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Article

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Towards Environmental Sustainability: Evaluating the Role of Energy Consumption, FDI, and Urbanization on Carbon Emission in Somalia: An Empirical Analysis using ARDL Bound Test

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ABSTRACT

CO_2 emissions stand for a global challenge due to their cross-border nature, contributing substantially to environmental degradation. Since the Industrial Revolution, affluent nations have accelerated economic growth, worsening this issue. However, this study examines the causal links between energy consumption, FDI, urbanization, and carbon emissions in Somalia from 1991 to 2020. The ARDL bounds test is used as a suitable method to estimate the long-run co-integration among the study's variables. The findings show that in the long run, energy consumption, FDI, and urbanization have a positive effect on CO_2 emissions in Somalia. Additionally, economic growth contributes to carbon emissions, while trade openness helps reduce environmental pollution in the long run. Moreover, the study applied Granger causality to find out the directions of these relationships, revealing bidirectional causal links between economic growth and carbon emissions, and between urbanization and FDI. It also found unidirectional causality from carbon emissions to energy consumption, from FDI to carbon emissions, and from urbanization to CO_2 emissions. The study recommended that Somali government must reconsider its energy policy to promote greener energy. Additionally, Somalia should increase investment in RandD for energy efficiency and renewable energy to minimize the carbon emissions resulting from FDI.

Keywords: Energy Consumption, FDI, Urbanization, CO_2 Emissions, ARDL, Somalia
JEL Classifications: Q53, F21, Q56

1. INTRODUCTION

CO_2 emissions present a global challenge characterized by their transboundary nature, leading to widespread environmental degradation. Since the Industrial Revolution, developed countries have accelerated economic growth, worsening this issue. Over the last three decades, environmental degradation has persistently intensified globally. Human-induced climate change significantly affects the release of pollutants, including greenhouse gases (GHGs). Notably, income levels are crucial in increasing carbon dioxide (CO_2) emissions, affecting the poor, middle class, and wealthy alike.

Moreover, extraction and burning of Fossil fuels include natural gas, coal, and petroleum, pollution from transportation, and deforestation all contribute to increase in CO_2 emissions. Among these greenhouse gas emissions, CO_2 emissions contribute over 60% to global warming, (Huang and Tan, 2014). Also, according to the (Olivier and Peters, 2020) suggested that over a period of 6 years, the global increase in Greenhouse gas (GHG) emissions, excluding land use changes, sustained a rate of 2.0%, totaling 51.8 gigatonnes of CO2 equivalent (GtCO2 eq). The yearly growth rate was considerably lower, at roughly 1.3%. The gain took place during the period of sustained global economic development in 2018, which maintained an average yearly rate of 3.4% since 2012.

Current greenhouse gas Greenhouse gas (GHG) emissions are around 57% greater than in 1990 and 43% greater than in 2000, excluding emissions from land-use change.

Furthermore, assessing the effect of climate change on international development has been the responsibility of economists and policymakers since the 1990s. Many global bodies, notably the United Nations (UN), have been working to prove enforceable conventions that countries must follow to mitigate the worst effects of climate change (Romero and Gramkow, 2021). Energy consumption refers to the quantity of energy utilized by different sectors such as industry, transportation, and manufacturing. The major sources of carbon dioxide emissions, which contribute to environmental pollution due to global warming, are fossil fuels such as natural gas, oil, and coal.

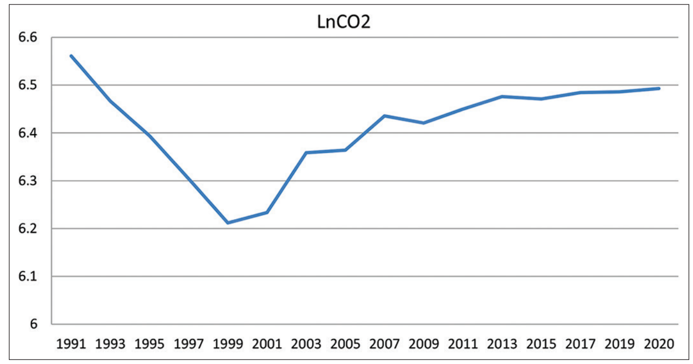
In Sub-Saharan Africa countries have experienced lower environmental pollution levels than regions like Asia, their growing energy demand worsens ecological degradation. This impending degradation threatens Sub-Saharan Africa significantly, as many nations are vulnerable and lack the necessary resources to adapt and respond effectively. Moreover, these are the ten nations in Sub-Saharan Africa that are the most vulnerable to the consequences of global warming. The 2015 Climate Change Vulnerability Index includes countries such as Equatorial Guinea, South Sudan, Nigeria, Chad, Ethiopia, Eritrea, and the Central African Republic, (Sarkodie, 2018).

Somalia grapples with some of the world's most daunting problems compared to other nations. For over 30 years following the state's collapse, efforts to rebuild a functional government, improve security, and stimulate economic growth have achieved gradual progress. This struggle continues despite the longstanding Al-Shabab insurgency, which has grown increasingly dangerous alongside the worsening effects of climate change, (Aynte et al., 2022). According to the World Bank reports that just 36 per cent of Somalia's population has Access to electricity is restricted, with just 11 percent of the nation's rural towns having electrical access. The nation is proud of its completely decentralized energy economy, which forms many privately owned, hyperlocal, and often tiny firms that run mini grids to electrify their villages. People face challenges, including not receiving enough services and the excessive costs of Somalia in comparison the rest of the world and neighboring countries.

However, Siad Barre's harsh dictatorship finally led to the civil war in Somalia. In the past three decades, Somalia has faced many problems, including a lack of state infrastructure, a lack of state protection, humanitarian crises, and broken state institutions. All of these problems cause Somalia to face its worst political crises and unrestricted of environmental deforestration. As a result of the collapse of state infrastructure, livelihoods and poverty are very high. Although society has felt the pain of the absence of the national functioning of natural ecosystems, (Warsame, 2023).

Figure 1, which depicts Somalia's carbon emissions as percentage. Despite 6.56 per cent in 1991, the country's carbon dioxide emissions has declined untill 1999. However, there have been significant changes in some years, and production has kept rising. Between 2009 and 2020, the nation's carbon emissions increased from 6.42 to 6.49 per cent.

