Bulletin of Business and Economics, 13(2), 966-973
https://bbejournal.com
https://doi.org/10.61506/01.00415

Analysis the Impact of Technology Innovation, Foreign Direct Investment, Trade Openness and Globalization on CO2 Emissions? Evidence from Developing Nations

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Abstract
The present study explores the effects of Technology Innovation, Foreign Direct Investment, Trade openness and globalization on environmental degradation (CO2 emissions) from 1999-2023 in developing (Afghanistan, Nepal, Pakistan Bangladesh, Bhutan, and India) Countries. The study employs the Autoregressive distributed lag (ARDL) method is applied to reveal the existence of long run and short run relationship between CO_2 emissions and its other determinants. A Granger causality test was also used in this investigation to ascertain the direction of causation between the variables. The results found that in Technology innovation and globalization are significantly increase the environmental degradation. The results of the analysis show that Trade openness and Foreign direct investment have a significant but negative effect on environment degradation. It is recommended that the developing nations give preference to sustainable trading procedures by including environmental factors into trade agreements and laws. This can involve promoting environmentally friendly labeling, assisting sustainable supply chains, and reducing trade obstacles for commodities that are good for the environment. Consistent with these empirical findings, this article suggests some vital policy implications in Developing countries to accomplish their sustainable development goals (SDGs).

Keywords: Technology Innovation, carbon emissions (CO2), Autoregressive distributed lag (ARDL), EKC, Trade-openness, Granger Causality, Developing Nations

1. Introduction

Over the past few decades, human activity has significantly increased global greenhouse gas emissions, causing unprecedented environmental deterioration. In 1990, 22,670,893 kilotons' of CO_2 emission into the air and this rose to 36,240,721,721 kilotons' in 2015.The surge in CO_2 Emissions has interest among researchers and experts. Environment degradation is one of the largest issue facing the world today. It has certain harmful effects on people, ecosystems, the ozone layer, and the general economic environment. The globally dramatic rise in CO_2 emissions is thus a significant global challenge. The protection of the environment has been a major global problem for the past 20 years (Song et al., 2024). In this study CO_2 emissions are used as proxy of environmental degradation. Environmental degradation is now seriously threatened by the rising temperature. Global carbon dioxide (CO_2) emissions are significantly increased as a result of this intensification. Although continental drift is a natural occurrence global warming is currently a more pressing concern than it once was but 4.5 billion years the drift caused significant geographical alterations on earth. The supremacy of local water resources has been severely impacted by melting glaciers, shifting rainfall brought on by global warming, and many other parts of the world. There won't be any progress or development without consideration for the effects of the climate. There are significant environmental problems brought on by this rapid economic growth, such as carbon emissions (Sadia Bint Raza et al., 2024).

Many macroeconomic issues arise in developing nations as a result of capital scarcity. Countries require foreign loans or foreign direct investment (FDI) to address these issues. To draw FDI, developing nations should prioritize economic growth and strengthen their environmental legislation. It might be said, arising nations might become contamination sanctuaries, and in his case, FDI might be a component that triggers ecological degradation (Amin et al., 2024). In a similar way a country's greater trade openness may raise its CO_2 emissions due to rising industrial production, consumption, and energy use. Using panel data analysis, examined the impact of FDI on environmental degradation indices for 20 countries between 1982 and 2013, including carbon emissions, carbon footprints, and ecological footprints. According to the authors, foreign direct investment has little impact on environmental deterioration. Emerging economies can boost their local production by utilizing foreign direct investment (FDI) (Zubair et al., 2024). The investment rate is also increased by having access to new technology and financing. Various investigations give various aftereffects of FDI influence on the climate as its effect on the climate fluctuates in various states and districts. In the study by (Parveen et al., 2024) foreign direct investment (FDI) is the main cause of environmental degradation in France. The environmental Kuznets curve (EKC), the halo hypothesis, and the pollution havens hypothesis are the three main theories that are considered in the study of the relationship between foreign direct investment (FDI) and sustainable development. The FDI halo theory has a beneficial environmental impact because it transfers advanced technologies from industrialized to poor nations (Rabbia Syed, Sehrish Arshad, Saif Ur Rahman, 2024).

