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The Impact of Trade Openness and Financial Development on the Environmental Pollution in South Africa: ARDL Bound test approach

*Salisu Baba Manu, Yahaya Yakubu, & Muhammad Adamu

Department of Economics Faculty of Social Sciences Sa'adu Zungur University, Bauchi, Bauchi State, Nigeria.

*Corresponding Author: sbmmisau@gmail.com

Abstract

This study empirically explores the impact of trade openness and financial development on carbon dioxide emission in South Africa. It utilized the time series data covering the period between 1980 and 2023. Unit root test based on ADF and PP were conducted and the results revealed the mixture of stationarity as some of the variables were stationary at level I(0) others at first difference I(1)which is suitable in our estimation technic. ARDL bound testing approach to cointegration was used as a main tool of data analysis. Bound test result confirms a long run cointegration among the variables. Negative and significant error correction term was obtained which indicate a speed of adjustment of the model back to the equilibrium. From the ARDL long run result environmental pollution was found to be positively dependent on trade openness. The implication is that any further expansion in trade openness will keep increasing the amount of pollution in the form of carbon dioxide significantly. On another vein financial development was found to be negatively impacting on carbon dioxide emission. The interpretation is that any further advancement in financial sector will keep lowering the carbon dioxide emission in the economy. The study therefore recommends that meaningful foreign trade policies should be put in place which discourages the importation of pollution ridden facilities. Where necessary, stringent measures should be applied to those who pollute beyond minimum pollution threshold. It is also recommend that financial sector development such as in the area of R&D which help in lowering pollution should be encouraged and ensured.

Keywords: financial development, carbon dioxide, trade openness, diagnostic, unit root.

1. Introduction

The effect of foreign trade on the environment has been a subject of discourse among international, environmental as well as health economists. The phase of globalization which crosses through the developed and developing countries in the same way have raised the issues of environmental pollution havens. The empirical findings on trade and environment elicits evidence in favour of decrease in environmental degradation and the negative impact of trade on the environment, thus making the field ridden with mixed results Bernard and Mandal, (2016). The discussion on the influence of foreign trade on the environment is pertinent considering the increasing volume of trade among world nations and the changes in environmental quality.

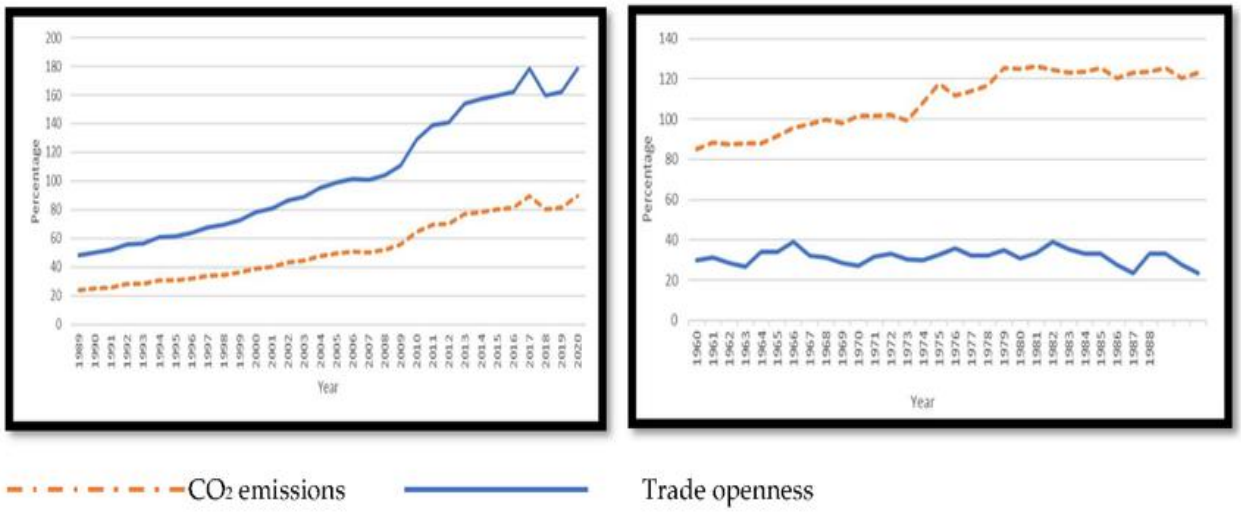

Figure 1: Trends in trade openness and CO2 emissions in South Africa, (1960–2020).