Figure 1: Somali's carbon emissions (1991–2020)



Sources: World bank

Developing countries, particularly Somalia, are experiencing severe impacts from climate change, including higher temperatures, floods, droughts, rising sea levels, and persistent poverty. Despite these challenges, existing research (e.g., Odhiambo, 2010; Shaari et al., 2022; Tured and Turedi, 2021; Kivyiro and Arminen, 2014; Maune et al., 2024; Khamjalas, 2024) often do not include Somalia in their analysis when investigating variables influencing carbon emissions. This study looks to address the research vacuum by investigating the impact of energy consumption, foreign direct investment, and urbanization on CO_2 emissions in Somalia. We will use the (ARDL) bound test to look at the co-integration relationship between the dependent variable and the factors that explain it. This test will look at both the short-run and long-run effects of the relationship in a single equation. Furthermore, we will employ Granger causality tests to decide the direction of causation among these variables.

Moreover, while many factors contribute to environmental degradation in Somalia, the primary aim of this study is to find how the country's energy consumption, urbanization, and foreign investment impact carbon emissions. Consequently, the study will provide necessary policy recommendations for future interventions. Additionally, this research offers policymakers new insights into developing essential policy instruments that promote environmental sustainability.

2. LITERATURE REVIEW

Energy consumption, foreign direct investment, and urbanization are the primary causes of environmental degradation. However, we group empirical research into three areas, the first showing the causal relationship between energy use and carbon dioxide emissions. The second research examines the influence of foreign direct investment on CO_2 emissions, while the last study investigates the correlation between urbanization and carbon emissions.

2.1. Energy Consumption Nexus CO_2 Emissions

The use of energy significantly influences carbon emissions. The first line of a research aims the impacts of energy usage on carbon emissions and several studies such Khan et al. (2020) analysed the causal link between energy consumption and carbon emissions in Pakistan over a period between 1965 to 2015. Findings demonstrated that energy use boosts carbon emissions both long shortly and over time. Similarly, Musah et al. (2021) investigated energy consumption and carbon emissions nexus in North Africa from 1990 to 2018 employing CS-ARDL and DCCEMG estimators. They concluded energy consumption significantly increases CO_2 emissions, also bidirectional causality among two variables. Sasana and Putri, (2018) analysed influence of increased energy consumption on CO_2 emissions in Indonesia over years between 1990 to 2014 using ordinary least square (OLS). They found that fossil fuels and population significantly causes to rising CO_2 emissions in Indonesia, while renewable energy usage reduces carbon emissions.

Moreover, Warsame and Sarkodie, (2022) aimed the influence of energy usage and economic growth on degradation of environment in Somalia years between 1085 to 2017 applying non-linear autoregressive distibuted lag (NARDL) model. The empirical results showed long term co-integration among interested variables. Also indicated one-way causal relations among energy consumption and environmental pollution. In addition, Bekun et al. (2019) investigated correlations between energy usage, economic development, and carbon dioxide emissions in South Africa from 1960 to 2016 using Bayer and Hanck (2013). According to the results concluded long term relationships between study's variables. Also unidirectional between energy use and economic growth. A study by Rahman, (2017) explored correlations among energy use, population density, economic growth, exports, and carbon dioxide emissions in 11 of Asian most popular countries over years between 1960 to 2014 utilizing fully modidied ordinary least square (FMOLS) and dynamic ordinary least square (DOLS). They indicated that energy use negatively affects carbon dioxide (CO2) emissions in some nations.

Furthermore, Warsame et al. (2023) used temporal sequence data derived from 1990 to 2019 applying (ARDL) model to investigate correlations among energy consumption, carbon emissions, and macroeconomic variables of Somalia. The empirical results demonstrated adverse effects of energy consumption on carbon emissions in Somalia. Also found industrial valued-added significantly increase on energy consumption. Shaari et al. (2022) found the influence of Malaysia' s energy consumption by sector and FDI on carbon dioxide emissions from 1989 to 2019 using ARDL approaches. According to the empirical findings, energy use in the transportation sector has the greatest effect of CO_2 emissions while energy use in the sector of agricultural mitigates carbon emissions.

Moreover, Mohamad et al. (2023) analysed carbon emissions in the United State and China over a period between 1985 to 2021 employing linear and non-linear autoregressive distributed lag models. They demonstrated fossil fuels contribute to increase their CO_2 emissions, meanwhile renewable energy usage decreases CO_2 emissions two nations. Similary showed a renewable energy transition decreases environmental degradation. A study by Acaravci and Ozturk (2012) employied (ARDL) bound test to explore the causal link between energy consumption, economic expansion, and carbon emissions in Europe over a period between 1960 to 2005. Results confirmed long run relationship among variables. Gorus and Aydin, (2019) investigated correlations among carbon emissions, energy consumption, and economic growth in MENA countries over a period between 1975 to 2014 using single and mult-country granger causality.

They concluded the effects of energy conservation measures on economic growth is not detrimental in the short and intermediate term, but it is unfavorable in the long run.

A study by Munir and Riaz, (2020) investigated disaggregate of energy use on Australia, China, and USA's environmental degradation using annual data from 1975 to 2018 and nonlineard ARDL (NARDL). Results indicated oil, coal, and natural gas contribute to expand carbon dioxide emissions in the long term. Moreover, Khan et al. (2019b) applied dynamic ARDL bound test to explore the impacts of energy consumption and economic growth on Pakistan's CO_2 emissions from a period 1965 to 2015. According to findings illustrated different of energy consumptions (Oil, Coal, and Gas) and economic development have positive impact on environmental degradation in Pakistan both termporary and permanenty.

2.2. Foreign Direct Investment Nexus CO_2 Emissions

Second area of study is to explore the role of foreign direct investment (FDI) on CO_2 emissions. Mostly, scholars suggest that foreign investment increases environmental degradation while further analyses FDI supports better management of the environment.

Accordint to Kima and Seok, (2022) Analyzed the effect of foreign direct investment (FDI) inflows on carbon emissions in Korea over a years between 1971 to 2015 using the autoregressive distributed lag (ARDL) model. Their results found that FDI significantly effect on CO_2 emissions. Blanceo et al. (2013) investigated the effects of foreign investment on CO_2 emissions in Latin America from 1980 to 2007 employing panel granger causality. They indicated FDI incentive to increase emissions. In addition, Kisswani and Zaitouni, (2021) used time series data from 1971-2014 to estimate the relationships involving FDI and carbon dioxide emissions for four Asian nations employing ARDL model. They concluded the presence of pollution haven hypothesis in the Philippines only while the pollution halo hypothesis confirmed in Malaysia and Singapore.