The concept of globalization is widely recognized in relation to facilitating trade in products and services, assisting individuals, economies, and FRMs in growing their outsourcing sector, and reducing global migration. Because of growing globalization and rapid industrialization, the world's production is continuously increasing. Since globalization involves the connection of a nation's economy with the global economy through trade and capital mobility, it has numerous negative effects on the environment as well as additional administrative and social factors. On the other hand, through spreading environmentally beneficial technologies, globalization can improve the quality of the environment(Shen et al., 2024). The KOF Globalization Index was used to provide the definitions and dimensions of globalization in this study…. Many research has discovered a favorable association between environmental degradation and proxies of globalization, supporting the pollution haven concept (Huang et al., 2024).

The primary driver of economic advancement has historically been considered to be innovations. As the economy grows, also rises the demand for energy which raise greenhouse gas emissions. The switch to low-carbon energy is driven by innovation, which also speeds up economic growth and manufacturing. have discovered that the technological spillover effect causes technical innovation to reduce environmental degradation in the host nation.

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In the findings of (Arshad et al., 2024) technological innovation substantially decreases energy consumption and carbon emissions. Bai et al. (2018) studied 39 industrial sites' environmental condition in China between 2005 and 2011. They contend that utilizing highly effective technology during the production process improves the quality of the environment. In accordance to several other studies, technological advancement could have a negative impact on the environment. Additionally, new developments in technology can reduce energy consumption, which will lessen the impact on the environment (Saeed et al., 2024).

On the contrary, use the generalized method of moments (GMM) and ARDL to investigate the effect of trade openness on CO2 emissions, and they discover that trade raises CO2 levels in the Chinese economy. For more effective outcomes. the research has enhanced the energy-income-emissions nexus with a number of macroeconomic variables, including trade openness, population density, and urbanization. (Maqsood1 et al., 2023) discovered that while trade openness reduces carbon emissions, growing urbanization in the USA results in increased gas emissions. Conversely, the gain from trade theory highlights how trade improves environmental quality (Minhas et al., 2024). Furthermore, there will be positive and negative environmental consequence of international commercial openness. On November 13, 2021, the United Nations Framework Convention on Climate Change and the 26th Conference of the Parties (COP26) adopted the Glass-Grow climate convention, which requires countries to uphold the Paris Agreement and maintain that three main factors—scale, technique, and composition—contribute to global temperatures rising to 1.5°C the effects. Because trade involves calculations involving exchange rates and price, trade-led development results in an obvious rise in revenue. Countries all throughout the world have set goals to become emissions-free as a result. That's why scientists are now focusing on how trade affects the reduction of carbon emissions (Abro et al., 2024). The validity of the environmental Kuznets curve (EKC) theory is also inspected. To check the authentication of inverted U shape of EKC, this study collected the data from 1990 to 2023 of selected developing countries (T. A. Shahid et al., 2024).

First, applying the most recent econometric techniques, the current study investigates the effect of FDI, TINNO, TOP and GLOB on CO_2 emissions. Second, this research uses the most recent econometric methodology, namely panel ARDL methods, in contrast to earlier studies that used antiquated techniques. This method yields more precise results that make it easier to develop both short- and long-term initiatives that encourage environmental sustainability. Considering both symmetry and asymmetry, the panel ARDL approaches appear appropriate for researching the effect of FDI, TINNO, TOP and GLOB on CO_2 emissions in Developing Nations. Thirdly, using the most recent data, this study investigates how these variables affect CO_2 emissions (Irfan et al., 2023). Finally, the findings have significant policy ramifications for these Developing countries dealing with severe pollution and environmental difficulties. The current investigation hopes to help policymakers tackle the increasing vulnerability that is caused by variations in the climate. This paper is further broken into four section: the “Literature Review” section summarizes earlier studies on the subject and assesses the literature review that is relevant to this study. The “Data and Methodology” section contains an introduction to the data and methodology. The results are shown in the “Results” section, while the discussion and “Policy Implications” part. This paper’s “Conclusion” section offers a summary of the findings and information for the research.