Source: World Bank's World Development Indictors (2021).

Figure 1 above depict the co-movement of trend of trade openness and CO2 emissions in south Africa from 1960 to 2020.

This research work came to realized that, many of the previous researches conducted on this same issue were mostly a panel data studies, additionally many of the literatures presents studies that explore the linkages of trade openness, financial development and CO2 emissions separately. This study empirically utilized time series data for the sample period of 43 years in order to test the connection instead of conducting panel analysis. As one of the uniqueness of this study it examines the joint impact of the trade openness and financial development using the same model. Hence this study contributed to the existing knowledge by adding to the literatures especially the time series based analysis and in the South Africa as well. The finding of this study was an extract from a comparative study which involved South Africa and its counterpart, hence the reason why the study is based on the South African economy.

Development in the financial sector may also have an influence on the country's size of foreign trade in the sense that it provides credit facilities to the new investors in the country who can produce at an export quantity. This may lead to the exportation of goods and services as well as the importation of new capital goods like machinery and other capital goods for advanced production, and may consequently contribute to the amount of carbon dioxide released in the country. Trade openness may bring about an increase in the inflows of FDI and multinational corporations (MNCs) as well as the importation of capital goods and technologies by domestic producers. This process may lead to an increase in the domestic total energy demand, which consequently increases the amount of CO_2 released into the atmosphere.

This study aimed at exploring the consequent impact of the financial sector development as well as trade openness on the environmental quality in the country under study. Trade openness focused more on the import-export, inflow of FDI as well as the operation of multinational corporations in the country. South Africa which belongs to the sub-Sahara Africa is one of the promising developing economies in the African region.

2. Literature review

Empirical literature reviews

Trade and the environment are two inseparable forces. There is a saying that 'everything on the earth takes place at its appropriate environment', so also trade. The issue of the relationship between international trade and environmental pollution has become a topical issue and has been an area of interest and investigation for the past decade or more. It should, however, be noted that to date, no consensus has been reached among international and environmental economists regarding the kind of impact trade openness has on the environment. Some have discovered and concluded that international trade doesn't impact negatively on the environment; see Bakari *et al*., (2025) where any further openness lowered down CO2 emission, Zhou, *et al.* (2025) discovered improved trade openness is associated with decreased CO2 emission as well as Wang & Zhang (2021). Some of the recent studies where financial development lowered CO2 emissions include Habiba, & Xinbang, (2022), and Pham, (2025). While others believe that international trade is always accompanied by some economic and environmental unwanted elements such as CO_2 emissions, imported inflation and economic shocks. This makes the area very open for further research on the same issue across the globe Advancement in international trade, which results in higher global output, has led to a significant increase in the energy demand, which consequently results in to release of some unwanted elements such as CO_2 emissions into the atmosphere and environment Shahbaz, *et al.,* (2017). Thus international trade has so many positive benefits to the trading partners and to the globe at large. International trade increases the world's output and welfare by providing varieties of choice of products or services to citizens. It also bridges the gap between places with abundant resources and those with fewer resources. It also enables countries to generate foreign earnings Du *et al.,* (2020). Wasti and Zaidi, (2020) empirically examined the relationship among trade liberalisation, CO_2 emission, energy consumption and economic growth in the case of Kuwait. Using time series data between 1971 and 2017 and the use of the ARDL bound test method, the empirical evidence revealed the existence of a long-run impact of trade openness and energy consumption on CO_2 emission in the Kuwait economy during the period under study. Causality test result indicates a unidirectional causality from trade openness to CO_2 emission and from energy demand to CO_2 emission as well.

Chen, *et al.* (2019) studied the interaction among trade openness, renewable and non-renewable energy consumption and economic growth in China. ARDL bound testing and VECM Granger causality were employed to carry out the analysis. The main finding revealed that, in the long run, both energy consumption and trade openness have a significant positive impact on CO_2 emissions. According to Huang, *et al.* (2019) in their study on SAR empirical result revealed that; population density, economic growth and trade openness all have a significant positive effect on the net CO_2 emission in the Hong Kong SAR. In their panel study Jijian, *et al.,* (2021) discovered a positive link between imports and carbon dioxide emissions, Nasir, *et al.* (2021) investigate the connection of trade openness and carbon emission in the case of Australia using time series analysis. It was discovered a strong positive impact of trade openness on CO2 emission in the economy. Mahmood, *et al.* (2020), Dauda, *et al.* (2021), Pata and Caglar, (2021), Wu,*et al.,* (2021), Ibrahim and Ajide, (2021), and Jijian, *et al.,* (2021) all discovered strong connection between trade openness and environmental pollution in their respective study areas.