Furthermore, Teng et al. (2021) examined the effect of FDI, use of energy consumption, economic growth, globalization, and institutional quality on CO_2 emissions for dataset for 10 economies nations over period between 1985-2018 using Pooled Mean Group (PMG). Empirical findings demonstrated foreign direct investment and economic growth positively effect on degradation of the environment, while renewable energy helps to increases environmental quality. Similarly, Shahbaz et al. (2018) analysed what determines the france's pollutions from 1955 to 2016 and they applied Novel SOR and bootstrapping bound test techniques. They found FDI improves environmental pollution while energy innovation helps to mitigate the impacts.

Additionally, Sarkodie and Strezov, (2019) studied the connections among FDI, economic development, energy use, and CO_2 emissions in developing countries over period 1982 to 2016 employing panel data of Driscoll-Kraay standard error, U test, and non-additive fixed-effects approaches. They conducted that the results confirmed the existence of the theory of pollution havens. Additionally, NguyenThanh et al. (2022) used panel data of 96 countries to identify the impact of FDI on environment from 2004 to 2014. They applied STIRPAT model. The results indicated that countries attracting foreign investment tends to enhance their regulation of environmental quality, improving environmental standards. Furthermore, To et al. (2019) analyzed the impact of foreign direct investment on environmental deterioration in developing Asian countries from 1980 to 2016 using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Least Squares (DOLS) methodologies. They established that foreign direct investment substantially influences the environment.

The research focused on the effects of investment of foreign and energy consumption on environmental degradation in the economies of the Gulf Cooperation Council by Rafindadi et al. (2018). The findings of the study showed that FDI inflows adversely effects and statistically significant on environments, while energy consumption indicated positive impact on environmental degradation.

2.3. Urbanization Nexus CO_2 Emissions

Urbanisation's effects on carbon emissions have garnered significant attention for the long run. Urbanization has a substantial and measurable effect on environmental contamination through various mechanisms. Therefore, the third objectives of research is to investigate the influence of urbanization on carbon emissions.

Moreover, Ali et al. (2019) explored how pakistan's urbanizations effect on carbon emissions from 1972 to 2014 using autoregressive distributed lag model. The results demonstrated urbanization improves to carbon emissions both short-term and long-term. In addition, Ali et al. (2017) emphasized effects of urbaniztion on CO_2 emissions in Singapore over period 1970 to 2015 employing (ARDL). They found that Singapore's urbanization does not contribute low of environmental quality. Otherwise, decreases carbon emissions.

Additionally, the relations between urbanization, energy consumption, and CO_2 emissions in Malaysia was topic studied by Bekhet and Othman, (2017). According to their findings indicated urbanisation has positive elasticity during its first stages, but transitions to negative inelasticity as urbanisation reaches a greater level. Similarly, Lee et al. (2023) adopted dynamic panel threshold method to analysed the influence of urbanization on China's carbon emissions from 1996 to 2018. They concluded increasing people from rural to urban enhance to carbon dioxide emissions. Wang et al. (2021) explored causal effecst of urbanization on carbon emissions in OECD countries over years and applying ADRL bound test. According to their findings showed Although there are differences in the resources available to each country, developed nations generally see comparable negative impacts of urbanization on carbon emissions.

Anwar et al. (2020) used panel data from far east Asian countries over period 1980 to 2017 to investgated determinants of carbon emissions adopting fixed effect method. They suggested that urbanization, economic growth, and trade openness are primary factors contribute environmental pollution. Since Pakistan's urbanization recently increasing, Sufyanullah et al. (2022) identified the effects of Pakistan's urbanization on CO_2 emissions over years between 1975 to 2018 using autoregressive distributed lag model (ARDL). The ARDL results demonstrated the relationship among variables, and urbanization help to enhance environmental pollution.

3. METHODOLOGY

3.1. Data

The present study aims to examine impacts of energy consumption, FDI, and urbanization on Carbon emissions in Somalia. Data was sourced from free homes, such as World Bank Data (WB), an organization of that collaborates with the Islamic cooperation. The study analyzes time series data covering the period from 1991 to 2020. We measured carbon emissions in kilotons (Kt) to serve as an indicator of environmental degradation and energy consumption (kilograms of oil equivalent per capita), net foreign direct investment (current US dollars), urbanization population (percentage of total the population), economic growth (GDP per capita in constant 2015 US dollars), and trade openness (percentage) as explanatory variables. In addition, the research employed the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) statistical methods procedures to figure out whether the variables are stationary at the level I(0) and at the first difference I(1). Additionally, Table 1 describes the data source together with its technical specifications.

3.2. Econometrics Method

The study used the Autoregressive Distributed Lag (ARDL) technique, to fulfil the study's goals developed by Pesaran et al. (2001), often outperforms other available co-integration approaches. One of its significant advantages is that it does not require extensive time series data, making it more suitable for smaller sample sizes compared to earlier co-integration methods. The ARDL framework allows for a general-to-specialized modeling approach, effectively capturing the data generation process by integrating a suitable number of lags.

In the context of ARDL, it is possible to incorporate short run variations into achieving long run stability via the development of the Error Correction Mechanism (ECM).

This is achieved through a fundamental linear transformation that does not involve any lingering long-term information. However, the original model of the equation was written by:

$$CO_2 = F(EC, FDI, URPOP, GDPC, TO) \quad (1)$$

Where CO_2 stands for carbon emissions, EC energy consumption, FDI, foreign direct investment, URPOP urban population, GDPC gross domestic products, and TO trade openness.

