Innocent devils: The varying impacts of trade, renewable energy and financial development on environmental damage: Nonlinearly exploring the disparity between developed and developing nations.

QALATI, Sikandar Ali <http://orcid.org/0000-0001-7235-6098>, KUMARI, Sonia <http://orcid.org/0000-0002-8272-1332>, TAJEDDINI, Kayhan <http://orcid.org/0000-0002-5087-8212>, BAJAJ, Namarta Kumari <http://orcid.org/0000-0003-1616-6622> and ALI, Rajib <http://orcid.org/0000-0001-9830-953X>

Innocent Devils: The Varying Impacts of Trade, Renewable Energy and Financial Development on Environmental Damage: Nonlinearly Exploring the Disparity between Developed and Developing Nations.

Sikandar Ali Qalati[1*], Sonia Kumari[2], Kayhan Tajeddini[3&4] Namarta Kumari Bajaj[2], Rajib Ali[2]

[1]School of Finance and Economics, Jiangsu University, China. Email: sidqalati@gmail.com; qalati@ujs.edu.cn. ORCID: https://orcid.org/0000-0002-7475-7685

[2]Department of Business Administration, Sukkur IBA University, Pakistan. Email: [S.K., sonia.kumari@iba-suk.edu.pk; N.B.K., namarta.bajaj@iba-suk.edu.pk; R.A, rajib.msm18@iba-suk.edu.pk]

[3]Sheffield Business School, Service Sector Management, Sheffield Hallam University, City Campus, Howard Street, Sheffield. S11, WB, UK.

[4]Institute for International Strategy, Tokyo International University, Tokyo, Japan. Email: kayhan120@gmail.com; k.tajeddini@shu.ac.uk; ktajeddi@tiu.ac.jp. ORCID: https://orcid.org/0000-0002-5087-8212

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Research Highlights:

1. Global warming has grown to be a significant issue on a global scale and is a result of human activities.

2. World is looking towards economic growth and renewable resources as possible solution to ensure least damage to the environment.

3. Results highlight asymmetrical role of trade, renewable energy and financial development on environmental damage represented by CO_2 emissions.

4. Trade and financial development in developing countries and financial development in developed countries are the main reason behind environment degradation.

5. Policymakers must come up with comprehensive knowledge regarding how nations can safeguard environmental quality while also achieving higher economic growth.

Innocent Devils: The Varying Impacts of Trade, Renewable Energy and Financial Development on Environmental Damage: Nonlinearly Exploring the Disparity between Developed and Developing Nations.

Abstract:

Global warming has grown to be a significant issue on a global scale and is a result of human activities. As a potential solution, nations are looking for sustainable economic growth and investments in clean energy technologies. Therefore, this study aims to empirically investigate the impact of trade, renewable energy, and financial development on environmental degradation among developed and developing countries in light of the EKC (Environment Kuznets Curve) hypothesis. The influence on carbon emissions for the years 1990–2019 is analyzed and contrasted using the Non-linear Auto Regressive Distributed Lag (NARDL) regression technique. Results show that industrialized and developing countries emit significantly different amounts of carbon. There is evidence of a non-linear and inverted U-shape relationship that supports the EKC hypothesis. Further evidence obtained shows that there is a high risk of carbon emissions among both groups of countries with the increase in financial development and trading activities. However, the usage of renewable energy reduces environmental damage and the association is non-linear. The study recommends the use of effective measures to reduce environmental damage by using clean energy sources and strengthening the financial system by offering environment-friendly investment loans. Policies should be designed that promote sustainable growth and investments in environment-friendly technologies.

Keywords: Trade, Financial Development, Renewable Energy, Environmental Damage, NARDL

1. Introduction

Global warming has become a big problem throughout the world and it is brought about by human activities. The burning of fossil fuels and industrialization leads to the emissions of harmful gases such as CO2 that lead to global warming; a form of environmental degradation (Kirikkaleli et al., 2022). Every country needs to grow its economy through investment and trading activities which results in environmental degradation (Adebayo et al., 2021). Carbon emissions are known to be mostly responsible for climate change and are considered a major cause of the rise in temperature by more than 20C that our world is facing today (UN, 2020). Moreover, global warming has resulted in severe rainfall, floods, drought, mass extinction of various species, ice melting, decreased crops, and health conditions (Charfeddine & Kahia, 2019).

The United Nations set Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) in its agenda to reduce carbon emissions till 2030 (UN, 2019; WHO, 2021). However, the World Bank figures reveal an increase in global carbon emissions between 1960 and 2019. According to Liu & Chao (2019) carbon emissions tripled as compared to emissions in 1960. Therefore, it is proposed that the globe has not succeeded in reducing carbon emissions and achieving better environmental quality (CFR, 2021; UN, 2020; WHO, 2022). Human actions are to blame for the fact that global warming has become a serious problem. Due to climate change, temperatures are further expected to rise by 2.80C by 2030 which is an alarming situation (UNEP, 2022). The emergency called for an overall change to limit greenhouse gas emissions by 2030 with a significant reduction. Further systematic transformation is demanded with immediate actions specifically in economic growth, energy, and financial sector to eliminate the non-sustainable means of growth with environmental-friendly and renewable sources (IPCC, 2022). Nations are seriously looking for sustainable growth and a major shift is witnessed recently toward investments in renewable energy sources as a viable solution (Delloitte, 2022). This raises the crucial question of whether recent developments in the financial, energy, and economic sectors have any bearing on reducing environmental degradation.

In the literature, EKC (Environment Kuznets Curve) hypothesis is used as a central framework to analyze the determinants of carbon emissions among academic scholars (Pata, 2021). This highlights that environmental quality indicators would fall initially during periods of modern economic expansion until the phase of development reached a specific point. After that environmental quality would improve with growth in economic factors (Shahbaz & Sinha, 2019).

Several influencing factors have been identified for carbon emissions and existing empirical studies can be grouped under three categories, based on the variables of interest. The first group of empirical studies Ling et al. (2022); Kumari et al. (2022) and Tsaurai (2019) demonstrate that there is a connection between financial development and environmental deterioration. In the second category of empirical studies, Adebayo et al. (2021); Sun et al. (2019) and Wang and Zhang (2021) validate that trading activities influence the environment quality which forms a U-shape relationship with carbon emissions (Gill et al., 2018). However, this view is inconsistent with the non-linear empirical investigation that the increasing and decreasing effects of trade on carbon emissions were both positive (Mahmood et al., 2019; Qamruzzaman & Jianguo, 2020). The third category of empirical literature suggests that renewable energy promotes the reduction of carbon emissions and suggested that the use of alternative sources of energy improves environmental quality (Adebayo et al., 2022; Bekun, 2022; Kecek et al., 2019).

