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The Nexus Between Renewable Energy Consumption, Financial Development, and Trade Openness Based on Environmental Quality in Uganda: An Application of the ARDL

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ABSTRACT

Environmental degradation is attributed to human activities associated with economic development. This study examines renewable energy consumption (REC), financial development (FD), trade openness, and environmental quality nexus in Uganda over the period 1990-2019 using the Autoregressive Distribution Lag (ARDL). Findings show that REC improves environmental quality both in the short and long run. In addition, while trade openness is negatively related to environmental quality in the short and long run, a negative correlation exists between FD and environmental quality only in the long run. Furthermore, economic growth has a positive relationship with environmental quality in the short run while in the long run, GDP^2 improves environmental quality. However, the results from the study find no statistical relationship between FDI and environmental quality, and thus neither the pollution haven nor pollution halo hypotheses are confirmed in the Ugandan case. This paper does not only recommend investing more in renewable energy development to improve the quality of the environment but also in financial sector development to support investments that promote a low-carbon and green economy.

Keywords: Environmental Quality, Carbon Dioxide Emissions, Financial Development, Trade Openness, Renewable Energy Consumption, ARDL
JEL Classifications: Q20, Q43, F18, Q53, C22

1. INTRODUCTION

The problems associated with increased environmental pollution have raised the demand for clean energy sources. Empirical studies have tried to address the issue of environmental quality by emphasizing the reduction in greenhouse gases (GHG) such as Sulfur dioxide (SO2), Nitrogen oxide (NOx), Carbon monoxide (CO), suspended particulate matter (SPM), and Carbon dioxide (CO_2) emissions (Uchiyama and Uchiyama, 2016). Specifically, this paper concentrates on CO_2 emissions because it accounts for 80% of the total GHG emissions (Foster and Bedrosyan, 2014, Dong et al., 2019) which means that it is a serious problem and an environmental concern that requires interventions.

Globally, the shortage in the supply of gas and fossils due to the collapse of the Nord Stream pipeline caused by the Russia-Ukraine war has led European countries (such as Germany, Denmark, Poland, Netherlands, Italy, and Austria) and other countries to revert to the use of coal-fired power plants that were abandoned to pursue clean energy goals, thereby increasing CO_2 emissions (Gu, 2023). African countries have also played a role in environmental degradation, and this is attributed to increased population growth, urbanization, and industrialization. For example, 79 African cities that generate 48% of the African gross domestic product (GDP) are among the world's top 100 fastest-growing cities threatened by climate change and natural disasters (Weforum, 2019; Coulibaly, 2020).

Uganda like any other country, signed the Paris Agreement requiring countries to reduce CO_2 emissions to combat the negative changes in the environment. However, this has failed to materialize due to the increased demands from industrialization and urbanization. For example, data from the Global Carbon Atlas show that Uganda's CO_2 emissions from fossil fuels and cement production were estimated to be around 4.2 million metric tons in 2019. Although this is a small fraction of the global CO_2 emissions (accounting for less than 0.1% of global emissions), evidence from World Development Indicators (WDI) shows that on average, there is a steady increase in CO_2 emissions in Uganda have been increasing since the year 1994 as demonstrated in Figure 1.