2. Literature Review

2.1. Nexus between FDI carbon dioxide emissions

Many academic works have also examined how foreign direct investment (FDI) contributes to environmental contamination because it is a primary means of knowledge transfer, which in turn impacts the contexts of the recipient nations. In their study (Rehman, 2023) examined the relationship between foreign direct investment (FDI), environmental pollution, and human capital in China from 1996 to 2016. They discovered that FDI raises environmental pollution in the regions with lower levels of human capital. Investigated how environmental pollution was affected in emerging Asian nations between 1990 and 2003 by the use of fossil fuels and foreign direct investment and revealed that foreign direct investment (FDI) is the main source of contamination of the environment in these nations (Nazik Maqsood, 2024) analyzed a worldwide panel of 54 nations between 1990 and 2011 and identified bidirectional causality among FDI inflows and carbon dioxide emissions. According to certain research, foreign direct investment (FDI) has no significant effect on environmental contamination (T. A. Shahid, 2024) found in a similar study conducted in the BRICS between 2000 and 2013 that FDI inflows and the use of renewable energy are ultimately contribute to a reduction in environmental pollution (T. A. Shahid et al., 2023; Naz et al., 2022).

2.2. Nexus between Globalization and carbon dioxide emissions

The effects of globalization on the quality of the environment are diverse. The following can be used to group these: The first is the income effect. As globalization increases, it leads to increased production and commerce, which in turn enhances CO2, indicating a decline in environmental sustainability (Ullah et al., 2023). The empirical findings on globalization and carbon dioxide emissions are also quite diverse (Qureshi et al., 2022) illustrate the positive correlation between carbon dioxide emissions and globalization (Zulfiqar et al., 2022) examined social and monetary globalization and denoted that the two kinds of globalization are proper for ecological supportability. According to (Javaid et al., 2023) research, globalization has worsened CO2 emissions and damaged environmental sustainability. According to (Awan et al., 2023) the EKC hypothesis is confirmed by the findings, despite the fact that globalization has not been able to cut carbon gas discharges or increase environmental sustainability in Turkey (Ur Rahman & Bakar, 2019) conduct an assessment of the worldwide environmental quality following globalization, indicating unsatisfactory findings (Chaudhary et al., 2023) analyzed the relationship between globalization and CO2 emissions for 105 nations and determined that globalization worsens environmental quality.

2.3. Nexus between Technology Innovation and carbon dioxide emissions

Many conversations are held in an attempt to determine the extent of technological change. This helped to reduce environmental contamination. Significant theories that address the environment and energy use in the context of climate change investigate how much and what kind of technological development there has been. Rising research and development (R&D) and advances in technology lead to decreased CO2 emissions (A. U. Shahid et al., 2022). There is also a claim that since CO2 emissions have decreased, environmental problems should be easier to handle. Advance technologies may be created in different ways and places within the biofuels industry depending on technological capabilities and environmental regulations. The term technological innovation (TI) refers to the development of new technologies as well as the creative use of already existing technology. This include coming up with fresh ideas, creating and putting into practice new patents, and altering the way how things are produced now (Zahra et al., 2023) A significant quantity of research has explored the relationship between CO2

emissions and trade openness since the early 1990s, when trade openness started to rapidly develop and environmental concerns began to escalate. Policymakers and scholars are starting to realize the importance of TI in minimizing CO2 emissions as a result of its expanding advancement. Research and development (R&D) activities, efficiency, and patent development are among the regularly utilized indicators employed in these studies to quantify the levels of TI (Bakar, 2019; (Saif Ur Rahman, Salyha Zulfiqar Ali Shah).