Hence, economies that consume fossil fuels contribute to environmental degradation. It has been observed that there are some shortcomings in the existing literature this study seeks to improve upon. First, it is observed that most of the studies are either country-specific (Bekun, 2022; Kirikkaleli et al., 2022; Pata & Caglar, 2021) or exploring regional countries (Caglar et al., 2022; Du et al., 2022; Gaies et al., 2022). However, the subject matter has not been explored as a comparative study between developed and developing economies. Recent studies also pointed out that organized monitoring of financial advancement and trading activities can reduce CO_2 emissions but there is a need to study the association (Adebayo et al., 2021; Charfeddine & Kahia, 2019; Frikh et al., 2021). The novelty of the study is in a successful bid to lower carbon emissions may be best achieved by ascertaining which of these two regions have economic and development activities that influence carbon emissions. Also, it is observed that most of these studies engaged the bound co-integration test and the traditional Johansen co-integration test; which all assume a linear relationship among the variables of the regression model. However, most economic variables do not exhibit linear relationships instead, they are nonlinearly correlated (Priyankara & Li, 2018). Hence, the choice of linear co-integration technique in the possibility of non-linear correlation aggregates spurious results (Gaies et al., 2022; Haug & Ucal, 2019; Priyankara & Li, 2018). To bypass this problem, this study is engaging the non-linear autoregressive distributed lag (NARDL) analysis by decomposing variables into positive and negative partial aggregates to allow for the asymmetric impressions of exogenous variables (Priyankara & Li, 2018; Shin et al., 2014). Based on the discussion, the following are the two main objectives of this study:

To compare how developed and developing countries' trade, renewable energy usage, and financial development affect the environment.

To assess how developed and developing countries trade, renewable energy usage, and financial development asymmetrical affect environmental damage.

This study offers relevant insights towards lowering carbon emissions; which is consequential to improving health status among countries and saving the planet from further environmental damage. Hence, this study contributes to the actualization of the SDGs targeted at improving environmental quality. The study covers fourteen countries, seven from developed and seven from developing countries. This would help to comprehend carbon emissions and would help in formulating appropriate policies targeted at reducing the emissions of carbon gas in these countries.

2. Literature Review

2.1 Theoretical Framework

The Kuznets Curve was formerly developed during the 1950s as a theoretical proposition for understanding the relationship between levels of per capita income and inequality; which was regarded to be inverted U-shaped (Kuznets, 2019). However, the EKC was adopted in the 1990s to explain the inverted U-shape association of environmental quality with economic growth (Chen et al., 2019; Li & Su, 2017). The relationship between carbon dioxide and its determinants was first proposed by the EKC. The climate rapidly degrades during the beginning of development as an economy begins to add industries along with continuous rise because of polluted air, deforestation, contaminated soil, and water, among other things. When the country begins to grow and income levels rise, the impact on the environment is positive. After a certain income level, carbon emissions start to decrease and environmental quality increases (Pata & Caglar, 2021; Shahbaz & Sinha, 2019). An inverted U-shape pattern indicates environmental degradation declines after attaining a certain economic performance. This claim has been validated by several empirical studies (Adebayo et al., 2021; Balogh & Jambor, 2017; Sun et al., 2019).

2.2 Trade and carbon emissions

Literature offers insights into the relationship between trade and carbon emissions. Adebayo et al. (2021) investigate the effect of trade and production on consumption-based CO2 using the NARDL model. The results indicate that there is a strong hold of trade and GDP on consumption-based CO2. Frikh et al. (2021) examine the relationship between regional appeal, free trade, and pollution and demonstrated that CO2 from exports significantly accounts for the country's population. Another empirical study was conducted in forty-nine (49) countries within Belt and Road regions by Sun et al. (2019), where the study analyse the relationship between trade and environmental pollution. The panel regression results highlight a clear role of economic activities cause environment deterioration and suggests that trade impact positively and negatively on carbon emissions; which suggests the existence of a U-shape relationship. Furthermore, Wang and Zhang (2021) examined the heterogeneous influence of trade openness on carbon emissions and clarified international trade offer latest technologies to poor nations.

Contrarily, Mahmood et al. (2019) suggest trade and carbon emissions exhibit a U-shape relationship over the periods of 1971-2014 in Tunisia using combined linear ARDL and non-linear ARDL techniques. Furthermore, nonlinear ARDL finds asymmetrical impacts of trade on carbon emissions with increasing and decreasing effects of trade positively producing higher carbon emissions. On the other hand, Rasoulinezhad and Saboori (2018) engage panel regression techniques to highlight the strong association of economic activities with the environment. However, this influence varies from region to region (Dou et al., 2021).

> ***H_{1a}: For developed countries, trade has an asymmetric effect on carbon emissions both in the short term and over the long term.***
>
> ***H_{1b}: For developing countries, trade has an asymmetric effect on carbon emissions both in the short term and over the long term.***

2.3 Renewable energy use and carbon emissions

Several empirical studies have investigated the claims of the EKC theory, over time to ascertain the factors that contribute to degradation of environment. Pata and Yilanci (2020) analyze the dynamic link between energy usage and carbon impact in a panel of G7 nations. The results show that energy use in the chosen nations promotes environmental deterioration. Kirikkaleli et al. (2022) examined the influence of renewable energy on CO2 while using ARDL, FMOLS, and DOLS. The study reveals that the usage of renewable energy minimizes carbon emissions in Chile. Similarly, Ding et al. (2021) found that renewable energy usage lowers carbon. This argument is supported by Adebayo et al. (2022). This result collaborates with Du et al. (2022) and Bekun (2022) whose empirical results suggest that the use of renewable energy improve environmental quality.

A more thorough investigation by Doğan and Can (2019), checked the impact of energy use, and economic complexity on harmful emissions for 55 nations with varying income levels. The findings revealed that energy consumption and economic heterogeneity decrease CO_2 emissions in middle-income countries while increasing in high-income nations. However, there is proof from a developed nation that the use of fossil fuels has a clear influence on carbon emissions, whereas the use of renewable resources is restricted and has little to no effect on the reduction of carbon emissions. (Menyah & Wolde, 2010; Shahbaz et al., 2021). From these results, there is a consensus in the literature that the consumption of renewable energy asymmetrically contributes to the reduction of carbon gas emissions.

H2a: For developed countries, the use of renewable energy has an asymmetric effect on carbon emissions both in the short term and over the long term.

H2b: For developing countries, the use of renewable energy has an asymmetric effect on carbon emissions both in the short term and over the long term.

2.4 Financial development on carbon emissions

Each nation's financial sector is its main driver of economic expansion and stability, but it also has detrimental effects on the environment that cannot be ignored. The financial industry uses a lot of energy to drive economic expansion, which has unforeseen environmental effects (Ling et al., 2022). Furthermore, the contribution of financial development to promoting good corporate governance and generating financial and reputational incentives may inspire businesses to pursue eco-friendly initiatives, hence lowering carbon emissions. According to Jiang and Ma (2019), there are substantial regional differences in the relationship between financial system expansion and environmental quality. Developing nations show a markedly positive correlation with environmental degradation brought on by the expansion of the financial sector (Ling et al., 2022). The findings also suggested that this effect is negligible for developed countries. Furthermore, Xiong et al. (2017) checked the linkage of financial development and harmful gases release using a panel data model. Results find that carbon emissions are lower in regions with a developed financial system, whereas higher carbon emissions are found in places with less developed financial systems.

A similar result was obtained by Li and Ouyang (2019) suggesting financial system expansion promotes a lean environment. Financial development and its sub-categories, such as depth and efficiency, minimize CO2 release in both developed and emerging nations while employing the GMM with the data of 83 economies (Acheampong et al., 2020). Additionally, noted that independent economies, as well as neither the general financial development nor its subcategories, had any appreciable impact on the intensity of CO2 emissions. Tsaurai (2019) used pooled OLS regression to propose that low financial deepening among West African counties deteriorates the environment. Use of VAR panel technique on MENA countries and provides a paucity of research on the impact of financial development on carbon emissions. Although, the study suggested that there is a need to study this relationship in other regions of the world (Ahmad et al., 2018; Charfeddine & Kahia, 2019).