Moreover, a multivariate model representation of the correlation among energy consumption, foreign direct investment, urbanization, and carbon emissions in Somalia can specified as follow in Eq. (2):

Table 1: Literature Reviews' Summary

Author (s)	Country (ies)	Method	Results
Khan et al. (2020)	Pakistan	ARDL bound test	Energy consumption ↑ CO_2 emissions.
Musah et al. (2021	North Africa	CS-ARDL and DCCEMG estimators	Energy consumption ↑ CO_2 emissions.
Sasana and Putri, (2018)	Indonesia	OLS model	Energy consumption ↑ CO_2 emissions.
Warsame and Sarkodie, (2022)	Somalia	NARDL model	Both energy consumption ↑ environmental degradation.
Khan et al. (2019b)	Pakistan	ARDL model	Energy use and economic growth ↑ environmental degradation.
Rahman, (2017)	11 Asian countries	FMOLS and DOLS	Energy consumption ↓ CO_2 emissions.
Warsame et al. (2023)	Somalia	ARDL approach	Energy consumption ↓ CO_2 emissions.
Mohamad et al. (2023)	U.S and China	ARDL and NARDL techniques	Energy consumption ↑ CO_2 emissions, while renewable energy use ↓ CO_2 emissions.
Kima and Seok, (2022)	Korea	ARDL bound test	Foreign direct investment ↑ CO_2 emissions.
Teng et al. (2021)	10 economies	Pooled Mean Group, ARDL	Foreign direct investment ↑ environmental degradation.
To et al. (2019)	Emerging Market in Asia	FMOLS and DOLS	Foreign direct investment ↑ environmental pollution.
Nguyen-Thanh et al. (2022)	96 countries	STIRPAT model	Supports Pollution Haven Hypothesis.
Sarkodie and Strezov, (2019)	Developing countries	Driscoll-Kraay standard error	Supports Pollution Haven Hypothesis.
Rafindadi et al. (2018)	Economies of GCC	Pooled Mean Group, ARDL	Foreign direct investment ↓ environmental pollution.
Ali et al. (2019)	Pakistan	ARDL approach	Urbanization ↑ CO_2 emissions.
Sufyanullah et al. (2022)	Pakistan	ARDL bound test	Urbanization ↑ CO_2 emissions
Ali et al. (2017)	Singapore	ARDL approach	Urbanization ↓ CO_2 emissions.

$$LnCO2_t = \beta_0 + \beta_1 LnEC_t + \beta_2 LnFDI_t + \beta_3 LnURPOP_t + \beta_4 LnGDPC_t + \beta_5 LnTO_t + \varepsilon_t \quad (2)$$

Where the natural logarithm of carbon dioxide emissions is denoted by LnCO2, while LnEC stands for the natural logarithm of energy consumption. LnFDI refers to the natural logarithm of foreign direct investment, and LnURPOP denotes the natural logarithm of the urban population. LnGDPC is the natural logarithm of economic growth, and LnTO signifies the natural logarithm of trade openness. The symbol ε stands for the stochastic error term, showing external influences that affect the dependent variables but are omitted from the study's estimators.

Furthermore, all relevant variables were transformed into their natural logarithms to express the results as elasticities, making them interpretable in percentage terms. This transformation also helps to avoid diagnostic issues such as non-normality, serial correlation, heteroskedasticity, and specification errors. The study uses the ARDL approach to find both short-term and long-term relationships between the dependent and independent variables, following the empirical results of Nor et al. (2024). The mathematical representation of the ARDL model is as follows:

$$\begin{aligned}\Delta \mathrm{LnCO2}_t &= \alpha_0 + \beta_1 \mathrm{LnCO2}_{t-1} + \beta_2 \mathrm{LnEC}_{t-1} + \beta_3 \mathrm{LnFDI}_{t-1} \\ &+ \beta_4 \mathrm{LnURPOP}_{t-1}\, \beta_5 \mathrm{LnGDP}_{t-1} + \beta_6 \mathrm{LnTO}_{t-1} \\ &+ \sum_{i=0}^{Q} \Delta\alpha_1 \mathrm{LnCO2}_{t-k} + \sum_{t=o}^{P} \Delta\alpha_2 \mathrm{LnEC}_{t-k} \\ &+ \sum_{i=0}^{P} \Delta\alpha_3 \mathrm{LnFDI}_{t-k} + \sum_{i=0}^{P} \Delta\alpha_4 \mathrm{LnURPOP}_{t-k} \\ &+ \sum_{i=0}^{P} \Delta\alpha_5 \mathrm{LnGDP}_{t-k} + \sum_{i=0}^{P} \Delta\alpha_6 \mathrm{LnTO}_{t-k} + \varepsilon_{t-k}\end{aligned} \quad (3)$$

In this context, α0 is the intercept, while α1 to α6 are the coefficients of the short-term variables. Additionally, β1 to β6 denote the long-run elasticities of the parameters. The term P shows the best lags of the dependent variable, while Q is the best lags of the explanatory variables. The symbol Δ signifies the first difference of a short-term variables, and ε stands for the stochastic error term.

The Autoregressive Distributed Lag (ARDL) cointegration method begins with bound testing. According to the null hypothesis (H0), there is no cointegration among the study's variables in the long term, expressed as β1 = β2 β3 = β4 = β5 = β6 = 0. In contrast, the alternative hypothesis (H1) suggests that there is.

Cointegration among the variables the long run, represented as β1 ≠ β2 ≠ β3 ≠ β4 ≠ β5 ≠ β6 ≠ 0.

To evaluate the validity of the null hypothesis, one can use the Wald-F statistic along with critical value statistics. If the Wald-F statistic is above the key value threshold, the null hypothesis is rejected, and a long-term relationship found. If Wald-F is below the upper bound, the null hypothesis of no variable co-integration cannot be rejected.

4. FINDINGS AND DISCUSSION

This section forms the fourth part of our research, and its purpose is to analyses and evaluate the study's findings. Also, we will find with different subsections such as descriptive statistics, correlation, also aims to address the unit root problem by employing the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods, determining the optimal lag length, and, most importantly, analyzing the relationship between relevant variables both a short period and long period terms using the autoregressive distributed lag (ARDL) method test.

4.1. Summary of Statistics

Table 2 displays descriptive statistics of the study, highlighting its main characteristics. The average values are carbon dioxide (CO_2) emissions at 6.406927, energy consumption at 5.663827, urbanization 3.601639. It also shows the mean foreign direct investment (FDI) values at 17.38471, economic growth at 22.11555, and trade openness at 3.310387. The data reveal that foreign direct investment (FDI) and economic growth have the highest values among the variables, reaching 20.10669 and 22.88517, respectively. In contrast, trade openness has the lowest value 1.728109. The variables with the highest standard deviations are carbon emissions (3.245783) and trade openness (3.124926).