On the connection between financial development and environmental pollution some previous studies were reviewed and presented in this section. Energy used by financial intermediaries may result in carbon emissions. Numerous studies in energy economics contend that energy consumption and economic growth are interdependent and may exert significant pressure on environmental quality, as noted by Omri A. (2005). Shahbaz *et al*. (2015) discovered that in the long run financial development leads to high energy demand which consequently results in increase in CO2 emission in India within the period of study. Tamazian and Rao, (2010), Omri *et al*. (2015), as well as Shahbaz and Lean (2012) arrived at similar conclusion regarding the impact of financial development on environmental pollution in their respective study places via increase in energy consumption. Conversely, Jalil and Feridun (2011) discovered that financial development and energy consumption may reduce carbon emissions. This indicates that financial progress and energy usage have not compromised environmental quality. Consequently, there is no agreement regarding the effects of financial development on energy consumption and environmental quality.

Ziaei (2015) examines the impact of financial indicator shocks, specifically credit and stock market fluctuations, on energy consumption and CO2 emissions in 13 European and 12 Asian and Oceanian countries. Empirical studies demonstrated that financial development indicators positively affected energy usage and CO2 emissions. Alamet *et al*. (2015) on Malaysia, Aslan et al. (2015) on 13 middle-eastern countries, using panel analysis on SAARC countries Alamet *et al*. (2015) all found an evidence of connection between financial development and environmental pollution particularly the CO2 emission in their respective study places.

3. Methodology

This section of the work describes the methodologies adopted throughout the study ranging from source of data to the econometric and statistical method used for data analysis. The data used for the variables in this study were all sourced from WDI of World Bank. The variables used in this study include environmental pollution proxied by carbon dioxide (CO2 emission) which is also a dependent variable in the main model. Trade openness proxied by import-export ratio (TOP), is one of the main explanatory variables, and the financial developments (FND) proxied by domestic bank credit to private sector. Another important explanatory variable is the energy consumption (ENC). Other supporting variables include gross domestic product per capita (GDPC), and foreign direct investment (FDI). With regard to the statistical method of data collection this study first employed the unit root test based on ADF and PP methods to check for the unit root properties of the time series data. The main statistical tool for data analysis in this study is the famous Auto regressive distributive lag popularly known as ARDL method. The reason why for choosing ARDL method is because of the superiority and advantages it has over other regression methods such as OLS, VAR and the rest. For examples in case of VAR all the variables must be stationary at their first difference that is I(1), while in case of OLS all the variables must be stationary at their level, that is I()). But ARDL accommodates the mixture of Stationarity. It can be applied even when some of the variables were stationary at level and others at first difference as in the case of this study. Hence the study decide to use the ARDL method. Using the ARDL method both short and long run cointegration between the dependent and explanatory variables was examined.

Model Specifications

To determine the impact of trade openness on environmental pollution in South Africa, the functional model specification is given in equation (1) below

$CO_2=f(TOP, ENC, FND, FDI, GDPC,)$…….. *(1)*

Equation (1) has been transformed into to econometric model specification with the introduction of an error term and parameters to be estimated in the model as given in equation (2)

$CO_{2t} = \beta_0 + \beta_1 TOP_t + \beta_2 ENC_t + \beta_3 FND_t + \beta_4 FDI_t + \beta_5 GDPC_t + \mu_t$ ……*(2)*

Where CO_2 which is environmental pollution proxied by carbon dioxide emission metric tons per capita, explanatory variables in the model include Trade openness which the main explanatory variable proxied by total trade as ratio/percentage of GDP, energy consumption ENC in Kg of oil per capita, financial development FND proxied by domestic credit to private sector as percentage of GDP, foreign direct investment inflows FDI, Economic growth proxied by RGDP as well as industrialization measured in terms of industrial value added as percentage of GDP.