H3a: For developed countries, financial development has an asymmetric effect on carbon emissions both in the short term and over the long term.

H3b: For developing countries, financial development has an asymmetric effect on carbon emissions both in the short term and over the long term.

3. Methodology

3.1 Sample and data selection

In this study, secondary data series is used that spans from 1990-2019, the data for domestic credit to the private sector, GDP, population, and exports are obtained from world development indicators (WDI)[1], renewable energy consumption, and total energy consumption data is taken from International Energy Agency (IEA)[2] and most recent carbon emissions data is obtained from Global Carbon Atlas[3] websites on annual basis, for the G7 group of seven major developed countries (Canada, France, Germany, Japan, Italy UK, and USA) and seven developing countries (Bangladesh, Brazil, China, India, Pakistan, South Africa, and Sri Lanka) by combining the two developing countries groups SAARC and BRICS countries selection based on the availability of data (Balogh & Jambor, 2017; Bhattacharya et al., 2016). All the data series employed in this study are converted to per capita divided by the total population of that country. All the data series are transformed into natural logarithmic approach to diminish heteroscedasticity and bring the normality in the data so that the comparison and interpretation of the variables can be accomplished in a uniform percentage form (Charfeddine & Kahia, 2019).

[1] Available at: World Bank Indicators, The World Bank. Retrieved 3rd January, 2022, from https://data.worldbank.org/

[2] International Energy Agency-IEA. *Data & Statistics.* Retrieved 7th April, 2022, from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource

[3] Global Carbon Atlas. CO_2 Emissions. Retrieved 3rd January, 2022, from http://www.globalcarbonatlas.org/en/CO2-emissions

3.2 Variables Measurement

3.2.1 Carbon dioxide emissions ($C0_2$) refers to carbon dioxide emissions in metric tons per capita.

3.2.2 Trade (TRA) measured as exports per capita by taking total exports amount in constant 2015 US$ and dividing by the total population.

3.2.3 Financial Development (FDE) measured as domestic credit to private sector per capita.

3.2.4 Renewable Energy Consumption (REE) measured as renewable energy consumption per capita.

3.2.5 Gross Domestic Product (GDP): This refers to Gross Domestics Product (Constant 2015 US$) per capita.

3.3 Model Specification

In order to lessen the impacts of climate change and global warming, nations are now making significant investments in renewable energy technology and moving toward sustainable forms of economic growth in terms of their financial development, GDP, and trade activities. Therefore, this study is making an effort to analyze the impact of international trade, renewable energy, financial development, and GDP on carbon emissions comparison among developed and developing countries. Following the theoretical underpinnings of the EKC hypothesis and the suggestions of previous studies, this study proceeds by formulating a multiple regression model that captures their impact on carbon emissions (proxy of environmental damage) (Gaies et al., 2022; Pata & Caglar, 2021; Qamruzzaman & Jianguo, 2020).

$$C0_2 = f\,(TRA, REE, FDE, GDP) \tag{1}$$

Equation (1) is linearized, and thus restated as:

$$C0_2 = \alpha_0 + \alpha_1 TRA_t + \alpha_2 REE_t + \alpha_3\, FDE_t + \alpha_4 GDP_t + \mu_t \tag{2}$$

For panel data equation (2) is restated as:

$$CO2_{it} = \alpha_{10} + \alpha_{it}^{+}\, TRA_{it}^{+} + \alpha_{it}^{-}\, TRA_{it}^{-} + \alpha_{it}^{+} REE_{it}^{+} + \alpha_{it}^{--} REE_{it}^{-} + \alpha_{it}^{+}\, FDE_{it}^{+} + \alpha_{it}^{-} FDE_{it}^{-} +$$

$$\alpha_{it}\, GDP_{it} + \alpha_{it}\, GDP_{it}\,\text{^}2 + \mu_{it} \tag{3}$$

Equation (2) present the time series model of the variables engaged in this study. Equation (3) show the regression equation for panel data with cross sections and time represented with i and t. GDP per capita and its square form are engaged to validate the existence of the EKC hypothesis. However, this study will restate equation (3) following Shin et al. (2014); Priyankara and Li (2018), and Gaies et al. (2022) that most economic models are non-linear. Thus, the study will incorporate the partial sum of positive and negative changes of the three exogenous variables:

$$\Delta CO2_{it} = \beta_{10} + \sum_{i=1}^{n} ß_{1i}\Delta CO2_{j,t-i} + \sum_{i=0}^{n}\beta_{2i}^{+}\Delta TRA_{j,t-i}^{+} + \sum_{i=0}^{n}\beta_{3i}^{-}\Delta TRA_{j,t-i}^{-} + \sum_{i=0}^{n}\beta_{4i}^{+}\Delta REE_{j,t-i}^{+} + \sum_{i=0}^{n}\beta_{5i}^{-}\Delta REE_{j,t-i}^{-} + \sum_{i=0}^{n}\beta_{6i}^{+}\Delta FDE_{j,t-i}^{+} + \sum_{i=0}^{n}\beta_{7i}^{-}\Delta FDE_{j,t-i}^{-} + \sum_{i=0}^{n}\beta_{8i}\Delta GDP_{j,t-i} + \gamma_{1i}^{+}TRA_{j,t-1}^{+} + \gamma_{2i}^{-}TRA_{j,t-1}^{-} + \gamma_{3i}^{+}REE_{j,t-1}^{+} + \gamma_{4i}^{-}REE_{j,t-1}^{-} + \gamma_{5i}^{+}FDE_{j,t-1}^{+} + \gamma_{6i}^{-}FDE_{j,t-1}^{-} + \gamma_{7i}GDP_{j,t-1} + \mu_{it} \quad (4)$$

$$TRA_{it}^{+} = \sum_{i=1}^{n} MAX\,(TRA_{it}^{+}, 0)\,, \;\; TRA_{it}^{-} = \sum_{i=1}^{n} MIN\,(TRA_{it}^{-}, 0) \quad (5)$$

$$REE_{it}^{+} = \sum_{i=1}^{n} MAX\,(REE_{it}^{+}, 0)\,, \;\; REE_{it}^{-} = \sum_{i=1}^{n} MIN\,(REE_{it}^{-}, 0) \quad (6)$$

$$FDE_{it}^{+} = \sum_{i=1}^{n} MAX\,(FDE_{it}^{+}, 0)\,, \;\; FDE_{it}^{-} = \sum_{i=1}^{n} MIN\,(FDE_{it}^{-}, 0) \quad (7)$$

Where C02 is carbon dioxide emissions; TRA is trade; FDE is financial development; REE is renewable energy consumption; GDP is gross domestic product per capita; α0 and β0 is the intercept of the models all αit, βit, and γit are slope parameter for the models; subscripts i, t are country and time operators; μit is the stochastic error term. The linear version of Equation (3) represents the panel analysis model with a partial sum of positive and negative shocks for each exogenous variable (represented by the + and - sign). Adding a partial sum of positive and negative shocks (indicated with a + and - sign) for each predictive variable to equation (4) to account for the asymmetry between the short- and long-term impacts. In order to take into consideration asymmetric impacts, equations (5, 6, and 7) demonstrate the breakdown of variables into positive and negative shocks. To determine if the EKC theory is applicable to both developed and developing nations, estimates for both groups will be made using this model with GDP per capita and its square.