2.4. Nexus between Trade Openness and carbon dioxide emissions

For a long time, numerous researchers have been attracted to the contentious link between trade and the environment. As reported by (Shahzadi, Sheikh, et al., 2023) trade openness and energy consumption are two of the primary factors influencing carbon emissions, which lead to increased pollution in the top ten emerging nations. According to an empirical stud, trade openness improved environmental quality for the members of the Association of Southeast Asian members (ASEAN) between 1995 and 2018. The same conclusions were reached by(Zhao et al., 2023) who observed that commerce in Latin America had a net beneficial environmental impact from 1970 to 2019. Alike to this (Tabassum et al., 2023) explored the relationship in ten nations and discovered a negative relationship between trade openness and carbon emissions ….. have provided recent data indicating a significant adverse effect of trade on environmental sustainability. However, (Li et al., 2022) found that although trade openness raises emissions overall, it has a dual effect by indirectly lowering emissions in CIS nations. Another researcher (Rahman et al., 2022) claims that, trade has both positive and negative effects on emissions in Belt and Road countries, depending on the different country samples evaluated. Hence, perspectives regarding how trade openness affects carbon emissions are inconclusive (Hafiza et al., 2022; Shahzadi, Ali, et al., 2023).

3. Methodology

This study analyzes the effect of Foreign direct investment, Technology innovation, globalization and trade openness on carbon emissions in the case of developing Countries like (Afghanistan, Nepal, Pakistan Bangladesh, Bhutan, and India) for 1999-2023. The data of these countries have been collected from the KOF and World Development Indicators (WDI) database provided by the World Bank 2023. The Co_2 Emission is measured in (kt), Foreign direct investment, net inflows (% of GDP), Globalization (KOFI index)), Technology Innovation Patent application (nonresidents, residents) and Trade-openness in (Imports of goods and services (% of GDP), Exports of goods and services (% of GDP) and all variables are descripted in logarithm form. The descriptions, measurement and data source of the variables used in this study are presented in Table 1.

Table 1: Description of variables and data sources

Variables	Description	Measurement unit	Data sources
CO_2	Carbon dioxide emissions	(k t)	WDI (2024)
FDI	Foreign Direct Investment	Net inflows (% of GDP)	WDI(2024)
GLOB	Globalization	KOFGI Index	KOFGI
TINNO	Technology Innovation	Patent application (nonresidents, residents)	WDI (2024)
TOP	Trade-openness	(Imports of goods and services (% of GDP), Exports of goods and services (% of GDP)	WDI (2024)

3.1. Econometric Model

The model specification is:

$$CO2 = f(\text{ FDI, GLOB, TINNO, TOP})$$

After adding the parameters, the equation form is

$$CO2 = \alpha_0 + \beta_1 FDI + \beta_2 GLOB + \beta_3 TINNO + \beta_4 TOP + \varepsilon_1$$

The Log-linear equation for the study is

$$lnCO2_{it} = \alpha_0 + \beta_1(lnFDI_{it}) + \beta_2 (lnGLOB_{it}) + \beta_3 (lnTINNO_{it}) + \beta_4 (lnTOP_{it}) + \varepsilon_{it}$$

4. Results and discussion

Table 2: Descriptive Statistics

	LOG-CO2	LOG-TOP	LOG-TINNO	LOG-GLOB	LOG-FDI
Mean	4.372245	1.628151	2.152879	1.631513	2.441131
Median	4.241712	1.624290	2.227881	1.652857	1.152871
Maximum	6.390613	2.034058	4.840374	1.796938	1.174467
Minimum	2.436251	1.230117	0.000000	1.372111	0.262819
Std. Dev.	1.146263	0.185728	1.396875	0.109680	3.245018
Skewness	0.167315	0.368109	0.379264	-0.586260	2.469347
kurtosis	1.966145	2.654272	2.057485	2.702636	8.675707
Jarque-Bera	7.380209	4.134651	9.148114	9.145179	353.7771
probability	0.024969	0.126524	0.010316	0.010331	0.000000

Table 2 reports descriptive statistics for the studied variables. The mean of CO2 emissions is 4.372245, with 6.390613 and 2.436251 being the lowest and highest values. The standard deviation of CO2 emissions is 1.146263and the average value of TOP, TINNO, GLOB and FDI is 1.628151, 2.152879, 1.631513 and 2.441131.

4.1. Panel Unit Root Test

The outcome of the unit root test is labeled in Table 3, which revealed a mixture of I (0) And I (1) results, while maximum series become stationary after taking first difference.