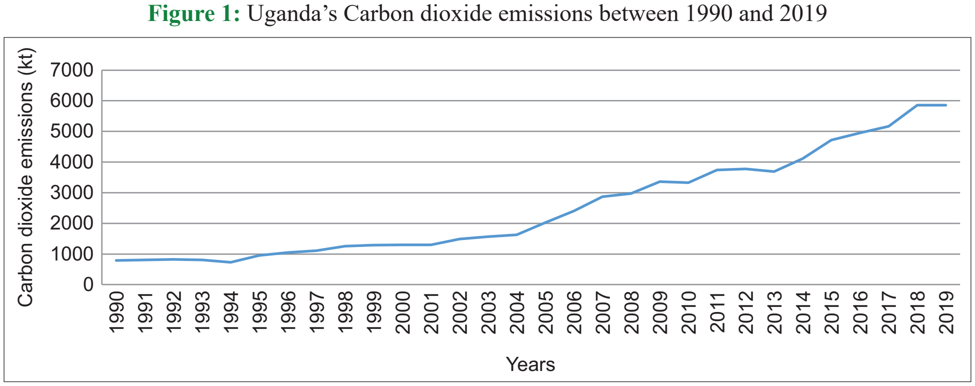
Several studies propose that renewable energy consumption (REC) improves environmental quality by reducing energy intensity and CO2 emissions (Hashmi and Alam, 2019) while Wang et al. (2020) note that REC negatively influences environmental quality because the manufacturing processes are primarily powered by fossil fuels which emit CO_2. In addition, other studies argue that trade openness deteriorates environmental quality because an increase in trade openness leads to an increase in CO_2 emissions (Duan et al., 2022). Furthermore, financial development (FD) also affects CO_2 emissions with mixed results. For example, FD may positively influence environmental quality by financing the production of technologically advanced equipment that emits less CO_2. On the other hand, FD negatively impacts environmental quality by financing enterprises' production which increases CO_2 emissions.

The paper consequently, investigates the nexus between REC, FD, trade openness, and environmental quality in Uganda. This is because most of the earlier studies done on the subject matter are either outside Uganda or region-based. For example, Afridi et al. (2019) used a fixed effects model in the South Asian Association for Regional Cooperation (SAARC), Cheng et al. (2019) used Panel Ordinary Least Squares (POLS) and panel quantile regressions in BRICS, Wang et al. (2018) employed a panel Vector Autoregressive model in 170 countries and find that total energy consumption hurts environmental quality. Other studies, for example, Jebli et al. (2015) in Tunisia, and Asongu et al. (2019) in Sub-Saharan Africa (SSA) find a positive relationship between REC and environmental quality. The current paper looks at the effect of REC on environmental quality in Uganda employing the Autoregressive Distribution Lag (ARDL) model unlike a study by Otim et al. (2022) that looked at the effect of GDP and total energy consumption on CO_2 emissions in Uganda using Vector Error Correction Model (VECM). In addition, other studies that have used ARDL are not in Uganda, for example, Jebli et al. (2015) in Tunisia, Shaari et al. (2022) in Malaysia, Udeagha and Ngepah (2022) in South Africa.

Also, studies that provide evidence on FD and environmental quality linkages provide mixed findings. For example, Ahmad et al. (2020) and Kihombo et al. (2021) show that FD damages the environment by increasing CO_2 emissions. Some studies have provided reasons why FD causes CO_2 emissions. First, developed financial systems increase foreign direct investment (FDI) to prompt economic growth causing increases in CO_2 emissions. Second, FD facilitates the provision of better consumption credit services that support the purchase of properties like automobiles and electric appliances among others that increase CO_2 emissions. However, FD may help firms to raise capital, thereby providing opportunities for improved environmental protection through reduced CO_2 emissions (Gokmenoglu and Sadeghieh, 2019). This has been supported by Qin et al. (2021) who found a positive influence of FD on environmental quality. Furthermore, the paper correspondingly scrutinizes the effect of trade openness on environmental quality because earlier works provide evidence for negative or positive effects depending on the traded goods. For example, a country with a comparative advantage in the production of a good that requires a lot of pollution may specialize in the production of that good adversely affecting environmental quality (Le, et al. 2016). The negative impact of trade on the environment is consistent with Danish and Wang (2019), and Afridi et al. (2019). However, Liobikiene and Butkus, (2019) and Ahmad, et al. (2020) show that trade openness enhances environmental quality. So does trade openness and FD benefit or harm the environment? Using the Ugandan case, this paper addresses this question.

The rest of this paper is organized as follows: Section 2 presents the relevant Literature Review on CO_2 Emissions while Section 3 presents the Methodology. The Empirical Results are presented in Section 4 while Section 5 presents the Conclusion and Policy Recommendations.