Additionally, Table 3 proves the data results of the correlation tests. The findings revealed that energy consumption negatively correlated with CO_2 emissions, while (FDI), urbanization economic growth, and trade openness are positively correlated with the dependent variable, CO_2 emissions.

4.2. Unit Root Test

We use time series to investigate indicator stationarity. Unit root variables may bias findings. This is evaluated using ADF and PP. Null hypothesis: unit root, alternative hypothesis stationarity. Null hypothesis rejected by non-stationarity. If variable t-statistics surpass critical. Accept null hypothesis if t-statistics are below essential value. Table 4 has a unit root issue. Other variables are stationary at I(1), while trade openness is steady at I(0). Because the ADF and PP tests show no unit root concerns, the Autoregressive Distributed Lag (ARDL) limitations test suited our data.

Additionally, the analysis checks for long-term cointegration between the relevant variables. We conducted the Wald-F statistics test using the data from Table 5. The Wald-F-bound test yielded an F-statistics of 13.34972, which we compared with the upper bound test. At the 1% significance level, the Wald-F-statistics show that the test is more significant than any upper bound test. Consequently, long run co-integration among the variables is likely to be present.

4.3. Long Term and Short Term Rerm ARDL Outcome with Diagnostic Testing

After determine the long term relationships among the study's participants. We investigated how energy consumption, foreign direct investment, urbanization, economic growth, and trade openness influences on Carbon emissions in Somalia. Respectively, Table 6 presents the long-term results indicated that an energy consumption bad response with CO_2 emissions and statistically significant both near future and long future. This demonstrate that a 1% increasing energy consumption lead to increase carbon emissions in Somalia by 1.59%. These results align with similar studies conducted (Yang et al., 2020) in Thailand, and (Cetin et al., 2018) in Turkey.

Similarly, the impact of rising FDI also has a positive impact of carbon emissions. The improving of foreign investment contributes to increase carbon dioxide emissions in Somalia. A 1% rise in FDI increase CO_2 emissions by 0.086 in the long run. These findings are consistent with research by (Pata et al., 2023).

Urbanization is concluded to be positively related to carbon emissions in long term. This indicates if a 1% increase of Somali's urbanization leads to increase in carbon emissions by 1.17% in the long run. In numerous studies implied urbanization helps to enhance environmental degradation such as (Suhrab et al., 2023), and (Cheng and Hu, 2023).

Table 2: Summary statistics and correlation

Stats	LnCO2	LnEC	LnFDI	LnUR	LnGDPC	LnTO
Mean	6.406927	5.663827	17.38471	3.601639	22.11555	3.310387
Median	6.437190	5.689607	17.77777	3.577115	22.10688	3.457891
Maximum	6.561171	5.838902	20.10669	3.831702	22.88517	4.626051
Minimum	6.187442	5.424170	13.81551	3.401431	21.39097	1.728109
Std. Dev.	0.094811	0.126361	1. 910518	0.139825	0.494073	0.999448
Skewness	−0.802890	−0.493982	−0.018327	0.243624	0.106216	0.215040
Jarque-Bera3.245783	2.456380	2.938217	2.587980	2.440923	3.124926	
P-value	0.197327	0.292822	0.230131	0.274175	0.295094	0.099619
Correlation						
LnCO2	1					
LnEC	−0.443241	1				
LnFDI	0.554403	−0.841636	1			
LnUR	0.410357	−0.874185	0.882015	1		
LnGDPC	0.489931	−0.838556	0.906225	0.975347	1	
LnTO	0.393749	−0.740355	0.873616	0.934236	0.956278	1

Table 3: Variable's Description

Parameters	Code	Measurements	Sources
CO_2 emissions	CO2	CO_2 emissions, (Kt)	WB
Energy consumption	EC	(Kg of oil equivalent per capita)	WB
Urbanization population	URPOP	(% of the total population)	WB
Foreign investment	FDI	Net inflow (current US$)	WB
Economic growth	GDPC	(GDP per capita in constant 2015 US dollars)	WB
Trade openness	TRO	Percent	SESRIC

Table 4: The Result of the unit root test

Variables	ADF		PP	
	At level	1^{st} difference	At level	1^{st} difference
LnCO2	−1.8079	−3.1749**	−1.8291	−3.1362**
LnEC	−0.3256	−6.0706***	−0.2287	−6.0354***
LnFDI	−0.7978	−5.5689***	−0.5249	−6.4464***
LnUR	−0.0467	−5.3764***	0.5380	−6.0060***
LnGDPC	−0.7515	−5.0771***	0.5264	−5.0189***
LnTO	−3.1404**	−1.7332	−0.8579	−3.1404***

***Shows a level of significance at 10%, ** at 5%, and * at 1%.

Table 5: Bound test

Test statistics	Value	Significant	I(0)	I(1)
F-statistics	13.34972	10%	2.08	3
K	5	5%	2.39	3.38
		1%	3.06	4.15

Table 6: Long run results and diagnostics

Variables	Coefficients
Constant	9.811552 (−3.9444)***
LnEC	1.596618 (6.3136)***
LnFDI	0.086505 (5.5662)***
LnUR	1.173254 (2.9766)***
LnGDPC	0.083395(0.8325)
LnTO	−0.115389 (−3.4820)***
Diagnostic test	
Reset test	0.9484 (0.06599)
Serial correlation	0.5432 (0.0601)
Heteroskedasticity	0.1352(0.9866)
Normality	0.3690 (0.8315)
Adjusted R^2	0.8597

Moreover, our results shown that economic growth contributes to increase carbon dioxide emissions in Somalia. A 1% increase the country's economic growth leads to increase 0.083% in CO_2 emissions in the long run.

However, our findings suggesting the negative effect trade without barries on carbon emissions, also (Zhang et al., 2017), and (Akhayere et al., 2023) who found that trade opennes reduces carbon emissions.

Respectively Table 6 also depicts the results of diagnostic tests. The time series data show no signs of normality, serial correlation, heteroskedasticity, or model specification issues. However, we rejected the null hypothesis of a diagnostic problem. CUSUM and CUSUM of squares tests, shown in Figures 2 and 3, write down that the model structure is still stable.