3.4 Estimation Technique

The study has engaged three co-integrating techniques non-linear autoregressive distributed lag (NARDL), Fully Modified Ordinary Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS) methods. The NARDL technique is best employed when there is a non-linear relationship among the variables in empirical analysis (Priyankara & Li, 2018), it has also been argued that the impact of the majority of the variables is non-linear (Esteve & Tamarit, 2012). Just like the traditional autoregressive distributed lag (ARDL), the NARDL can be employed regardless data series are purely co-integrated at levels or first difference, or as a mixture of both levels (Nkoro & Uko, 2016). Furthermore, for ARDL and NARDL the study uses 30 years of observation which is sufficient. This argument is supported by Adebayo et al. (2021); Cıtak et al. (2021); and Neog and Yadava (2020). Wald test is adopted to test for the presence of asymmetries of the variables. Additionally, the study uses the pooled FMOLS and DOLS co-integrating approaches to produce reliable findings on the subject studied. Pedroni (2001) developed the FMOLS regression approach, a residual-based test with effective outcomes for co-integrated variables. Additionally, FMOLS is regarded as a valid estimate when the sample size is small since it solves the issues of endogeneity and serial correlation among the variables. Furthermore, in 1993, Stock and Watson created a DOLS estimate. Compared to FMOLS, DOLS yields superior results and goes well with regressors correlation. The stationarity test will be conducted to ensure that none of the variables are integrated at the second differencing level.

4. Findings and Discussion

It has been argued that the countries which have achieved a certain level of growth shift their focus to environmental protection (Apergis, 2016; Bhattacharya et al., 2016). This argument also supports the EKC hypothesis that makes it look like an inverted U-shape (Esteve & Tamarit, 2012). By evaluating figures I and II it is quite clear that developed countries are more inclined towards reducing carbon emissions in recent years. The UK has achieved it well, while Germany and USA are following.

Figure I

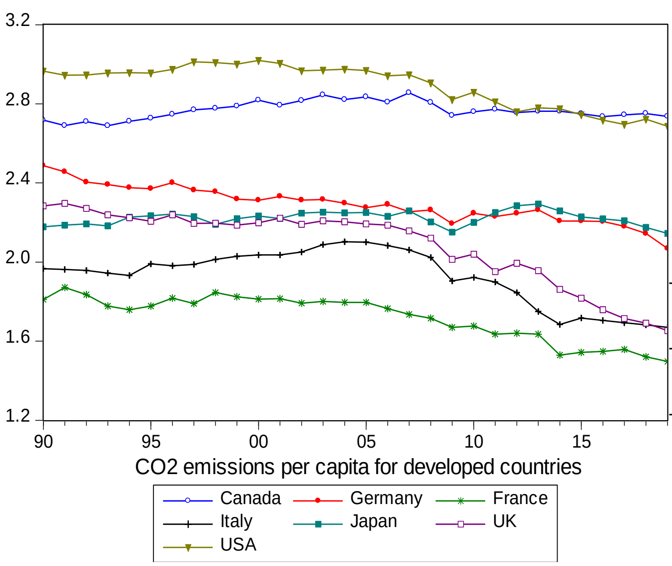
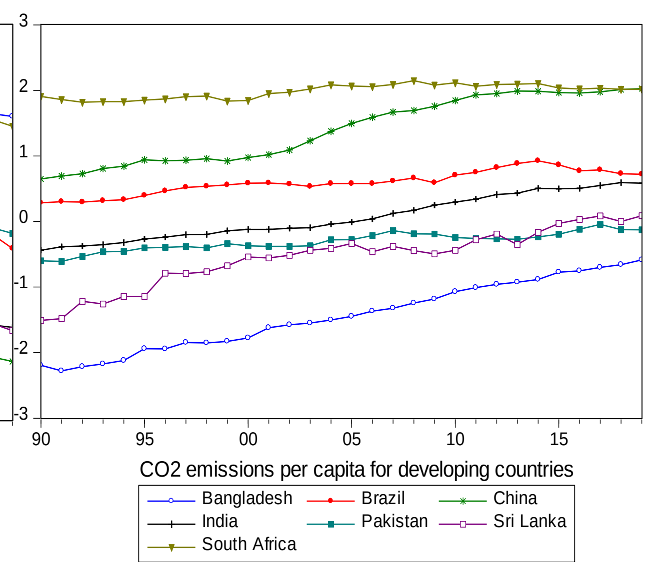


Figure II



Contrary, developing countries' carbon emissions have been increasing since as they are focusing on growth more than environmental damage as can be witnessed in the case of China, Bangladesh India, and Sri Lanka. Overall, per capita, carbon emissions in developing countries are lower than in developed countries as shown in graphs that are mainly due to population levels (Hansen & Sato, 2016). However, apart from population differences, the rate at which emissions are increasing in developing countries is alarming. Trade levels show an increase in trading activities in both regions there is the achievement of higher trading activities in terms of exports in both regions see Figures III and IV. However, the rate at which trading activities are growing is higher for developed countries as compared to developing economies.

Figure III

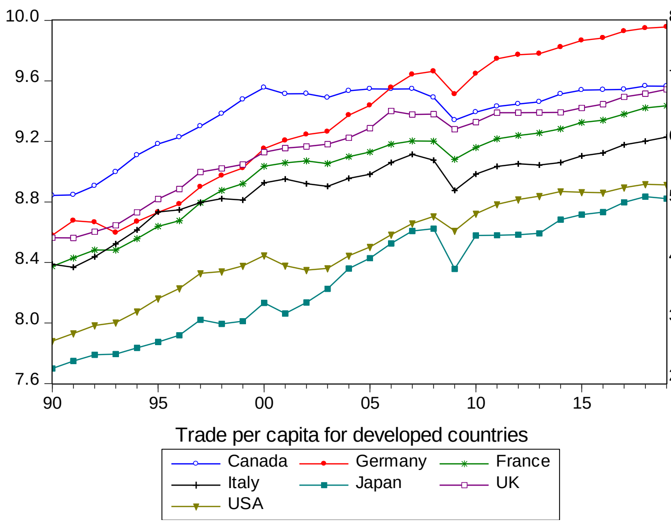
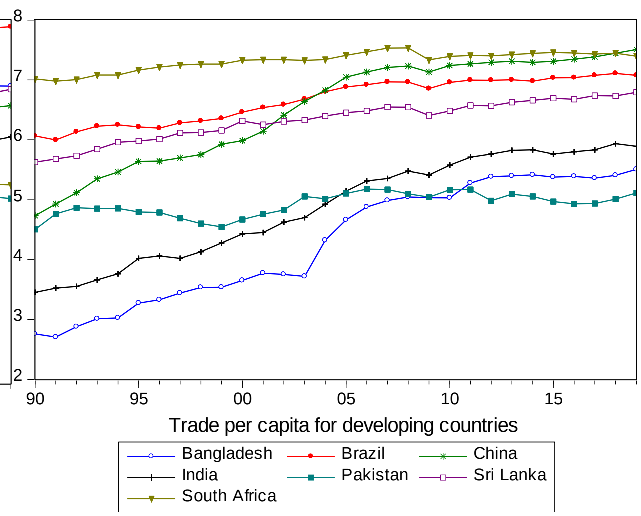


Figure IV



In terms of the use of renewable energy per capita majority of the countries have increased/maintained their position as the overall trend is not increasing like trade. However, few countries have increased the use of renewable energy on a per capita basis like UK, Germany, Italy, Brazil, and Sri Lanka. One can argue here that in developed countries, growth in the use of renewable energy on a per capita basis is more than in developing countries (refer to Figures V & VI). It can also be argued here that in developing countries the trend is somewhat declining except for Brazil. In developed countries, the trend of adopting renewable resources is increasing except for Canada and France.