Figure 1: Uganda's Carbon dioxide emissions between 1990 and 2019



Source: World Development Indicators

2. LITERATURE REVIEW

The examination of REC, economic growth, FD, Trade openness, and environmental quality contradictions has strengthened, dividing the literature into four groups. The first group assesses the connection between CO_2 emissions and economic growth (GDP) through the Environmental Kuznets Curve (EKC) hypothesis (Kuznets, 1955 and Grossman et al. 1991). The EKC hypothesis assumes that GDP first relates to environmental deterioration, but as the economy grows, the trade-off gradually reduces, thus improving environmental quality. The EKC hypothesis further argues that as the economy expands, its production method enlarges to hire more pollution-intensive apparatus, resulting in environmental degradation (Adebayo, et al. 2022). However, the EKC hypothesis has been criticized for concentrating on economic growth as the sole factor that explains environmental deterioration the world over. The second group provides a theoretical argument between REC and environmental quality as energy is assumed to be a major element in the process of manufacturing where an increase in REC boosts economic production (Adebayo, 2020). As Yuping et al. (2021) and Adebayo, et al. (2022) argue, increasing REC harms environmental quality since the combustion of energy resources, principally fossil fuels (coal, gas, and oil), leads to the emission of CO_2. Conversely, REC is seen as a viable substitute for fossil fuels, which helps to alleviate energy-associated environmental issues.

The third group provides the theoretical justification between trade openness and environmental quality. Economic theory suggests that trade openness between countries with dissimilar environmental protection may cause pollution-intensive industries to concentrate in countries with sloppy environmental standards and this effect is called the pollution haven effect (Baumol and Oates, 1988). As Copeland and Taylor (2004) argue, if one country internalizes the social cost of the environment, and the environment does not include trade between countries, the last country presents a comparative advantage over commodities with high environmental costs. The last group concentrates on the debate between FD and environmental quality with opposing results. Theoretically, FD may affect environmental quality either positively or negatively. Documented by Tamazian et al., (2009), FD increases environmental quality by reducing CO_2 emissions through financing renewable energy projects and environmentally friendly technological innovations while FD boosts economic growth, which in turn accelerates energy consumption and CO_2 emissions reducing environmental quality (Ahmad, et al. 2020; Khan et al., 2022).

However, the empirical literature provides mixed results for the important variables used in this paper. For example, Ahmad et al. (2020) examine the effect of FD and FDI on the environmental quality for a panel of 90 Belt and Road countries employing the Driscoll-Kraay standard error pooled ordinary least square method over the period 1990-2017. Study findings show that while trade openness and FDI enhances environmental quality, REC and FD deteriorate environmental quality through increased CO_2 emissions. Shahbaz et al. (2013) also explore the linkages among economic growth, REC, FD, trade openness, and CO_2 emissions over 1975Q1-2011Q4 in Indonesia using the ARDL approach. Their findings indicate that economic growth and REC increase CO_2 emissions, while FD and trade openness negatively affects CO_2 emissions.

Employing ARDL over the period 1960-2020, Udeagha and Ngepah (2022) evaluate the dynamic relationship between trade openness and environmental quality in South Africa and find that energy consumption, FDI, and industrial value-added deteriorate environmental quality. Their findings also confirm the EKC hypothesis and pollution haven hypothesis (PHH). Wang et al. (2020) analyze the determinants of CO_2 from 1990-2017 and look at FD, human capital, REC, and GDP employing Pesaran's (2007) unit root test, common correlated effect mean group, and augmented mean group and the findings reveal a positive relationship between CO_2 emissions and FD, as well as GDP while REC negatively affected CO_2 emissions. Employing the ARDL approach, dynamic ordinary least squared (DOLS) and VECM Granger causality test, Ali et al. (2017) investigates the dynamic relationship between structural changes, real GDP per capita, energy consumption, trade openness, population density, and CO_2 emissions within the EKC framework over a period 1971-2013. The results indicate a positive association between energy consumption, trade openness, and CO_2 emissions. However, empirical but the study findings do not support the presence of the EKC relationship between GDP and CO_2 emissions.