The outcome of short term is reported in Table 7, indicated the energy consumption exerts the positive impact on carbon emissions. Carbon emissions will increase 0.27% due to increase 1% by energy consumption in short run. The effect of foreign investment inflow on CO_2 emissions is positive and highly significant. This implies when 1% rise in FDI will directly improve to carbon emissions by 0.01% in the short term. Also, urbanization contributes carbon dioxide in Somalia in a short period. A 1% increase in urbanization will lead to increase CO_2 emissions by 0.19% in short run. An economic activities negatively associated

Table 7: Short run and ECT results

Variables	Coefficients
ΔLnEC	0.272439
$\Delta LnEC_{t-1}$ (−4.0439)*	−0.331500 (−4.0439)*
ΔLnFDI (4.0974)**	0.014992 (4.0974)**
$\Delta LnFDI_{t-1}$ (−5.3307)***	−0.022688 (−5.3307)***
ΔLnUR (1.5013)	0.199151 (1.5013)
ΔLnGDPC (−3.0762)**	−0.167567 (−3.0762)**
ΔLnTO (−4.8327)***	−0.124171 (−4.8327)***
ECT_{t-1}(−11.5541)***	−0.538529 (−11.5541)***

Figure 2: CUSUM test

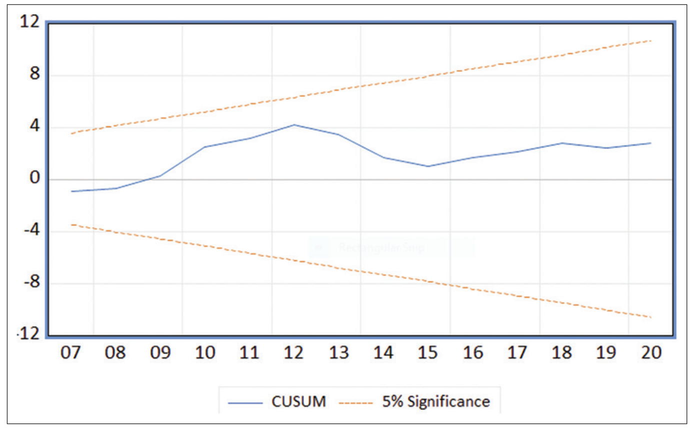
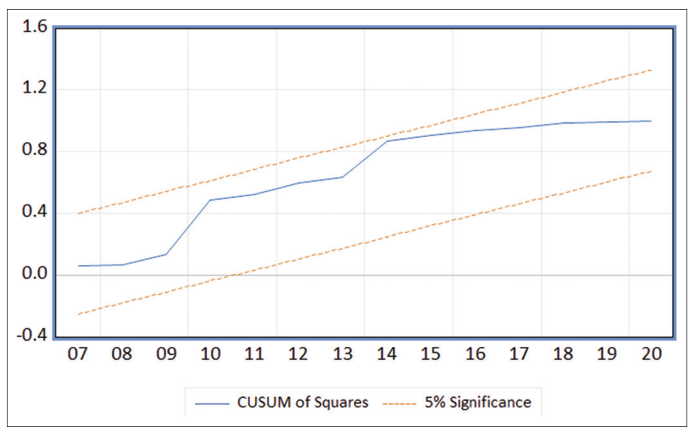


Figure 3: CUSUM Square test



with carbon. And it is found that 1% raises will cause to decline by 0.16 in carbon dioxide. The findings also demonstrated that trade openness negatively correlated with carbon emissions. A 1% increase in trade openness CO_2 emissions will decrease by 0.12% in the short run.

Furthermore, the error correction model (ECT) is used to analyze the short run impacts of the explanatory variables on CO_2 emissions. The ECT coefficient is negative and statistically significant, showing convergence rather than divergence. The model adjusts approximately 53% of short-run imbalances in CO_2 emissions each year.

4.4. Granger Causality Tests

Although ARDL results write down a co-integration relationship between significant variables, it is still crucial that the explanatory

Table 8: Pairwise Granger Causality Tests

Null Hypothesis	Obs	F-statistic	P-value
LnEC → $LnCO_2$	28	1.25274	0.3045
$LnCO_2$ → LnEC	28	2.90106	0.0752
LnFDI → $LnCO_2$	28	2.80212	0.0815
$LnCO_2$ → LnFDI	28	0.20279	0.8179
LnUR → $LnCO_2$	28	3.92231	0.0342
$LnCO_2$ → LnUR	28	0.87526	0.4302
LnGDPC → $LnCO_2$	28	4.61590	0.0206
$LnCO_2$ → LnGDPC	28	3.96371	0.0332
LnTO → $LnCO_2$	28	4.77226	0.0185
$LnCO_2$ → LnTO	28	2.38549	0.1144
LnFDI → LnEC	28	3.18893	0.0599
LnEC → LnFDI	28	0.84402	0.4429
LnUR → LnEC	28	2.55930	0.0992
LnEC → LnUR	28	0.01494	0.9852
LnGDPC → LnEC	28	2.21797	0.1316
LnEC → LnGDPC	28	0.66703	0.5229
LnTO → LnEC	28	2.10755	0.1444
LnEC → LnTO	28	0.43062	0.6552
LnUR → LnFDI	28	3.30454	0.0548
LnFDI → LnUR	28	0.81169	0.0464
LnGDPC → LnFDI	28	4.61467	0.0207
LnFDI → LnGDPC	28	0.04007	0.9608
LnTO → LnFDI	28	3.25945	0.0567
LnFDI → LnTO	28	0.18936	0.8288
LnGDPC → LnUR	28	2.55827	0.0993
LnUR → LnGDPC	28	0.52554	0.5982
LnTO → LnUR	28	1.65505	0.2130
LnUR → LnTO	28	0.03693	0.9638
LnTO → LnGDPC	28	4.92199	0.0166
LnGDPC → LnTO	28	0.71388	0.5003

variables co-integrate with the dependent one. However, it does not show which way the causality runs. Therefore, we will employ the Granger causality (1987) test to learn the causal relationship between dependent variable and independent variables. Our findings from Table 8 show unidirectional causality from carbon emissions to energy consumption, foreign investment to carbon emissions, urbanization to carbon dioxide, trade openness to carbon. Moreover, there are bidirectional causal relationships between economic growth and carbon emissions, urbanization and foreign direct investment.

5. CONCLUSION AND POLICY IMPLICATIONS

The study investigated the role of energy consumption, foreign investment inflows, and urbanization on carbon emissions based environmental effect in Somalia over years between 1991 and 2020 employing ARDL bound test.