Figure V

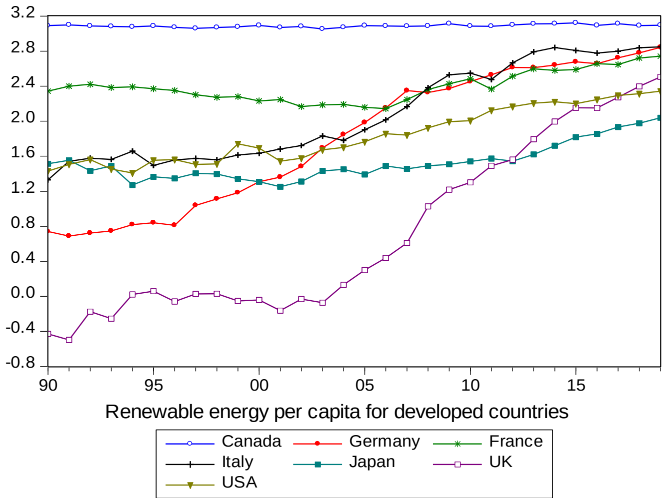
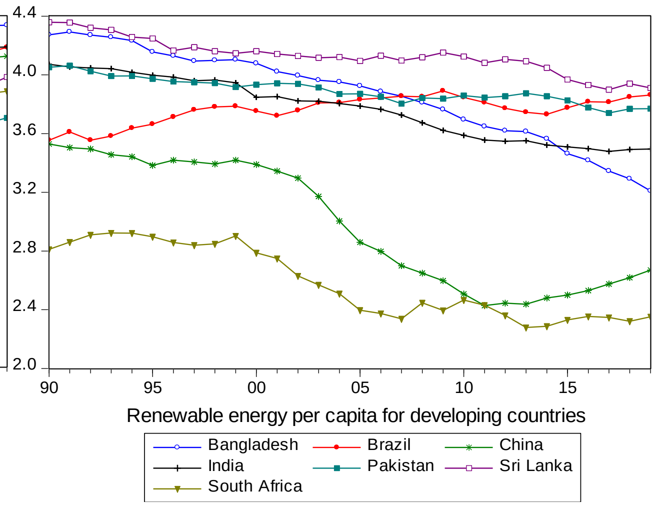


Figure VI



Furthermore, there have been fluctuations in the financial sector among both regions. However, it can be claimed that the trend is increasing in terms of providing domestic credit to the private sector as reported in Figures VII and VIII.

Figure VII

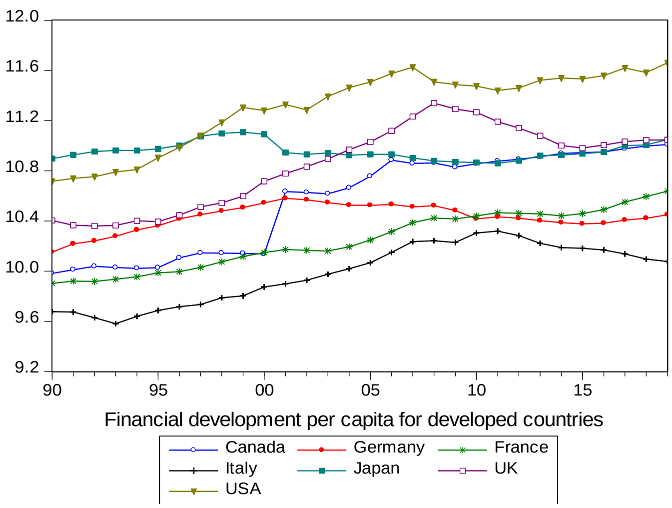
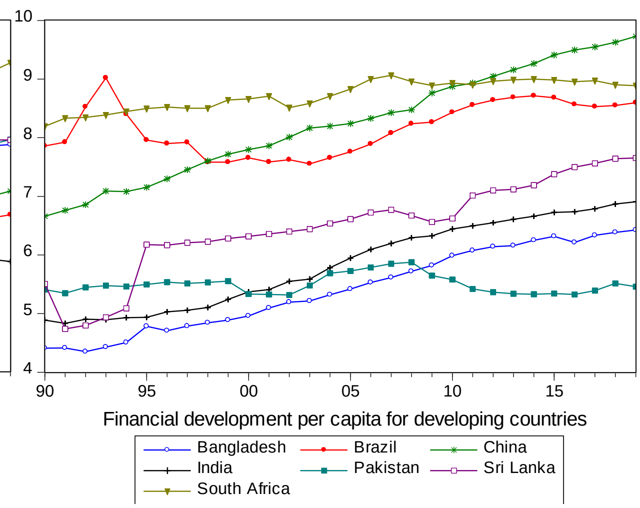


Figure VIII



Using balanced panel data, descriptive statistics values for CO_2, trade, financial development, renewable energy, and GDP for developed and developing countries are presented in Table I. It shows that the mean value for CO_2 emissions in metric tons per capita is (2.3, 0.3) which is higher in developed countries as compared to developing countries. Value for standard deviation (0.4, 1.15) of carbon dioxide emissions shows higher standard deviation in developing countries than developed countries. It is also interesting to note the gap between minimum and maximum values in developing countries (2.15, -2.88) is greater than in developed countries (3.02, 1.5) for CO_2 emissions per capita. There is evidence that the level of standard deviation in all variables of developing countries is higher than in developed countries. In terms of normal distribution of the data, the values for skewness and kurtosis reflect that data is slightly long left tailed, and platykurtic with more values lower values than the sample average for both regions. The majority values for kurtosis are near 3 identifying the near normal distribution. Panel B of Table I shows the correlation among the data series employed in this study for two groups of countries. All the correlation values are less than 0.8 which means none of the series is perfectly correlated and there is no problem of serial correlation among the data series of the study.

Table I. Descriptive statistics and correlation matrix

Panel A: Descriptive Statistics. Panel A shows the values of mean, maximum, minimum standard deviation, skewness, kurtosis, JB test with probability, and the number of observations engaged for each data series of developed and developing countries.