Shaari et al. (2022) investigate the impacts of energy use in Malaysia by sector and the FDI nexus on CO_2 emissions from 1989 to 2019 using the ARDL technique. Results demonstrate that energy consumption in the transportation sector has a greater impact on CO_2 emissions than in the industrial sector whereas energy use in the agricultural sector reduces CO_2 emissions. In another study, Gokmenoglu and Sadeghieh (2019) scrutinize the relationship between FD and environmental degradation in Turkey over the period 1960-2011 using a multivariate framework. Results from the VECM show a negative relationship between economic growth and CO_2 emissions in the long run while fuel consumption has a positive impact on CO_2 emissions. Elsewhere, using panel data over the period 1980-2016, Afridi et al. (2019) analyze the impact of per capita income, trade openness, urbanization, and energy consumption on CO_2 emissions in the SAARC. Results show that trade openness has a negative connection with CO_2 emissions while urbanization and energy consumption positively influence CO_2 emissions.

Relatedly, Kihombo et al. (2021) explore the causal and long-run relationship between FD, research and development expenditures (R&D), and CO_2 emissions for West Asia and the Middle East (WAME) economies. The long-run panel findings reveal that FD and energy intensity aggravate environmental quality. Cheng et al. (2019) also explore the heterogeneous impacts of renewable energy and environmental patents on CO_2 emission in BRICS countries over the period 2000-2013 using POLS and panel quantile regression methods. Study findings show that renewable energy reduces CO_2 emissions per capita, with the strongest effect at the 95^{th} quantile. The development of environmental patents quickens CO_2 emissions per capita but only significantly affects the CO_2 emissions per capita at the upper tail of the conditional distribution. Further, GDP per capita increases CO_2 emissions per capita, with the most substantial effect in the 5th quantile. Exports increase CO_2 emissions per capita with an asymmetric inverted U-sharped impact while FDI reduces CO_2 emissions per capita, but only significantly influences the CO_2 emissions at the medium and upper of the conditional distribution.

Anwar and Malik (2021) examine the connection between economic growth, technological innovation, institutional quality, REC, population, and CO_2 emission for G-7 economies for the period 1996-2018 with results indicating that REC reduces CO_2 emissions. Danish and Wang (2019) investigate biomass energy consumption and environmental pollution in BRICS countries using the generalized system method of moment (GMM) model over the period 1992-2013. The results show that biomass energy consumption reduces CO_2 emissions while trade openness increases emissions in BRICS countries. Liobikiene and Butkus (2019) evaluate the impact of GDP, trade openness, FDI, urbanization, industrialization, REC, and energy efficiency on GHG emissions using a Systems GMM estimator for 147 countries establishing a positive impact of GDP on GHG emissions. Moreover, a negative connection between trade and GHG emissions is established contradicting the leakage effect. The results show that GDP, urbanization, and trade contribute to reducing CO_2 emissions only via energy efficiency but not via REC.

Otim et al. (2022) examine the effects of energy consumption and per capita GDP on CO_2 emissions in Uganda for the period 1986-2018 using VECM. Their results reveal that, while energy consumption does not Granger cause CO_2 emissions, a positive relationship between GDP per capita and CO_2 emission is established.

3. METHODOLOGY

Using data from World Development Indicators (WDI) over the period 1990-2019, this paper examines the effect of REC, FD, trade openness, and environmental quality in Uganda following the works of Boutabba (2014), and Shahbaz et al. (2013). Other macro economic variables such as Gross Domestic Product (GDP) and GDP^2 are used in this study as control variables. Ths study uses data from World Development Indicators (WDI) from 1990 to 2019. The environmental quality is measured by the CO_2 emissions per capita in metric tons as shown in equation 1.

$$LNCO2_t = \beta_0 + \beta_1 FD_t + \beta_2 FDI_t + \beta_3 GDP_t + \beta_4 GDP_t^2 + \beta_5 OTT_t + \beta_6 REC_t + \varepsilon_t \quad (1)$$

Where LN CO_2 is the log of the country's CO_2 emissions per capita in metric tons as a measure of environmental quality. GDP is economic growth measured by GDP per capita growth where an increase in economic growth is expected to reduce environmental quality. A positive relationship between economic growth and environmental quality is expected. GDP^2 is the square of economic growth that indicates the progress in economic growth and it is at this point that emissions stop increasing (Maduka, et al. 2022). GDP^2 is included in the model to measure the EKC curve and also to enable researchers to gauge the sensitivity of the growth in GDP concerning the increase in CO_2 to the increase in GDP.