Following Shahzad *et al.* (2017) and Shahbaz, *et al.* (2013) with some modifications, the model is specified as below;

$\Delta CO_{2t} = \phi_0 + \sum_{i=1}^{l} \lambda_i \Delta TOP_{t-I} + \sum_{i=0}^{l} \gamma_i \Delta ENC_{t-i} + \sum_{i=0}^{l} \vartheta_i \Delta GDPC_{t-i} + \sum_{i=0}^{l} x_i \Delta FND_{t-i} + \sum_{i=0}^{l} \lambda \Delta FDI_{t-1} + \sum_{i=0}^{l} \propto_I IND_{t-1} + \delta_1 TOP_{t-1} + \delta_2 ENC_{t-1} + \delta_3 RGDP_{t-1} + \delta_4 FND_{t-1} + \delta_5 FDI_{t1} + \xi_t$…… *(3)*

H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ (No cointegration)

H_a: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$ (Cointegrated)

From equation (3) above the Δ is a difference operator, ϕ_0 is a constant intercept representing the base line value, $CO2_t$ is the dependent variable in the model, X_{it} stand for number of explanatory variables in the equation and they are the estimators, μ_t which is an error term which captures all other influences not captured in the model. λ is a speed of adjustment coefficient in ECM form, it shows the speed of adjustment back to the equilibrium

4. Results and Discussions

This section presents various estimated results for discussions and inferences.

Table 1.0: The Augmented Dickey Fuller (ADF) Unit root stationarity test result

Variables	Constant	Level of Integration	Constant with Trend	Level of Integration
ENC	-6.509985 (0.0000)***	I (1)	-6.411129 (0.0000)***	I (1)
FDI	-3.835388 (0.0055)***	I (0)	-5.427286 (0.0004)***	I (0)
GDPC	-4.498379 (0.0009)***	I (1)	-4.413620 (0.0062)***	I (1)
FND	-7.291032 (0.0000)***	I (1)	-7.225392 (0.0000)***	I (1)
CO2	-5.355813 (0.0001)***	I (1)	-5.335320 (0.0005)***	I (1)
TOP	-6.375065 (0.0000)***	I (1)	-6.285387 (0.0000)***	I (1)

*Note: values in parentheses are P-values, while *** and ** represent 1% and 5% significance level, respectively.*

Table 2.0 ***The Philip Perron (PP) stationarity test result***

Variables	Constant	Level of Integration	Constant With Trend	Level of Integration
ENC	-6.536255 (0.0000)***	I (1)	-6.434735 (0.0000)***	I (1)
FDI	-4.661108 (0.0006)***	I (0)	-5.445327 (0.0004)***	I (0)
GDPC	-3.533408 (0.0123)***	I (1)	-3.951504 (0.0192)**	I (1)
FND	-7.613041 (0.0000)***	I (1)	-7.563618 (0.0000)***	I (1)
CO2	-5.352777 (0.0001)***	I (1)	-5.335320 (0.0005)***	I (1)
TOP	-6.825506 (0.0000)***	I (1)	-6.793404 (0.0000)***	I (1)

Note: values in parentheses are P-values, while *** and ** represent 1% and 5% significance level, respectively.

Table 1.0 and 2.0 above presents the unit root results from both ADF and PP technics. Checking unit root property in the time series data is very crucial in order to avoid having a spurious results which may be policy misleading. The results of ADF and PP shows that, all the variables were found to be stationary at level I(0) and first difference I(1). That is to say there exists a mixture of stationarity or order of integration. One of the strength of ARDL as main tool of data analysis accommodate the mixture of I(0) and I(1) hence we can proceed with the estimation.

Table 3.0: ***ARDL Bounds Test Result: Environmental Pollution Model***

Test Statistic	**Value**	**K**
F-statistic	4.459844**	5
Critical Value Bounds		
Significance levels	**I(0) Bound**	**I(1) Bound**
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35

Note: these '*' conclusions are based on Narayan's (2005) Table III

** signifies that @ 5% significance level of the critical bounds values, the F-statistic is greater than the upper bound values, which confirms the presence of a very strong cointegrating relationship.

From table 4.0, it can be seen that the estimated value of the F-statistic (4.459844) exceeded the critical values of the lower and upper bounds at five and ten per cent (5% and 10%) level of significance, respectively. Hence, it can be concluded that there is a presence of a cointegrating relationship among the variables in the long run. Thus, the dependent variable CO2 has a long run cointegration with the explanatory variables, namely, TOP, GDPC, ENC, FND and FDI respectively

Estimation of the Long Run relationships

This section deals with the estimation and discussion on the nature and type of the relationship which exists amongst the variables in the model in the long run. Thus, it explores the long-run impact of trade openness and financial development on the environmental pollution in the study country. Table 4.0 below presents the ARDL long run result.