Variables	**Mean**	**Max.**	**Min.**	**St. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera (Prob.)**	**Obs.**
	Descriptive Statistics of Developed Countries							
CO_2	2.27	3.02	1.50	0.41	0.20	2.02	9.87 (0.01)	210
TRA	8.94	9.96	7.70	0.50	-0.34	2.59	5.64 (0.06)	210
REE	1.92	3.12	-0.50	0.86	-0.68	3.12	16.55 (0.00)	210
FDE	10.62	11.66	9.58	0.49	0.08	2.26	5.00 (0.08)	210
GDP	10.51	11.01	10.22	0.18	0.72	2.74	18.64 (0.00)	210
	Descriptive Statistics of Developing Countries							
CO_2	0.25	2.15	-2.28	1.15	0.02	2.29	4.46 (0.11)	210
TRA	5.84	7.53	2.71	1.22	-0.51	2.42	12.14 (0.00)	210
REE	3.54	4.36	2.28	0.59	-0.80	2.29	27.08 (0.00)	210
FDE	6.91	9.73	4.35	1.47	0.10	1.68	15.70 (0.00)	210
GDP	7.71	9.23	6.24	0.90	0.11	1.60	17.50 (0.00)	210

Panel B: Correlation Matrix. Panel B shows the values for correlation among the variables of two groups of countries. Carbon emissions represented as CO_2 and all three regressors are decomposed into the partial sum of positive and negative shocks. Where, Trade (is represented as TRA^+, TRA^-), Renewable Energy (REE^+, REE^-), Financial Development (FDE^+, FDE^-) and GDP per capita as GDP

	Correlation Matrix of Developed Countries							
	CO_2	TRA^+	TRA^-	REE^+	REE^-	FDE^+	FDE^-	GDP
CO_2	1.00							
TRA^+	-0.15	1.00						
TRA^-	0.10	-0.76	1.00					
REE^+	-0.36	0.68	-0.47	1.00				
REE^-	0.19	-0.63	0.53	-0.39	1.00			
FDE^+	0.08	0.56	-0.55	0.53	-0.26	1.00		
FDE^-	0.30	-0.50	0.65	-0.44	0.23	-0.70	1.00	

GDP	0.41	0.68	-0.49	0.21	-0.55	0.49	-0.19	1.00
	Correlation Matrix of Developing Countries							
CO_2	1.00							
TRA^+	0.08	1.00						
TRA^-	-0.01	-0.14	1.00					
REE^+	0.48	-0.06	-0.19	1.00				
REE^-	-0.39	-0.30	-0.39	-0.18	1.00			
FDE^+	0.22	0.59	-0.19	0.74	-0.66	1.00		
FDE^-	0.02	0.14	0.21	-0.49	0.29	-0.43	1.00	
GDP	0.74	0.04	-0.06	0.64	-0.49	0.46	-0.51	1.00

Before conducting the stationarity test of the data series the test of cross-section dependence is conducted. The results show that there is an availability of correlation of the residuals with data series (see Panel A of Table II). Cross-section dependency results imply that member countries in a group are related to each other in terms of their economic activities. This guides here towards the use of the second-generation unit root test which offers more accuracy and reliability as compared to 1st generation unit root test. Panel B of Table II shows the stationarity values of the data series based on two second-generation unit-root tests. The majority of the data series are stationary at the first difference (@diff.) because the p-values at level (@level) are greater than 10% (>0.1) significance level. Moreover, the results demonstrate that GDP per capita, the increasing trade term, and the falling financial development term are stationary at level. All other variables, however, are stationary at the initial difference. These results though indicate that none of the data series is stationary at I(2). The mixed stationarity test results indicate that it is appropriate to use the NARDL estimation technique (Haug & Ucal, 2019).

Panel C summarizes the results of the wald statistic used to indicate asymmetry in the positive and negative shocks. The probability value of the f-statistic proposes statistical significance at a 1% level. This indicates that the data sets decomposed into the partial sum of increasing and decreasing shocks specify asymmetry making it appropriate to use a non-linear technique in the study (Haug & Ucal, 2019; Qamruzzaman & Jianguo, 2020).

Table II. Results of cross-section dependence, unit root, and wald test

Panel A: Cross-Section Dependence Test. Panel A shows the results of the cross-section dependence test results performed for developed and developing countries

	Developed Countries			Developing Countries		
	Statistics	**Df**	**Prob.**	**Statistics**	**Df**	**Prob.**
Breusch-Pagan LM	273.46	21	0.00	154.92	21	0.00

Pesaran Scaled LM	38.96	0.00	20.67	0.00
Pesaran CD	0.36	0.72	9.15	0.00

Panel B: Unit-Root Tests shows the p-value of unit root tests performed for all the data series of developed and developing countries using second-generation tests for panel data.

Variables	Developed Countries				Developing Countries			
	CIPS		CADF		CIPS		CADF	
	@level	@diff.	@level	@diff.	@level	@diff.	@level	@diff.
CO_2	>0.10	0.00*	>0.01*	0.00*	>0.01*	0.00*	>0.10	0.00*
TRA^+	>0.10	0.00*	>0.05*	0.00*	0.00*	0.00*	>0.10	0.00*
TRA^-	>0.10	0.01*	>0.10	0.00*	>0.10	0.00*	>0.10	0.01*
REE^+	>0.10	0.00*	>0.05*	0.00*	0.00*	0.00*	>0.10	0.00*
REE^-	>0.10	0.00*	>0.10	0.00*	>0.10	0.00*	>0.10	0.00*
FDE^+	>0.10	0.00*	>0.10	0.00*	0.00*	0.01*	0.00*	0.00*
FDE^-	>0.10	0.00*	>0.10	0.00*	0.00*	0.00*	>0.05*	0.00*
GDP	>0.05*	0.00*	0.01*	0.00*	>0.10	0.00*	>0.10	0.00*

Panel C: Wald test. Panel C shows the results of the wald test for asymmetry of positive and negative shocks of exogenous variables

	Developed Countries			Developing Countries		
	value	**Df**	**Prob.**	**value**	**Df**	**Prob.**
F-Statistics	11.67	(3, 77)	0.00*	69.51169	(3, 77)	0.00*
Chi-Square	35.01	3	0.00*	208.5351	3	0.00*

(*) indicate the significance.

4.1 Short-Run Estimation

The study proceeded to estimate asymmetric estimates engaging the NARDL model. The results are presented and interpreted accordingly for two categories of countries, the selected developed countries group and the selected developing countries group along with the asymmetric association. Results from Panel A of Table III show that in the short term progressing and falling aggregates of trade, renewable energy, and financial growth have insignificant influence on carbon release among developing countries. Only GDP per capita presents a positive influence on emissions in the short run. in the context of developing countries. This suggests that the increasing and decreasing shocks in trade and other factors do not change the carbon levels in near future significantly. This implies that the association of growth indicators is not contemporary specifically for emerging economies. Contrary, estimates of developed countries suggest a significantly asymmetric effect in the short run. Increasing aggregates of trade, renewable energy, and financial growth hold significant influence on the production of harmful gases. 1% increase in the positive aggregate of renewable energy and its lag (-1) significantly decreases the carbon emissions by 0.17% and 0.13% respectively. Similarly, a 1% growth in the lag of trade increasing term increases the production of harmful gases by 0.11%. Moreover, the increasing effect of financial development negatively affects carbon emissions at a 10% significance level. This implies that growth in the financial sector reduces environmental degradation. Furthermore, the value of the short-run co-integration term is negative in both groups of countries that show slow adjustment into long-run estimates. Though, it is evidenced that convergence of the short-run to the long-run phenomenon is negatively signed but significant only for developing countries group. This shows significant convergence at a rate of 17% of short-term factors becoming long-run factors.

