Westerlund (2007), Kao (1999), nor Pedroni (1999, 2004) cointegration tests establish cointegration among variables (long-run relationship).

Table 2. Descriptive statistics

Var.	Obs#	Mean	St.Dev	Min.	Median	Max.	P(JB)	Skew	Kur
CO_2	448	0.308	0.243	0.001	0.236	1.181	0.000	1.381	4.666
GDP	448	6.758	0.557	5.844	6.590	8.155	0.000	0.638	2.442
DF	448	2.411	0.767	-0.909	2.458	4.293	0.000	-0.382	4.065
TRA	448	4.005	0.324	3.031	4.346	4.878	0.000	-1.613	5.127

Source: Author's calculation

Table 3. Results of slope homogeneity test

	Statistics	P-value
Δ	-2.734	0.006
$\Delta adj.$	-3.123	0.002

Note: Δ denotes delta, $\Delta adj.$ is adjusted delta or $\tilde{\Delta}$. H_0 slope coefficients are homogenous.

Table 4. Results of cross-sectional and unit root tests

Var.	CIPS (Level)		CIPS (First Difference)	
	Without trend	With trend	Without trend	With trend
CO_2	-1.690**	-1.212	-14.593***	-13.520***
GDP	0.906	2.363	-11.755***	-11.105***
GDP^2	0.906	2.363	-11.755***	-11.105***
DF	-2.805	-2.489***	-14.819***	-13.976***
TRA	-1.436*	0.938	-5.907***	-1.813**
	Cross-section dependence tests			
	LM_{BP}	Frees	Friedman	
Statistics	620.461***	2.461***	28.526***	

*Note: LM_{BP} represents Breush-Pagan (1980) cross-sectionally test, ***, **, * denote the statistical significance at 1%, 5% and 10% respectively. H0: no cross-section dependence in residuals.*

A solution to investigate the impact of GDP per capita on carbon dioxide emissions is to use the first differences in the dataset (Dogan et al., 2020; Albulescu et al., 2019; Zhu et al., 2016). Table 5 reports the results of the cointegration tests.

Table 5. Results from panel cointegration tests

		Westerlund test		
Statistic	Value	Z-value	P-value	Cointegration
G_t	-3.873	-6.890	0.000	Yes
G_α	-16.995	-3.744	0.000	Yes
P_t	-19.115	-10.313	0.000	Yes
P_α	-11.105	-2.554	0.005	Yes
		Pedroni test		
$Panel\ ADF\ stat$	-15.977	-	0.000	Yes
		Kao test		
$ADF\ t-stat$	-12.476	-	0.000	Yes

Note: Null hypothesis H_0 : No cointegration; Alternative hypothesis H_1 : cointegration between at least one cross-sectional units (G_t and G_α) or cointegration for the panel as a whole (P_t and P_α).

The results reject the null hypothesis of no cointegration and verify the long-run relationship among CO_2 emissions, GDP per capita, trade, and financial development. Our main findings are based on Powell's (2016) model, which includes an intercept and a set of control variables. Table 6 presents the estimate for panel quantile regression. Results are given for the quantiles from the 10th to 90th and provide a detailed analysis of the determinants of carbon emissions (Alharthi et al., 2021). The gross domestic product affects positively and differently the CO_2 emissions across each quantile except for the median. An increase of 1% of GDP per capita leads to an increase of CO_2 emissions around 0.570, 0.578, and 0.883, respectively, for the 20th, 70th and 90th quantiles. Our results align with Khan et al. (2020) and Ozokcu and Ozdemir (2017). The square of GDP per capita is only positive for the 10th quantile and indicates a monotonic relationship between income and carbon dioxide emissions. However, the square GDP per capita is negative and significant at the 1% level for the 80th and 90th quantiles. These results imply that income level can mitigate the increase in carbon emissions in high-emissions countries. Furthermore, the main finding is the validity of the EKC hypothesis only for the two last (higher) quantiles. This result is consistent with Anwar et al. (2021), Dogan and Seker (2016), and Dong et al. (2018) earlier findings.

The financial development decreases the CO_2 emissions across the quantiles 10th, 20th, and 90th. A rise of 1% level of financial development leads to a reduction of CO_2 emissions corresponding to 0.048%, 0.027%, and 0.08% levels, respectively, for the 10th, 20th and 90th quantiles. One can say that the effect of financial development on CO_2 emissions varies for each quantile and affects environment degradation for low and high quantiles (i.e., 10th, 20th, and 90th) and is non-significant with middle quantiles.