The empirical results of the study show that energy consumption bad response with CO_2 emissions and statistically significant both near future and long future. This shows that a 1% increasing energy consumption lead to increase carbon emissions in Somalia by 1.59% in the long run.

Similarly, the impact of rising FDI also has positive impact of carbon emissions. The improving of foreign investment contributes to increase carbon dioxide emissions in Somalia. A 1% rise in FDI increase CO_2 emissions by 0.086 in the long term.

Urbanization is concluded to be positively related to carbon emissions in the long term. This indicates if a 1% increase of Somali's urbanization leads a increase in carbon emissions by 1.17% in long run. Moreover, our results also shown that economic growth contributes to increase carbon dioxide emissions in Somalia. A 1% increase the country's economic growth leads to increase 0.083% in CO_2 emissions in the long run. Additionally, our findings suggesting trade without barries has a negative impact on carbon emissions in Somalia in the long run.

The short-term data shows that energy consumption has a positive impact on carbon emissions. In the short run, a 1% increase in energy consumption will result in a 0.27% rise in carbon emissions. Foreign direct investment inflows also have a significant and positive effect on CO_2 emissions. Specifically, a 1% increase in foreign direct investment will lead to a 0.01% increase in carbon emissions in the short term.

Additionally, in Somalia, urbanization rapidly increases carbon dioxide emissions. A 1% rise in urbanization will cause a 0.19% increase in CO_2 emissions in the short run. Economic activity, on the other hand, shows an inverse correlation with carbon emissions. A 1% increase in economic activity will result in a 0.16% reduction in carbon dioxide levels.

Furthermore, the findings prove an inverse relationship between trade openness and carbon emissions. A 1% rise in trade openness will lead to a 0.12% decrease in CO_2 emissions in the short term.

With regards to granger causality, found there are bidirectional causal relationships between GDPC and CO_2 emissions, urbanization, and FDI. Unidirectional causality from carbon emissions to energy consumption, foreign investment to carbon emissions, urbanization to carbon dioxide, trade openness to carbon.

However, based on the study's empirical data, the study suggests several policy implications concerning energy consumption in Somalia. First, the aim is Somalia's government must re-evaluate their energy policy to encourage greener energy sources. This may include subsidies for renewable energy, improvements in energy efficiency, and a tax or regulatory deterrence of fossil fuel use.

Second, government must develop solutions that reduce the terrible effects of foreign direct investment and trade on carbon emissions in Somalia, such as improving investment in research and development (RandD) in environmentally friendly technologies and sectors, particularly in energy efficiency and renewable energy. In addition, policymakers may adopt initiatives to develop more sustainable cities, including the promotion of public transit, the enhancement of green spaces, and the endorsement of energy-efficient construction techniques. Also, the government should offer incentives like tax cuts or subsidies to companies.

REFERENCES

Acaravci, A., Ozturk, I. (2012), On the relationship between energy consumption, CO_2 emissions and economic growth in Europe.

Energy, 35, 5412-5420.

Akhayere, E., Kartal, M.T., Adebayo, T.S., Kavaz, D. (2023), Role of energy consumption and trade openness towards environmental sustainability in Turkey. Environmental Science and Pollution Research, 30, 21156-21168.

Ali, H.S., Abdul-Rahim, A., Ribadu, M.B. (2017), Urbanization and carbon dioxide emissions in Singapore: Evidence from the ARDL approach. Environmental Science and Pollution Research, 24, 1967-1974.

Ali, R., Bakhsh, K., Yasin, M.A. (2019), Impact of urbanization on CO_2 emissions in emerging economy: Evidence from Pakistan. Sustainable Cities and Society, 48, 101553.

Anwar, A., Younis, M., Ullah, I. (2020), Impact of urbanization and economic growth on CO_2 emission: A case of far East Asian countries. International Journal of Environmental Research and Public Health, 17, 2531.

Aynte, A., Chen, E., Mozersky, D. (2022), POWERING AHEAD: The United Nations and Somalia's Renewable Energy Opportunity. United States: The Henry L. Stimson Center and Energy Peace Partners, p5956.

Bekhet, H.A., Othman, N.S. (2017), Impact of urbanization growth on Malaysia CO_2 emissions: Evidence from the dynamic relationship. Journal of Cleaner Production, 154, 374-388.

Bekun, F.V., Emir, F., Sarkodie, S.A. (2019), Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. Science of the Total Environment, 655, 759-765.

Blanceo, L., Fidel, G., Ruiz, I. (2013), The impact of FDI on CO_2 emissions in Latin America. Oxford Development Studies, 41(1), 104-121.

Cetin, M., Ecevit, E., Yucel, A.G. (2018), The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: Empirical evidence from Turkey. Environmental Science and Pollution Research, 25(36), 36589-36603.

Cheng, Z., Hu, X. (2023), The effects of urbanization and urban sprawl on CO_2 emissions in China. Environment, Development and Sustainability, 25, 1792-1808.

Gorus, M.S., Aydin, M. (2019), The relationship between energy consumption, economic growth, and CO_2 emission in MENA countries: Causality analysis in the frequency domain. Energy, 168, 815-822.

Huang, C.H., Tan, C.S. (2014), A review: CO_2 Utilization. Aerosol and Air Quality Research, 14, 480-499.

Khamjalas, K. (2024), Nexuses between food, energy, and water consumption on urban-rural income gap in South-Eastern Asian countries using difference in difference in modelling technique. International Journal of Economics and Financial Issues, 14(2), 186-195.

Khan, M.K., Khan, M.I., Rehan, M. (2020), The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innovation, 6(1), 1-13.

Khan, M.K., Teng, J.Z., Khan, M.I. (2019b), Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. Environmental Science and Pollution Research, 26(23), 23480-23490.

Kima, S.E., Seok, J.H. (2022), The impact of foreign direct investment on CO_2 emissions considering economic development: Evidence from South Korea. The Journal of International Trade and Economic Development, 32(4), 537-552.

Kisswani, K.M., Zaitouni, M. (2021), Does FDI affect environmental degradation? Examining pollution haven and pollution halo hypotheses using ARDL modelling. Journal of the Asia Pacific Economy, 28(4), 1406-1432.

Kivyiro, P., Arminen, H. (2014), Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. Energy, 74, 595-606.