4.2 Long-Run Estimation

Results from Panel B of Table III show that in the long-run, developed countries' positive and negative aggregates of trade (TRA+, TRA-) have a negative effect on carbon emissions, indicating 1% variation in trade reduces CO_2 emissions by 0.75% and 0.003% respectively. However, the results are only significant for the positive aggregate of trade. This implies that growth in trading activities of G7 developed countries is not hurting the environment and the argument is supported by Adebayo et al. (2021) and Caglar et al. (2022). Similarly, it is evident that increasing components of renewable energy consumption significantly reduce carbon emissions. The findings show that increasing the usage of renewable energy is protecting the environment, which is corroborated by Kirikkaleli et al. (2022) and Bekun (2022). On the other hand, its decreasing shock negatively affects the environment. This difference in the magnitude of both shocks clarifies the existence of an asymmetric association of renewable energy use and trade with environmental degradation in the long run.

Moreover, the outcome highlights that in the long term there is an asymmetric association of increasing and decreasing effect of financial development (FDE) likewise of trade and renewable energy among developed countries. A 1% increase in FDE positive shock negatively affects the environmental quality by producing more harmful gases but the impact is insignificant. For decreasing components of FDE there is no improvement in the condition of harmful gases but rather promoting the emissions of CO_2 but again the association is insignificant among developed countries. The study conducted by Xiong et al. (2017) find the same results that financial development is one of the main factors causing environmental degradation.

Table III. NARDL short-run and long-run estimates

Panel A: shows the results of NARDL Short-run Estimates for Developed countries and Developing countries groups.

	Developed Countries		Developing Countries	
Variables	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
COINTEQ01	-0.13	0.28	-0.17*	0.09
$D(TRA^{+})$	0.19	0.13	-0.08	0.25
$D(TRA^{+}(-1))$	0.11**	0.03	-0.004	0.95
$D(TRA^{-})$	0.11	0.58	-0.18	0.34
$D(REE^{+})$	-0.17**	0.02	-1.35	0.12
$D(REE^{+}(-1))$	-0.13**	0.05	-0.147	0.78
$D(REE^{-})$	-0.13	0.49	-0.75	0.13
$D(FDE^{+})$	-0.20*	0.07	-0.08	0.12
$D(FDE^{-})$	-1.03	0.15	-0.18	0.26
D(GDP)	0.05	0.92	0.77***	0.00
D(GDP^2)	-0.39	0.36	0.037	0.34

Panel B: shows the results of NARDL Long-run Estimates for both groups of countries.

	Developed Countries		Developing Countries	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
TRA^{+}	-0.75***	0.00	0.11***	0.00
TRA^{-}	0.003	0.23	0.38***	0.00
REE^{+}	-0.24***	0.00	-0.64**	0.02
REE^{-}	-0.51***	0.00	-0.30***	0.00
FDE^{+}	0.38	0.24	0.30***	0.00
FDE^{-}	-1.04	0.13	-0.17	0.38
GDP	1.55*	0.10	0.48**	0.03
GDP^2	-0.07**	0.04	-0.02*	0.06

This table presents the outcome of NARDL estimates. Carbon emissions is a dependent variable represented as CO_2 and all three regressors are decomposed into the partial sum of positive and negative shocks. Where, Trade (is represented as (TRA+, TRA-), Renewable Energy (REE+, REE-), Financial Development (FDE+, FDE-), GDP per capita, and its square. (*) (**) & (***) indicate significance at 10%, 5% and 1% levels respectively.

In the context of developing countries, the positive component of trade significantly increases carbon emissions which damages the environmental quality. A 1% increase in trade enhances carbon emissions in the environment by 0.11%. On the other hand, a 1% decrease in negative trade terms improves the environment quality by 0.38% at a level of 1% significance. Contrary to developed countries, in developing countries positive change in trade causes environmental deterioration which reflects the idea that these countries are in their growth phase. Similar to the results for developed countries, growth in increasing components of renewable energy consumption decreases environmental damage by negatively affecting carbon emissions. Developing countries

represent the same pattern in terms of the impact of renewable energy on carbon emissions. However, the magnitude is higher in developing countries and results indicate that a 1% change in positive and negative components of REE negatively affects emissions by 0.64% and 0.3% respectively. This negative association of both components of REE with CO_2 emissions shows significance at a 1% level in both groups of countries. This implies that renewable energy sources' utilization protects the environment's quality. Similar results were found by Kirikkaleli et al. (2022) and Bekun (2022) that renewable energy usage reduces carbon emissions.
Further estimates show that the partial sum of increasing and decreasing shocks of FDE pollutes the environment. This infers that financial development in developing countries causes environmental damage and fails to guard the protection. GDP per capita also raises the levels of carbon emissions in both groups however, the results show a higher magnitude for developed countries. This elucidates that GDP per capita is an important factor in predicting carbon emissions. Its growth has a clear negative association with environmental quality in both groups of countries. Further, there is evidence of the existence of the EKC hypothesis due to the negative sign of its square with environment quality measure. The coefficient of the square term of GDP per capita with a negative sign indicates that after a certain point, an increase in GDP per capita results in an improvement in the quality of the environment for both groups. Due to the positive sign of GDP per capita and its square with a negative sign, the data support the existence of EKC. This lends credence to the theory that while economic growth initially causes a rise in carbon emissions, it has a negative impact on them after a certain point.

Likewise, the long-term estimates using FMOLS and DOLS regression models are tested to check the reliability of the results. These results NARDL model are consistent with FMOLS and DOLS estimation presented in Panel A and B of Table IV. Results reveal that in the long run, there are asymmetric effects of trade and renewable energy on the environment. Growth in positive shocks of trade and financial development causes significant environmental damage in developing countries. There is clear evidence of the asymmetric effect of changes in renewable energy consumption components, its growth significantly lowers carbon emissions among developed and developing countries during the long-run period and results are fully supported by FMOLS and DOLS estimates. The score of VIF (variance inflation factor) indicates the level of multicollinearity present among variables in the regression. The score is below the level of 10 which is within the acceptable range of multicollinearity.

Table IV. Other estimation results

Panel A: FMOLS and DOLS estimation for developed countries

	FMOLS			DOLS		
Variable	**Coefficient**	**Prob.**	**VIF**	**Coefficient**	**Prob.**	**VIF**
TRA^+	0.16***	0.00	3.24	-0.106	0.254	6.23
TRA^-	0.35***	0.00	1.91	0.336	0.451	6.03
REE^+	-0.40***	0.00	1.60	-0.182***	0.00	5.09
REE^-	-0.07	0.32	1.51	-0.338*	0.07	3.67
FDE^+	-0.04	0.35	2.77	-0.315**	0.01	5.75
FDE^-	0.134***	0.00	1.22	-0.280	0.15	6.43
GDP	0.48**	0.02	4.24	0.737*	0.10	4.95

Panel B: Shows the results of FMOLS and DOLS estimates for developing countries.

	FMOLS			DOLS		
Variable	**Coefficient**	**Prob.**	**VIF**	**Coefficient**	**Prob.**	**VIF**
TRA^+	0.13***	0.00	2.76	0.013*	0.07	5.7
TRA^-	-0.02	0.83	1.47	-0.15	0.40	2.90
REE^+	-0.61***	0.00	1.18	-0.69***	0.00	5.34
REE^-	-0.33***	0.00	2.50	-0.21*	0.08	4.00
FDE^+	0.08***	0.00	4.66	0.35***	0.00	9.20
FDE^-	-0.56	0.39	1.43	0.03	0.81	4.41
GDP	0.81***	0.01	3.41	0.49*	0.09	7.15

(*) (**) & (***) indicate significance at 10%, 5% and 1% levels respectively.