Table 4.0: ***ARDL Long Run Result: Environmental Pollution Model***

Long Run Coefficients				
Variables	**Coefficients**	**Standard Error**	**t-Statistic**	**Prob. values**
GDPC	-0.000901	0.000654	-1.378303	0.6654
ENC	0.005664	0.001763	3.212607	0.0031***
FND	-0.157506	0.045823	-3.437306	0.0017***
FDI	0.166287	0.215373	0.772088	0.4459
TOP	0.169434	0.053477	3.168338	0.0034***
C	-0.692325	1.585372	-0.436696	0.0487**

*Note: *** and ** represent 1% and 5% levels of significance*

From the above results our main concern or focus is on the main hypothesised variables such as the trade openness (TOP) and financial development (FND) then domestic energy demand and FDI inflows. Trade openness as a main hypothesised variable in the model has a positive and significant relationship with the CO2 emission in South Africa. This implies that trade openness has a positive influence or contribution on the environmental pollution in South Africa at a one percent significance level. Based on the coefficient obtained for TOP (0.169434), it can be said that one (1) one-unit increase in trade openness TOP will bring about an increase in the CO2 emission by approximately 0.17 units, and vice versa. This result is consistent with several studies of this nature. Several studies have been conducted and have discovered that trade openness and environmental degradation are positively correlated in some economies. However, some studies

discovered the contrary, meaning that they found a situation where trade openness improves environmental quality and reduces CO2 emissions.

Financial development FND, with the coefficient of (-0.157506), have a negative and statistically significant relationship with CO2 emission in South Africa. Looking at its probability value of (0.0017), it has a negative influence or contribution on environmental pollution in South Africa at a one percent (1%) level of significance. What this outcome implies is that an additional improvement or advancement in financial development tends to reduce or bring down the level of environmental pollution. From this result or coefficient, it can be said or inferred that a one-unit increase in the level of financial development will reduce environmental pollution in the form of CO2 emission by approximately 0.16 units and vice versa. Financial development was tipped by many researchers to pull down environmental pollution in the economy. Financial development facilitates economic growth, encourages research and development, as well as the introduction of new, modern technology that is more environmentally friendly in nature. Domestic energy consumption as well has a positive and significant influence on the level of environmental pollution in South Africa. Other control variables in the model such as economic growth (GDPC) and FDI appeared to have no meaningful effect on the level of environmental pollution.

Table 5.0: ***ARDL Short Run and Error Correction Result: Environmental Pollution Model***

Short Run Coefficients				
Variables	**Coefficients**	**Standard. Error**	**t-Statistics**	**Prob. values**
D(FND)	-0.023896	0.018405	-1.298370	0.2037
C	-0.692325	0.133991	-5.166969	0.0000***
CointEq(-1)*	-0.439311	0.078807	-5.574499	0.0000***

Note: *** represents 1% significance level

From the above table it can be seen that, the error correction term ECT of –0.44 fulfilled the necessary conditions that it must be negative, statistically significant and less than one (<1). The speed of adjustment back to the equilibrium in this model is approximately 44%.

Diagnostic Tests

Table 6.0 below presents the estimated results for the ARDL diagnostic tests for South Africa's environmental pollution model. The model is free from the serial correlation of the variables in the model as the null hypothesis of there is no serial correlation failed to be rejected based on the Breusch-Godfrey serial correlation LM test. In the same vein using Breusch-Pagan-Godfrey test for heteroskedasticity was conducted. The empirical result confirmed that the null hypothesis that there is no heteroskedasticity failed to be rejected and hence concluded that the model is free from the heteroskedasticity issue. Based on the Jarque-Bera normality test, it was discovered that the stochastic error is normally distributed and concluded that the residuals are normally distributed. Using Ramsey's RESET test it was confirmed that, the model's function and specifications are perfect. It can be concluded that none of the assumptions of CLRM is violated in any of the models and hence the models are perfect to be used for making valid conclusions and inferences.

Table 6.0 ***ARDL Diagnostic Test results: Environmental Pollution Model***

	Tests	F-statistic	Obs*R-squared
(A)	**Serial Correlation Test**	0.380189 (0.6871)	0.996451 (0.6076)
(B)	**Heteroskedasticity Test**	2.242541 (0.0574)	13.11012 (0.0695)
(C)	**Normality Test**	76.48292 (0.000000)	Not Applicable
(D)	**Ramsey RESET Test**	1.760879 (0.1945)	Not Applicable
(E)	**Stability Test**	Stable	

Note: A: Lagrange Multiplier test of residual serial correlation

B: Based on regression of squared residuals on squared fitted values

C: Based on the test of skewness and kurtosis of the residuals

D: Ramsey's RESET test using a square of the fitted value

E: based on plots of CUSUM and CUSUMQ

Figures in parenthesis represent probability values

CUSUM and CUSUMQ stability tests

Figures 1.0 and 2.0 present the plots of South Africa's CUSUM and CUSUM-Q respectively.