Lee, C.C., Zhou, B., Yang, T.Y., Yu, C.H., Zhao, J. (2023), The impact of urbanization on CO_2 emissions in China: The key role of foreign direct investment. Emerging Markets Finance and Trade, 59, 451-462.

Maune, A., Matanda, E., Chitombo, E. (2024), Energy consumption and economic growth: Evidence from SADC countries. International Journal of Economics and Financial Issues, 14(6), 403-411.

Mohamad, A.H., Zainuddin, M.K., Ab-Rahim, R. (2023), Does renewable energy transition in the USA and China overcome environmental degradation? International Journal of Energy Economics and Policy, 13(6), 234-243.

Munir, K., Riaz, N. (2020), Asymmetric impact of energy consumption on environmental degradation: Evidence from Australia, China, and USA. Environmental Science and Pollution Research, 27(11), 11749-11759.

Musah, M., Owusu-Akomeah, M., Boateng, F., Iddris, F., Mensah, I.A., Antwi, S.K., Agyemang, J.K. (2021), Long-run equilibrium relationship between energy consumption and CO_2 emissions: A dynamic heterogeneous analysis on North Africa. Environmental Science and Pollution Research, 29, 10416-10433.

Nguyen-Thanh, N., Chin, K.H., Nguyen, V. (2022), Does the pollution halo hypothesis exist in this "better" world? The evidence from STIRPAT model. Environmental Science and Pollution Research, 29, 87082-87096.

Nor, B.A., Yusof, Y., Warsame, Z.A. (2024), Exploring the potential for renewable energy consumption in reducing environmental degradation in Somalia. International Journal of Energy Economics and Policy, 5, 643-650.

Odhiambo, N.M. (2010), Energy consumption, prices and economic growth in three SSA countries: A comparative study. Energy Policy, 38, 2463-2469.

Olivier, J., Peters, J. (2020), Trends in Global CO_2 and Total Greenhouse Gas Emissions: 2019 Report. The Hague: PBL Netherlands Environmental Assessment Agency, p4068.

Pata, U.K., Dam, M.M., Kaya, F. (2023), How efective are renewable energy, tourism, trade openness, and foreign direct investment on CO_2 emissions? An EKC analysis for ASEAN countries. Environmental Science and Pollution Research, 30(6), 14821-14837.

Rafindadi, A.A., Muye, I.M., Kaita, R.A. (2018), The effects of FDI and energy consumption on environmental pollution in predominantly resource-based economies of the GCC. Sustainable Energy Technologies and Assessments, 25, 126-137.

Rahman, M.M. (2017), Do population density, economic growth, energy use and exports adversely affect environmental quality in Asian populous countries? Renewable and Sustainable Energy Reviews, 77, 506-514.

Romero, J.P., Gramkow, C. (2021), Economic complexity and greenhouse gas emissions. World Development, 139, 105317.

Sarkodie, S.A. (2018), The invisible hand and EKC hypothesis: What are the drivers of environmental degradation and pollution in Africa? Environmental Science and Pollution Research, 25(22), 21993-22022.

Sarkodie, S.A., Strezov, V. (2019), Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Science of the Total Environment, 646, 861-871.

Sasana, H., Putri, A.E. (2018), The increase of energy consumption and carbon dioxide (CO_2) emission in Indonesia. E3S Web of Conferences, 31, e01008.

Shaari, M.S., Lee, W.C., Ridzuan, A., Lau, E., Masnan, F. (2022), Energy consumption by sector and foreign direct investment on CO_2

emissions in Malaysia. Sustainability, 14(23), 16028.

Shahbaz, M., Nasir, M.A., Roubaud, D. (2018), Environmental degradation in France: The effects of FDI, financial development, and energy innovations. Energy Economics, 73, 843-857.

Sufyanullah, K., Ahmed, K.A., Ali, M.A. (2022), Does emission of carbon dioxide is impacted by urbanization? An empirical study of urbanization, energy consumption, economic growth and carbon emissions - Using ARDL bound testing approach. Energy Policy, 164, 112908.

Suhrab, M., Soomro, J.A., Ullah, S., Chavara, J. (2023), The effect of gross domestic product, urbanization,trade openness, financial development and renewable energy on CO_2 emission. Environmental Science and Pollution Research, 9, 22985-22991.

Teng, J.Z., Khan, M.K., Khan, M.I., Chishti, M.Z., Khan, M.O. (2021), Effect of foreign direct investment on CO_2 emission with the role of globalization, institutional quality with pooled mean group panel ARDL. Environmental Science and Pollution Research, 28, 5271-5282.

To, A.H., Ha, D.T.T., Nguyen, H.M., Vo, D.H. (2019), The impact of foreign direct investment on environment degradation: Evidence from emerging markets in Asia. International Journal of Environmental Research and Public Health, 16(9), 1636.

Tured, S., Turedi, N. (2021), The effects of renewable and non-renewable energy consumption and economic growth on CO_2 emissions: Empirical evidence from developing countries. Business and Economics Research Journal, 12(4), 751-765.

Wang, W.Z., Liu, L.C., Liao, H., Wei, Y.M. (2021), Impacts of urbanization on carbon emissions: An empirical analysis from OECD countries. Energy Policy, 151, 112171.

Warsame, A.A., Sarkodie, S.A. (2022), Asymmetric impact of energy utilization and economic development on environmental degradation in Somalia. Environmental Science and Pollution Research, 29, 23361-23373.

Warsame, Z.A. (2023), The significance of FDI inflow and renewable energy consumption in mitigating environmental degradation in Somalia. International Journal of Energy Economics and Policy, 13, 443-453.

Warsame, Z.A., Ali, M.M., Mohamud, L.B., Mohamed, F.H. (2023), The Causal relation between energy consumption, carbon dioxide emissions, and macroeconomic variables in Somalia. International Journal of Energy Economics and Policy, 13(3), 102-110.

Yang, B., Jahanger, A., Khan, M.A. (2020), Does the inflow of remittances and energy consumption increase CO_2 emissions in the era of globalization? A global perspective. Air Quality, Atmosphere Health, 13, 1313-1328.

Zhang, S., Liu, X., Bae, J. (2017), oes trade openness affect CO_2 emissions: Evidence from ten newly industrialized countries? Environmental Science and Pollution Research, 24, 17616-17625.