FD represents financial development proxied by broad money as a percent of GDP. FD is expected to have either a positive or negative relationship with environmental quality. Qin et al. (2021) argue that FD stimulates technological progress in the energy sector thereby reducing emissions. On the other hand, FD may promote CO_2 emissions through manufacturing activities. REC is renewable energy consumption measured as a percentage of total energy consumption. REC is expected to have either a positive or negative relationship with environmental quality. FDI stands for foreign direct investment as a percentage of GDP. The relationship between FDI and CO_2 emissions may either be both positive or negative. A positive or negative relationship may indicate the existence of the pollution haven hypothesis or pollution halo hypothesis, respectively (Ridzuan et al., 2022). The pollution haven hypothesis suggests that foreign investors are more interested in investing in countries with less stringent environmental policies, especially in developing countries such as Uganda. On the other hand, the pollution halo hypothesis is associated with strict environmental regulations that must be complied with by foreign investors who commit themselves to introducing cleaner technologies into production and reducing emissions. Furthermore, OTT is trade openness measured as a percentage of GDP and its relationship with CO_2 emissions may be negative or positive. International trade benefits the environment by promoting the efficient use of scarce resources due to competition among countries (Shahbaz et al., 2013) and on the other hand, works from Liobikiene and Butkus (2019) find a positive association between trade openness and CO_2 emissions.

The study applies the Augmented Dickey-Fuller (ADF) and Phillps Perron (PP) unit root tests to test the stationarity properties of the variables used (Dickey and Fuller, 1979; Phillips and Perron 1988).

The ARDL model is used in the paper because it is applied if all the time series variables are either I(0) or I(1) and/or if they are a combination of I(0) and I(1) but it cannot be used if one of the time series variables is I(2) (Pesaran et al., 2001). In addition, the method produces unbiased estimates even in the presence of endogenous covariates, applies to small sizes like for our paper, and estimates the short-run and long-run dynamic relationship among macroeconomic variables (Shaari et al., 2022 and Aswata et al., 2018). The estimated ARDL model is specified as presented in Equation (2).

The estimated ARDL model is specified as follows:

$$\begin{aligned}\Delta LNCO2_t &= \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LNCO2_{t-i} \\ &+ \sum_{i=0}^{q_1} \beta_2 \Delta FD_{t-i} + \sum_{i=0}^{q_2} \beta_3 \Delta FDI_{t-i} \\ &+ \sum_{i=0}^{q_3} \beta_4 \Delta GDP_{t-i} + \sum_{i=0}^{q_4} \beta_5 \Delta GDP_{t-i}^2 \\ &+ \sum_{i=0}^{q_5} \beta_6 \Delta OTT_{t-i} + \sum_{i=0}^{q_6} \beta_7 \Delta REC_{t-i} + \\ &\alpha_1 LNCO2_{t-i} + \alpha_2 FD_{t-1} + \alpha_3 FDI_{t-1} \\ &+ \alpha_4 GDP_{t-1} + \alpha_5 GDP_{t-i}^2 + \alpha_6 OTT_{t-i} + \alpha_7 REC_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

The first difference operator and the error term over time are represented by Δ is the first difference operator, and ε_t is the white-noise disturbance term. The residuals for the ARDL model should be stable and serially uncorrelated. The model indicates that the level of environmental quality (LN CO_2) can be influenced and explained by its past values, and other explanatory variables.

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ and β_7 represent the short-run effects as captured by the coefficients of the first differenced variables. while α_1, α_2, α_3, α_4, α_5, α_6, and α_7 represent the long-run coefficient.