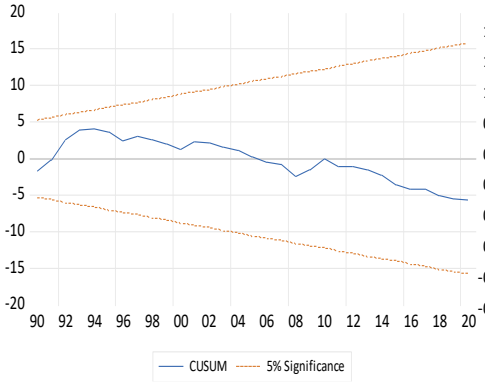

Figure 1.0: CUSUM

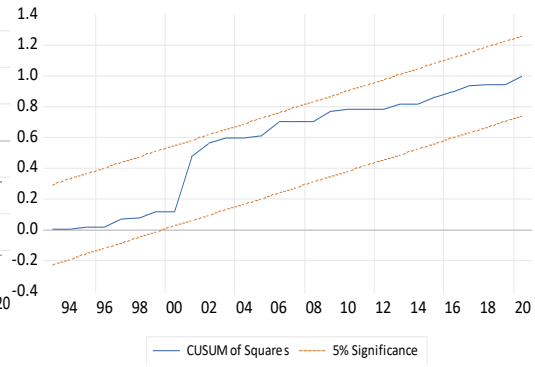

Figure 2.0: CUSUM-Q

The results of CUSUM and CUSUMQ show that the plot of the CUSUM and CUSUMQ statistics stay within the critical bounds of a 5% confidence interval, implying no rejection of the null hypothesis of stability. Therefore, it indicates the absence of any instability of the regression coefficients.

5. Conclusion and recommendations

This study empirically examined the influence of trade openness on the environmental pollution in South Africa between the periods 1980 and 2023. Pre estimation test such as unit root test and post estimation diagnostic tests were made. ARDL bound testing approach was used as a main statistical method of data analysis. Based on the empirical evidences obtained this study conclude that there exist a long run relationship between financial development, trade openness and the environmental pollution in South Africa over the period under study.

The study identifies trade openness as one of the major influencers or contributors of environmental degradation particularly in the release of carbon dioxide in the economy. Empirical evidence confirmed a positive and significant role and influence of TOP on CO2 emission in South Africa. Result coefficient revealed that a unit expansion in trade openness may bring about an increase in CO2 emission by approximately 20% which is huge. This finding has confirmed some findings obtained in by some previous studies such as Shahbaz, et al. (2017), Wasti & Zaidi

(2022), Du, et al (2021), Chen et al. (2019), Dauda et al. (2021) and Jijian et al. (2021). The study also concludes that, there is an evidence of negative correlation between financial development and environmental pollution in the study area. Empirical evidence revealed that FND has negative and significant impact on CO2 emission. From the coefficients a unit expansion in FND lowered the CO2 emission by an approximately 20%. This result is similar to what has been obtained in the studies of Pham, (2025), Habiba & Xinbang, (2022) and in Jalil & Feridun, (2011). Based on the empirical results obtained the study make some recommendations which need to be implemented by the relevant authorities. With respect to the effect of TOP on environmental pollution, government in its good efforts of enhancing financial development in the economy should at the same time embark on green economy or green financing such that the economy will not be affected by foreign trade. The study recommends that; foreign trade policy should be design and implemented which discourage the importation of pollution ridden facilities. Stringent pollution measures should be imposed on the pollutants sectors. Where necessary incentive should also be used or given to those importers who import less polluting facilities and to the domestic producers as well. On the impact of FND on CO2 the study recommend that, financial sectors should encourage and expand the size of research and development in the economy which provide technologies that are non or less polluting in the environment. Since the impact of FND on CO2 negative the trend should be maintained such that pollution in the form of CO2 emission will be kept minimal. Finally government or authorities should expand the use renewable energy consumption in the economy as it is more environmental friendly.

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