Table 3: Unit Root Test

Variables	Level		1st Difference		Level of integration
	T-Statistics	P-Value	T-Statistics	P-Value	
CO2	-2.28973	0.0110	1.93708	0.97360	I(0)
TOP	-1.91530	0.0277	-4.76814	0.0000	I(0)
TINNO	-0.84012	0.2004	-2.20423	0.0138	I(1)
GLOB	-5.23233	0.0000	-2.17080	0.0150	I(0)
TOP	0.74753	0.2274	-4.08289	0.0000	I(1)

First, some conventional tests are performed to check the data stationarity at level and at first difference: augmented Dickey-Fuller (ADF) test….. All variables must be stationary at level I (0) or at first difference I (1) in order to apply ARDL bounds test. Therefore, ARDL technique is the most appropriate model, because it is not biased, and it is superior to other small sample size models. The null hypothesis of ADF unit root tests assumes the presence of the unit root, while the alternative hypothesis is the absence of the unit root and that the time series is stationary. It follows from Table 3 that CO2, TOP, GLOB are Stationary at level I (0), while TINNO and FDI are stationary at first difference I (1).

The equation of an ARDL formula as the model with intercept can be written as:

$$\Delta CO_{2_{it}} = \alpha_0 + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{2_{j,t-i}} + \sum_{i=1}^{m} \beta_{ik} \Delta FDI_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta GLOB_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta TINNO_{j,t-i} + \sum_{i=1}^{m} \beta_{ik}\, \Delta TOP_{j,t-i} + \varphi_1 CO_{2_{t-1}} + \varphi_2 FDI_{t-1} + \varphi_3 GLOB_{t-1} + \varphi_4 TINNO_{t-1} + \varphi_5 TOP_{t-1} + e_{it}$$

I=1,….,N for each country and t=1,…..,T for each period, βik and it are country and time fixed effects respectively. eit show the estimated residuals.

4.2. Long-run results of Panel ARDL

However, ARDL has been more used recently, due to some useful advantages that are embedded in it. One of the main merits of this technique is that it can be used irrespective of whether series are I(0) or I(1) or fractionally co-integrated(Dawood et al., 2023) Another advantage is that both short-term and long-term estimates can be made simultaneously.

Table 4; Results of Long – run Panel ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
		Long Run Equation		
LOG_TOP	-1.950660	0.051102	-38.17176	0.0000
LOG_TINNO	0.181188	0.028518	6.353544	0.0000
LOG_GLOB	7.030404	0.225940	31.11623	0.0000
LOG_FDI	-0.009791	0.002187	-4.477716	0.0001
Mean dependent var	0.012681		S.D. dependent var	0.079132
S.E. of regression	0.051988		Akaike info criterion	-4.293432
Sum squared resid	0.118921		Schwarz criterion	-2.165916
Log likelihood	428.0074		Hannan-Quinn criter.	-3.429090

Note: ***, ** and * specify the significant at 1%, 5% and 10% level, respectively

According to (Khawaja Hisham Ul Hassan, 2021), as ARDL model has no residual correlation, less concern remains for en-dogeneity problem, since suitable lag inclusion causes elimination of serial correlation as well as en-dogeneity. The long-run coefficients of ARDL method depict the positive effectiveness of FDI, TINNO, GLOB and TOP for environmental upgrading of Developing countries. The short-run and long-run estimates of impact of economic opening-up on environmental upgrading are similar and statistically significant at the level of 5% and 5% significance, respectively. Other things remaining constant, a

1% rise in the TOU causes to enhance Carbon emissions in these countries by -1.950 % and it has a negative and significant relation between them. On the other hand, TINNO, GLOB also has a positive and significant impact on CO_2 Emissions and TOU has a negative and significant relation with CO_2 emissions. The estimates for TINNO Reveal that, in both long and short run, TINNO affect environmental upgrading positively. Ceteris Paribus, 5% increment in TINNO enhances the CO_2 Emissions by 0.18% and -0.0003910 % in the long and short-run, respectively. These findings are statistically significant at 5% level of significance. These results indicate that the GLOB also affect environmental upgrading positively, in both short and long run. Ceteris Paribus, a 1% enhancement of TOP is associated with -0.009791% and 0.431144 % increase in CO2 Emissions in the long- Run respectively. The long-run results are statistically significant at 5% level of significance, whereas the short-run results are not significant. The impact of FDI on environmental upgrading was negative and significant impact in the long run.
According to (Rahman & Bakar, 2019) and (Ur Rahman & Bakar, 2018) the value of ECT (-) is a significant outcome of short run dynamic and demonstrates the pace of adjustment from the short to the long run.