Table 6. Quantile regression results

	Quantile regression								
	10th	20th	30th	40th	50th	60th	70th	80th	90th
$dGDP$	0.367*** (0.298)	0.570*** (0.049)	0.533*** (0.072)	0.594*** (0.081)	0.888 (1.616)	0.592*** (0.056)	0.578*** (0.050)	0.623*** (0.033)	0.883*** (0.042)
$dGDP^2$	0.015*** (0.004)	0.006 (0.007)	0.022 (0.017)	0.001 (0.009)	-0.105 (0.576)	0.002 (0.008)	0.008 (0.005)	-0.008*** (0.011)	-0.030*** (0.004)
dDF	-0.048*** (0.006)	-0.027** (0.012)	-0.033 (0.021)	0.001 (0.018)	0.023 (0.148)	-0.004 (0.013)	-0.030* (0.017)	-0.041 (0.029)	-0.080*** (0.007)
$dTRA$	0.157*** (0.012)	0.126*** (0.022)	0.100*** (0.025)	0.072*** (0.017)	0.052 (0.076)	0.053*** (0.016)	0.067*** (0.013)	0.056*** (0.021)	0.027 (0.020)
$cons$	-0.307*** (0.059)	-0.134 (0.090)	-0.328 (0.243)	-0.022 (0.124)	1.400 (7.597)	-0.004 (0.119)	-0.069 (0.080)	-0.038 (0.159)	0.551*** (0.062)

*Note: ***, ** and * represent 1, 5, and 10% levels of significance. "d" is the difference operator.*

The negative coefficients of financial development on CO_2 emissions support the finding of Wang et al. (2019) and Pata (2018). Trade effect on environmental pollution is positive and significant at 1% for each quantile except for the 50th and 90th quantiles. Our findings mean that trade openness increases carbon emissions in low- or high-emissions countries. This result is contrary to Zhu et al. (2016) earlier findings. Table 7 compares the quantile regression results to the results obtained using the fully modified OLS and dynamic OLS methodologies. Using the FMOLS and DOLS approach, the GDP per capita and its square value are significant.

Furthermore, the coefficient of GDP per capita is positive and significant, and the square of GDP per capita is negative and significant for the two approaches. This result validates the EKC hypothesis in ECOWAS. Compared to the previous quantile regression method, the EKC hypothesis is only valid for the last two high quantiles (80th and 90th).

Contrary to FMOLS and DOLS approaches which show that financial development and trade effects are not significant, the quantile regression method shows a negative and significant effect of financial development on CO_2 emissions, suggesting a deterioration of CO_2 emissions due to financial development at different quantiles (10th, 20th, 70th, and 90th). The quantile approach also suggests a positive and significant effect of trade on CO_2 emissions in ECOWAS (except for the 50th and 90th quantiles); contrary to table 6 results, our result is similar to those of Zhu et al. (2016).

Policy implications based on the FMOLS and DOLS results could not be reliable because these approaches do not consider a non-normal data series, slope heterogeneity, and outliers (Amin et al., 2020).

Table 7. Results from conventional long-run estimators

	DOLS	FMOLS
$dGDP$	3.778*** (0.823)	3.435*** (0.551)
$dGDP^2$	-0.004*** (0.001)	-3.144*** (0.007)
dDF	-0.107 (0.267)	-0.068 (0.147)
$dTRA$	-0.045 (0.501)	0.097 (0.292)

*Note: ***, ** and * represent 1, 5 and 10% levels of significance.*

4. Conclusion and Policy Implications

The main aim of this study is to explore the impact of income, financial development, and trade on carbon dioxide emissions. This study uses the panel quantile regression method to achieve the objectives because it is useful to outliers and provides more reliable estimates for climate policies than FMOLS and DOLS regressions. Our study covers the annual sample period from 1990 to 2021 in ECOWAS members, i.e., Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Empirically, we first use cross-section dependence, slope heterogeneity, and unit root tests. Results indicate non-normality in the data, evidence of slope heterogeneity, and cross-sectional dependence, allowing us to use quantile regressions. The cross-sectional results (Breusch-Pagan, 1980; Frees, 1995; Friedman, 1937) allow us to use the second-generation unit root test. We then employ Westerlund (2007), Kao (1999), and Pedroni (1999, 2004) cointegration tests and verify the long-run cointegration relationship among the variables used.

The quantile regression analysis indicates heterogeneous evidence impact of various variables on carbon dioxide emissions. We find that financial development exerts a negative and significant effect on CO2 emissions at lower quantiles and higher quantiles in lower and higher emission countries but not significantly in the middle quantile. We also find a positive and significant effect of trade on CO2 emissions for all quantiles except for the 50th and 90th. Furthermore, this study examines the validity of the EKC hypothesis. The result indicates the inverted U-shaped EKC hypothesis only with the two last higher quantiles (80th and 90th quantiles) in high-emission ECOWAS members. Contrarily to the quantile regression method, the FMOLS and DOLS approaches validate the EKC hypothesis without taking into account the heterogeneity, data outliers, and non-normality in data.

Following the empirical outcomes, our study provides the following policy recommendations:

- Uniform control policies of carbon dioxide emissions are unlike to succeed equally across countries with different carbon emission levels. CO2 emissions control measures should be adapted differently across low and high-emissions countries.

- To attain low carbon emissions and sustainable development, countries need a viable financial institution focusing on green growth strategies.

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