The bounds F-test is used to test the existence of the long-run relationship between the variables in the models. The null of no cointegration is not rejected if the F-statistic is closer to zero than the lower bound of the critical values. The null is rejected if the F-statistic is more extreme than the upper bound of the critical values.

To establish if the model meets the standard classical linear regression model assumptions, diagnostic tests are performed and these include the Breusch and Godfrey serial correlation LM test, the Breusch-Pagan test of heteroscedasticity, Jarque-Bera test test for normality, and the Ramsey RESET test for omitted variable bias. The CUSUM and CUSUMSQ tests are used to check for parameter stability tests.

The study carried out a descriptive analysis to show the different characteristics of variables used and the results are presented in Table 1.

Table 1 show a high variation in CO_2 emissions with the highest value being 5,860 and the lowest value being 730 kilotons. FDI inflows are about 2.9% with a minimum value of −0.1% and a maximum value of 6.7%. GDP averaged 3.% with a minimum value of −0.7% and a maximum value of 8.1%. There is mild variation in REC ranging from 90.07 to 96.84 with an average value of 93.91 while the average value of FD and trade openness is 16.3% and 36.8%, respectively.

This paper also conducted both the (ADF) and PP unit root tests at levels and at first difference with one lag to examine the stationarity properties of the data as indicated in Table 2.

The ADF and PP unit root tests show that FD, CO_2, OTT, GDP^2, and REC are non-stationary at levels since the P-values for both tests are >0.05. These variables become stationary after the first difference. However, GDP and FDI are stationary since their P-values are <0.05. Therefore, the ARDL model provides valid and reliable regression results.

Table 1: Descriptive statistics

Variables	N	Mean	SD	Min	Max
CO_2	30	2,525	1,655	730	5,860
FD	30	16.32	3.943	7.597	23.62
FDI	30	2.915	1.539	−0.137	6.657
GDP	30	3.065	2.21	−0.67	8.138
GDP^2	30	14.11	16.64	0.0009	66.23
OTT	30	36.83	6.404	26.61	56.26
REC	30	93.91	1.936	90.07	96.84

Source: Authors' computations

The Schwarz's Bayesian information criterion (SBIC) is used to select the optimal lags for the study variables. This is because the SBIC provides consistent and parsimonious estimates of the true lag order when compared to the Akaike information criterion (AIC) and the final prediction error (FPE) that tend to overestimate the true lag order. During estimation, a maximum of two lags is considered and the model selected by SBIC is ARDL (2,1,1,0,2,1,1).

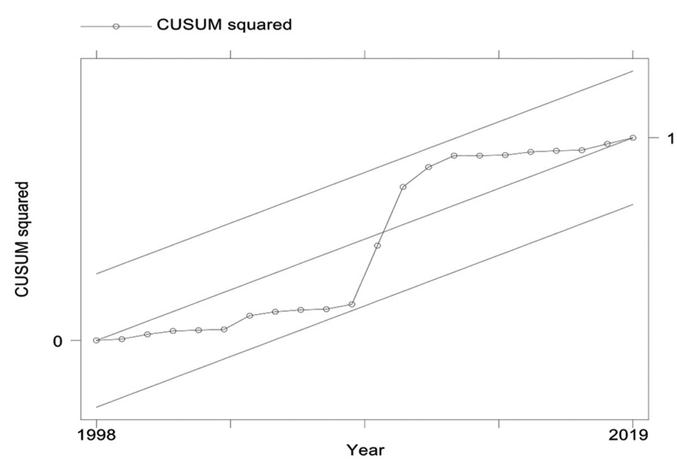
Following Pesaran et al. (2001), the study conducted a bounds test to examine the existence of the long-run relationship between the variables in the model and the results are presented in Table 3.

Results of the bounds test confirm the existence of a level relationship between CO_2 emissions, GDP, GDP^2 FD, REC, FDI, and OTT in Uganda since the F-statistic value (5.73) is above the upper bound at all levels of significance signifying the rejection of the null hypothesis of no level relationship. Similarly, some diagnostic tests were also conducted and the results are presented in Table 4.

The study carried out diagnostic tests and the results are indicated in Table 4.