4.3. Short-run results

Additionally, the short-run ARDL estimates are included in Table 5. FDI, GDP, TOP and TOU all have substantial positive and negative relationships with CO_2 emissions, but all coefficients are significant.

Table 5

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
ECT	-0.195576	0.066813	-2.927198	0.0041
D(LOG TOP_)	0.431144	0.397618	-1.084317	0.2834
D(LOG TINNO)	-0.0003910	0.062601	-0.062465	0.9504
D(LOG GLOB)	-0.987895	1.684411	-0.586493	0.5602
D(LOG FDI)	0.034230	0.05568	0.962376	0.3405
C	-0.296342	0.094903	-3.122575	0.0023

A Positive TOP coefficient (0.034230) indicates that, at a 5% significance level, a 1% rise (fall) in education will result in a 0.3405 % reduction (rise) in CO_2 emissions. On the other hand, FDI, GLOB and TOP has positive and negative coefficients (0.431, -0.0003 and -0.987) and an insignificant relation toward CO_2 emissions.
In this study, error correction representations with the following specifications are used to analyze the event of long- and short-run dynamics:

$$\Delta \mathrm{CO}_{2\mathrm{it}} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{2_{j,t-i}} + \sum_{i=0}^{m} \beta_{ik} \Delta\, FDI_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta\, GLOB_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta TINNO_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta TOP_{j,t-i} + e_{it}$$

If there is a co-integration, next step of ARDL process holds the long-run ARDL equation as follows:

$$\Delta CO_{2_{it}} = \beta_0 + \sum_{i=0}^{p} \beta_{ik}\, CO_{2t-i} + \sum_{i=1}^{q} \beta_{ik}\, FDI_{t-i} + \sum_{i=1}^{r} \beta_{ik}\, GLOB_{t-i} + \sum_{i=0}^{s} \beta_{ik}\, TINNO_{t-i} + \sum_{i=0}^{t} \beta_{ik}\, TOP_{t-i} + e_t$$

To select the lag values p, q, r and s in Eq. (4), model selection criteria such as AIC, SIC, Hannan–Quinn information criteria, Adjusted R-squared are used. The best estimated model is the model which has the minimum information criteria or the maximum R-squared value. Finally, short-run estimation of ARDL model also known as error-correction model is estimated in the equation below

$$CO_{it} = \delta_0 + \sum_{i=0}^{p} \delta_{ik} \Delta\, CO_{2t-i} + \sum_{i=1}^{q} \delta_{ik} \Delta\, FDI_{t-i} + \sum_{i=0}^{r} \delta_{ik}\, \Delta GLOB_{t-i} + \sum_{i=0}^{s} \delta_{ik}\, \Delta TINNO_{t-i} + \sum_{i=0}^{t} \delta_{ik}\, \Delta TOP_{t-i} + e_{it}$$

If there occurs a shock in short-run, the estimation of ECM (α) aids in determining the rate of adjustment toward the equilibrium conditions throughout the Long-Run.

4.4. Granger causality

In order to determine the trend of the association amid two variables which is required for the ARDL method, we further looked into Granger causality amid environmental upgrading and its determinants we chose for research (FDI, GLOB, TINNO, and TOP). We assessed granger causality using the Granger method (1969) in order to examine the direction of causation (Ghazia Khoula, 2022).

In table 4 results shows that CO_2 , Glob and TINNO have unidirectional causality, while on the other hand FDI and CO_2 have no causality among them.