4.3 Discussion of Findings

Results obtained from the data analysis revealed that the level of carbon emissions is higher among the developed countries on a per capita basis mainly due to the population gap (Ahmad et al., 2018). However, the regression results show that there is a significant difference in the impact of examined variables on carbon emissions among developing and developed countries. This suggests that both regions are responsible for the increase in carbon emissions with its negative consequences and consistent with previous studies (Gaies et al., 2022; Kumari et al., 2022).

Tests for asymmetry showed that the model for the study is not linear; thus, the choice for the NARDL technique is justified. The results obtained from the NARDL estimates find differences in economic growth approaches in both regions (Qamruzzaman & Jianguo, 2020). However, advancements in REE protect the environment by reducing the emissions of harmful gases. In both regions increase in the use of REE safeguards the environment, These findings are in line with prior research indicating the use of REE sources has a substantial benefit to the environment (Bekun, 2022; Kirikkaleli et al., 2022) Contrarily, studies of developing economies argue that due to capacity issues and limited knowledge there is no prominent evidence of reducing the carbon levels (Qamruzzaman & Jianguo, 2020). It must be considered that advanced technologies used with renewable resources offer new opportunities for economic growth with the least damage to the environment (Du et al., 2022; Zha et al., 2022).

Moreover, there is evidence that a surge in financing and trading activities significantly escalates carbon emissions (Gaies et al., 2022). Estimates of long-run analysis clearly show a negative association with environmental sustainability and the reason for environmental degradation. It is important to understand that financial structure must be designed in a way that supports the overall benefits to society. Its development must be aligned with the sustainability of the environment by encouraging investment in renewable and sustainable technologies (Qalati et al., 2022). In its current form, the growth in FDE pitch compromise with environmental quality which requires a transformation of its existing policies (Li & Ouyang, 2019; Ling et al., 2022; Neog & Yadava, 2020). Furthermore, trade is another major indicator of economic growth when dealing with other countries (Adebayo et al., 2021; Kumari et al., 2021). However, the exchange of goods, services, and technologies with other countries indicate non-sustainable practices which means there is a need to look for the best possible ways that consider environmental quality as a priority. However, in the existing state, the expansion of trading activities among developing economies indicate a compromise on environmental quality which necessitate a change in existing rules (Frikh et al., 2021). Similar findings are proposed by various researchers that highlight that advancement in financial and trading activities causes environmental degradation (Mahmood et al., 2019; Pata & Caglar, 2021; Wang & Zhang, 2021). In contrast to industrialized places where growth has reached a stage where the environment is protected, this study shows that commerce considerably harms the environment in emerging countries (Sun et al., 2019). Furthermore, this study support the EKC hypothesis that developed countries have reached to a level of economic activities where the focus is on environment protection (Pata, 2021).

Overall, the findings of this analysis for both sets of nations show that there is an asymmetric association, which is consistent with the assumption that most variables in the actual world are asymmetric (Ahmad et al., 2018; Haug & Ucal, 2019; Mahmood et al., 2019). In addition, stressing the idea of a growth-driven increase in carbon emissions for developing nations where environmental sustainability is given the least priority.

5. Conclusion and Policy Implications

The study empirically analyses and compares trade, renewable energy, financial development, and GDP impact on environmental damage among developed and developing countries. The factors in this study were chosen based on the countries' goals and the severe effects of climate change that the world is currently experiencing (Delloitte, 2022; UNEP, 2022; WHO, 2022). The study specified a non-linear regression model; which captured the impact of a partial sum of positive and negative shocks of trade, renewable energy, and financial development on carbon emissions. Data was sourced for the G7 group of seven major developed countries and seven developing countries considered for the period starting from 1990 to 2019. The robustness of the model is also examined using FMOLS and DOLS estimation techniques; along with the non-linear ARDL model. Regression analysis confirms the asymmetric association of variables with environmental damage. Growth in GDP per capita, trade, and financial development cause the deterioration of the environment. On the other hand, the growth in the use of renewable energy sources protects the environment. There is evidence of an asymmetric association between positive and negative shocks of trade, renewable energy, and financial progress.

It is important to understand that growth in trading activities must be aligned with sustainable practices to amplify its outcomes for maximum benefit in emerging economies. Similarly, financial advancement also needs strict compliance to ensure that its expansion operations are in line with rules for environmental protection in both groups of countries. Therefore, the region needs strict policies that reduce carbon emissions while paying particular attention to the opportunities that sustainable economic activity may present. The strength of this research lies in its investigation into the possibility of asymmetric impacts by examining whether positive shocks to economic activity have a greater and long-lasting influence on the emissions of carbon dioxide than negative shocks. Another contribution of this study is its examination of the asymmetries in the short- and long-term effects of the change in CO_2 emissions. There is evidence of the presence of an inverted U-shape relationship between economic activities and environmental degradation. This study explains that developed countries have reached a level of economic activity where the focus is on environmental protection.

5.1 Policy Implication

The study recommends higher efficiency is required in the management of carbon emissions among developing countries as financial development and trading activities significantly cause environmental degradation in the long run. There witnessed a higher level of efficiency in developed countries in terms of managing carbon emissions in connection to trading activities in recent years by focusing more on environmental-friendly technologies. The study also emphasizes the necessity to assess financial system improvements, which are not already protecting the environment. Additionally, to achieve sustainable practices and significantly lower carbon emissions, authorities must employ financial resources as one of their policy instruments. Moreover, governments in developing nations should invest in the generation of renewable energy sources since they are cost-effective to operate and offer access to inexpensive electricity. The creation of inexpensive power that is accessible to the underprivileged needs to be the government's top priority. Regulators in developed and developing nations should encourage investment in ecologically safe and economically viable sectors, even when the financial system indirectly increases carbon emissions intensity by fostering comprehensive expansion in these countries. However, required financial system changes might lead to an efficient way to protect the environment.

One of the biggest challenges of developing regions is to carry on economic growth without damaging the environment. However, it is vital to control the amounts of carbon emissions in emerging nations that prioritize economic expansion over environmental protection. The adoption of environmentally friendly technology should be mandated by the government and policymakers, and existing financial system laws should be changed to support environment-friendly loans. They must come up with comprehensive knowledge regarding how nations can safeguard environmental quality while also achieving higher economic growth. At this time, the promotion of renewable technologies with a concerned attitude is desired to make economic progress compatible with environmental protection. The current global warming challenge is mainly caused by the emissions of harmful gases which require countries to take coordinated policy measures. To protect the environment, strong regulations that cause as little environmental harm as possible must be put in place. Policymakers need to ensure strict compliance with directions for environmental protection.

5.2 Limitations and Future Direction

The present study has considered a few variables which impact the environment either negatively or positively. Thus, future studies can include the other important variables which may impact the environment quality. Moreover, the present study has ignored the level of environmental damage caused by different energy sources. Future studies can be conducted by measuring the level of environmental damage caused by various sources of energy along with their cost-effectiveness.

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