Results from Table 4 show that the residuals in the model do not suffer from serial correlation and heteroskedasticity. In addition, the residuals are normally distributed as indicated by the Jarque-Bera test result. The result of the Ramsey RESET test indicates that the model is well specified. The LM test for arch effects shows that the errors are free from autoregressive conditional heteroskedasticity. The model exhibits parameter constancy shown by the CUSUMQ curve.

The CUSUMQ Curves



The R-squared for the model is 0.921 which shows that the regressors included in the model explain 92.1% of the variations in Uganda's environmental quality. The overall F-statistic for the model is 10.9 with a probability value of 0.0001, which suggests that all the variables included in the model jointly determine CO_2 emissions.

The error correction term (ECT) estimates the speed of adjustment at which CO_2 emissions return to long-run equilibrium after a

Table 2: Stationarity test results for study variables

Test	ADF			PP		
Variables	Level	First	Remark	Level	First	Remark
CO_2	−0.014	−3.713***	I(1)	0.138	−5.197***	I(1)
FD	−2.164	− 4.777***	I(1)	−2.274	−8.267***	I(1)
FDI	−3.076**	−4.284***	I(0)	−2.396	−3.760***	I(1)
GDP	−2.887**	−4.505***	I(0)	−4.051***	−8.315***	I(0)
GDP^2	−3.179**	−5.617***	I(0)	−4.376***	−8.363***	I(0)
OTT	−2.135	−4.535***	I(1)	−2.365	−5.691***	I(1)
REC	−0.141	−3.316**	I(1)	0.265	−4.038***	I(1)

Source: Authors' computations

Table 3: Results of the bounds test

Critical Values								
Significance Level	10%		5%		2.5%		1%	
F-statistic	L-bound	U-bound	L-bound	U-bound	L-bound	U-bound	L-bound	U-bound
5.73	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43

Table 4: Diagnostic tests

Model diagnostic	P-value	Decision
Breusch Godfrey Serial correlation LM test	0.4323	No serial correlation
Heteroskedasticity test	0.7703	No heteroskedasticity
Jarque-Bera test on normality	0.6048	The distribution is normal
Ramsey RESET test	0.966	The model is well specified
ARCH effects	0.2298	No Arch effects

Source: Authors' computations

change in the explanatory variables. The ECT must be negative and lie between 0 and 1 in absolute terms. The ECT for the model is −0.2761, significant at 1%, which implies that about 27.6% of the CO_2 emissions adjust towards long-run equilibrium after a shock in the explanatory variables and this takes place within a year.

The short-run and long-run coefficients of the ARDL regression model are presented in Table 5.

As demonstrated in Table 5, increasing the share of Renewable Energy Consumption (REC) reduces Uganda's CO_2 emissions and improves environmental quality in both the short and long run, and this relationship is statistically significant at 1%. A unit percentage increase in REC reduces CO_2 emissions by 17.4% in the short run and 6.1% in the long run, holding other factors constant. This result is explained by the fact that Uganda has steadily increased its REC, a clean energy source that reduces its CO_2 emissions. These results are consistent with those of Wang et al. (2020) for 170 countries, Anwar and Malik (2021) for G-7, and Danish and Wang (2019) for BRICS who confirms that REC reduces CO_2 reduces emissions.

Financial Development (FD) is statistically significant at 1% and has a positive relationship with CO_2 emissions in the long run. The results show that a unit percentage increase in FD increases CO_2 emissions by 1.77% in the long run. This finding indicates that Uganda's financial sector is underdeveloped and does not allow access to financial resources to invest in the innovative technologies needed to reduce CO_2 emissions. This implies that FD occurs in Uganda at the cost of an increase in CO_2 emissions.