5. Conclusion, limitations, and future research

The objective of this study is to analyze the asymmetrical correlation between technological innovation (TI), Globalization (GLOB), Foreign Direct Investment (FDI) and Trade-openness (TOP) on CO_2 emissions in Developing nations applying ARDL method. This analysis is based on panel data spanning from 1999 to 2023, encompassing the most recent data available.
In these developing nations TOP and FDI is negatively or significantly correlated with CO_2 emission and large impact on it. On the other hand, TIINO and GLOB positively and significantly correlated CO_2 emissions. According to the empirical results, Technology Innovation has a positive relationship with CO_2 Emissions. The results of the panel ARDL method revealed that TINNO and Glob is reducing the environmental quality of the DN region, as we observed a significant positive effect of

technology innovation on CO_2 emissions in the long-run and that could be helpful to mitigate CO_2 emission. Second, consider there is negative effects of Trade openness in developing economies which results decreasing environmental degradation.

This suggests that the host government should impose capability and establish the legal framework in order to control FDI inflow. With more trustworthy organizations, the local government effectively manages and directs the negative impacts of foreign direct investment inflows. Green and environmentally friendly technology may also significantly mitigate the detrimental effects of foreign direct investment on the environment. Environmentally friendly technology is able to contribute to environmental protection by reducing toxic waste while utilizing fewer resources.

These developing economies have been greatly impacted by globalization. By opening their markets, drawing foreign direct investment, and participating in international trade, these nations have embraced globalization. They understand that engaged in international investment and trade can have a number of advantages, including enhanced competitiveness, access to new markets, and technology transfer. Improving and optimizing environmental laws, norms, and regulations is essential to reducing carbon dioxide emissions, especially when it comes to international trade.

This study has some limitations. However, it can be expanded upon by considering every developing nation, we have only looked at a small number of them because data was not readily available. Thus, additional research that analyzes developed and many other emerging nations will increase our awareness of the ways how trade and advances in technology cooperate in preventing environmental degradation.

Furthermore, in our study, we have utilized carbon dioxide emissions as a proxy for environmental pollution; yet various environmental indicators, like nitrogen and sulfur emissions or ecological footprint, could also be added for more analysis. Further empirical research may also split the effects of technological advancements on environmental quality into components such as R&D spending, energy innovation, and the number of patent applications. Additionally, advanced techniques can be used for the empirical analysis in accordance with the development of new empirical methodologies.

Table 5

Null Hypothesis:	Obs	F-Statistic	Prob.
LOG_TOP does not Granger Cause LOGCO2	138	1.46038	0.2358
LOGCO2 does not Granger Cause LOG_TOP		2.77783	0.0658
LOG_TINNO does not Granger Cause LOGCO2	138	3.83746	0.0240
LOGCO2 does not Granger Cause LOG_TINNO		2.20394	0.1144
LOG_GLOB does not Granger Cause LOGCO2	138	2.36856	0.0976
LOGCO2 does not Granger Cause LOG_GLOB		4.42422	0.0138
LOG_FDI does not Granger Cause LOGCO2	138	0.21634	0.8057
LOGCO2 does not Granger Cause LOG_FDI		0.35530	0.7016
LOG_TINNO does not Granger Cause LOG_TOP	138	2.87171	0.0601
LOG_TOP does not Granger Cause LOG_TINNO		0.06912	0.9332
LOG_GLOB does not Granger Cause LOG_TOP	138	3.70503	0.0272
LOG_TOP does not Granger Cause LOG_GLOB		1.32979	0.2680
LOG_FDI does not Granger Cause LOG_TOP	138	1.18021	0.3104
LOG_TOP does not Granger Cause LOG_FDI		1.12307	0.3283
LOG_GLOB does not Granger Cause LOG_TINNO	138	1.48514	0.2302
LOG_TINNO does not Granger Cause LOG_GLOB		8.38862	0.0004
LOG_FDI does not Granger Cause LOG_TINNO	138	0.10598	0.8995
LOG_TINNO does not Granger Cause LOG_FDI		0.20415	0.8156
LOG_FDI does not Granger Cause LOG_GLOB	138	0.19479	0.8232
LOG_GLOB does not Granger Cause LOG_FDI		0.25407	0.7760

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