Table 5: Short-run and long-run coefficients of the ARDL regression

Dependent variable: CO_2				
	Variables	Coefficients	t-ratio	P-value
Long run	FD	0.0177***	3.269	0.006
	FDI	−0.0139	−0.991	0.340
	GDP	−0.0710*	−1.850	0.088
	GDP^2	0.0025	1.589	0.136
	OTT	0.0121***	3.104	0.008
	REC	−0.0607***	−3.459	0.004
Short run	D. FD	0.0056	1.080	0.300
	D.FDI	0.0047	10.521	0.143
	GDP	0.0196*	−1.964	0.071
	D. GDP^2	0.0037**	2.785	0.015
	LD. GDP^2	0.0025***	4.530	0.001
	D. OTT	0.0055*	2.000	0.067
	D. REC	−0.1740***	−8.747	0.000
	Constant	7.177***	3.640	0.000
	ECT	−0.2761***	−4.585	0.001
ANOVA	R-squared	0.921		
	Adj R-squared	0.8369		
	F-stat (P-value)	10.90 (0.0001)		

(i). T-ratios for coefficients are in parentheses. (ii). ***P<0.01, **P<0.05, *P<0.1

The findings are in line with those of Ahmad et al. (2020) in China and Gokmenoglu and Sadeghieh, (2019) in Turkey who find that FD worsens environmental quality in both countries However, they contradict the findings of Shahbaz et al. (2013) for Indonesia and Kihombo et al. (2021) for West Asia and the Middle East who find a negative effect of FD on environmental quality.

Trade openness (OTT) is positive and statistically significant in the short and the long run at 10% and 1% respectively. A unit percentage increase in trade openness increases carbon emissions released by 0.55% in the short run and 1.21% in the long run. This finding shows that trade openness contributes to resource depletion and environmental degradation in Uganda. This result is due to the trade liberalization policy allowing massive importation of CO_2 emitting goods like metals, chemicals, and automobiles among others, which has increased pollution and thus reduced the country's environmental quality. The findings of this study mirror those of Ali et al. (2017) in Malaysia, Nasir et al., 2021 in Australia, and Nguyen et al. (2021) in G6 countries. On the other hand, the results contradict the findings of Afridi et al. (2019) in the South Asian region, Liobikiene and Butkus (2019), and Shahbaz et al. (2013) for Indonesia, where trade openness supports environmental quality.

Economic growth (GDP) has a positive relationship with environmental quality in the short run and it is statistically significant at 10%. The coefficient of 0.0196 implies that a 1 unit increase in GDP reduces environmental quality by 1.9% if all other explanatory variables are kept constant. The results are in line with the findings of Hussian et al. (2012); Saidi and Hammami (2015). However, in the long run, GDP has a negative relationship with CO_2 emissions which is statistically significant at 10%. A unit percentage increase in GDP improves environmental quality by 7.1%, keeping all other explanatory variables constant. Similarly, GDP^2 which is used to capture the second stage of economic growth has a positive relationship with CO_2 emissions in the short run. A unit increase in GDP^2 increases CO_2 emissions by 0.0037 and 0.0025 in the short run. This implies that in the short run, there is a monotonically decreasing relationship between GDP and CO_2 emissions. In the long run, the effect of GDP^2 on CO_2 emissions is not significant. Therefore, the study does not find the EKC hypothesis to be applicable in Uganda.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined the effect of renewable energy consumption, trade openness, and financial development on environmental quality in Uganda using the ARDL approach over the period 1990-2019. The study confirms a long-run relationship between carbon dioxide emissions, economic growth, renewable energy consumption, foreign direct investment, and trade openness in Uganda. The findings show that increased financial development and trade openness hurts the environment not only in the short run but also in the long run. Although economic growth contributes to environmental degradation in the short run, the impact is negative in the long run, suggesting that economic growth improves Uganda's environmental quality in the long run. On the other hand, renewable energy consumption not only improves the quality of the environment in the short run but also in the long run. The empirical results further underscore the impact of FDI has no statistically significant effect on environmental quality thus both the pollution haven hypothesis and pollution halo hypothesis are not confirmed in the Ugandan case.

The study recommends more investment in renewable energy sources such as solar, wind, and hydropower to curb CO2 emissions and also ensure a cleaner environment in the country. In addition, there is a need to improve the financial sector by directly supporting investments that promote Uganda's low-carbon and green economy.

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