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# ASSESSING THE ROLE OF TECHNOLOGICAL INNOVATION IN THE RELATIONSHIP BETWEEN FDI AND ENVIRONMENTAL DEGRADATION

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## ABSTRACT

*The present study explores the interactive role technological innovations with foreign direct investment in influencing environmental degradation, using panel dataset of Next eleven countries, ranging from 1990 to 2023. A series of econometric techniques are used to investigate the dynamics between FDI and environmental degradation. The study, in the outset tested the cross-sectional dependence among the countries to capture the potential interdependencies in their growth and investment trends, followed by slope heterogeneity test and then panel unit root test, all are conducted to ensure the reliability of the analyses. The Augmented Mean Group (AMG) technique is then applied to explore the possible interactive role of TI with FDI in influencing environment degradation. Moreover, to verify the robustness of our panel AMG estimation results, the CCEMG technique is used. Our results suggest that technological innovation play significant interactive role with FDI in alleviating the adverse outcomes of FDI on the environment. In particular, this factor helps reduce territory-based carbon emissions linked with FDI inflows, indicating a potential pathway for fostering sustainable development. This study contributes to the existing literature by highlighting the importance of integrating complementarity factors in policymaking, encouraging developing nations to capitalize this synergy to balance economic growth with environmental preservation. Policymakers can leverage this insight to design targeted strategies that effectively reduce environmental degradation.*

***Key words:*** *Foreign Direct Investment FDI; Technological Innovation TI; Environmental Degradation ED*

## INTRODUCTION

Over the last three decades, one of the most critical challenges facing the world that has threatened human life, is environmental degradation. The global temperature is continuously rising, resulting polar ice melting, floods, forest fires, storms, droughts, water scarcity etc. all because of human actions. Greenhouse gas emissions (GHG) is one of the main causes of environmental degradation and global warming, resulted from human activities. These gases include CO2, CH4, N2O and other fluorinated gases, of which 75% constitutes only carbon dioxide related emissions and degradations, that all according to UN report 2024, have caused the earth temperature to rise by 1.2 degree Celsius since the mid of 18$^{th}$ century. This is slightly lower than the beginning of irreversible climate change temperature of 1.5 degree Celsius (Nations 2024). Two-third of the global emissions are due to the use of Non-renewable energy consumptions only, whereas, since 1750 half of the emissions due to human actions have resulted only in the last 40 years (OECD 2016). About 6% increase in CO2 emissions related to energy sector took place only in year 2021 and by the year 2100 this trend is expected to rise sea level by 30 to 60cm.(Nations 2022). The world time is running out, threatened by SDG report 2023 and urged that countries need to take serious actions regarding this challenge.(Nations 2023). The statistics 2024 shows that, since 1990, more than 60% increase in CO2 emissions has occurred to our atmosphere.(Statista 2024).

Environmental degradation has extensive and devastating consequences that impact natural resources, human health, biodiversity, air quality, economy etc. necessitating urgent attention and actions. The 2019 Global Burden of Disease study revealed that air pollution in its all forms contributed for about 11.3% of all female deaths and 12.2% of all male deaths worldwide, highlighting its serious impacts on global mortality rates, emphasizing the need for urgent action to address this critical public health concern. Air pollution-related deaths globally recorded were 8.1 million in 2021. According to the State of Global Air Repot-2024, around 15% of all the global deaths are linked with air pollution, that includes 4.2 million deaths resulted from outdoor toxicity and 3.8 million due to indoor toxicity. More than the world 99% population breath air which exceeds organization's guidelines for air quality (Sannoh, Fatmi et al. 2024). According to the UNICEF report 2024, the death rate among children under the age of five in Southern Africa due to air pollution is an alarming 100 times higher than in high-income nations. The main cause of this alarming phenomenon are industrial activities, vehicle emissions, biomass combustion, and dust storms, all of which deteriorate air quality and pose significant health problems. Yalew (2020) reveals that the earth's climate is exceeding the natural fluctuations that have historically supported economies and societies. Critical climate indicators-including global temperature, sea level, acidification, and extreme weather events, all are surpassing the established norms. If these trends continue to intensify, the likelihood of rapid and irreversible climate change will increase, putting us at the risk of sudden and devastating climatic transformations that could have permanent and far-reaching consequences, placing our societies, economies, and ecosystems at grave risk. A report of GALA, the Global Assessment of Land Degradation and improvement, recently reveals that 25% of the world's land area suffers from degradation. This environmental decline has far reached consequences, affecting about 1.5 billion lives and degrading approximately 15 billion tons of fertile soil every year. Human activities and the continuous changing pattern of climate are the primary causes of this degradation, highlighting the need for urgent action to mitigate its effects (Arora 2019).

Technological innovation (TI) has achieved widespread acceptance as a potential driver for sustainable development. Technological innovation describes the development of new technologies including the skillful usage of already existing technology, that comprises, coming up with fresh ideas, creating and putting into practice new patents, and modifying the way things are currently produced.(Zahra, Nasir et al. 2023). TI is accepted as one of the basic factors for sustainable development and a key remedy for environmental challenges (Lin and Zhu 2019) that can mitigate carbon emissions through different ways, directly, such as through carbon fixation during photosynthesis usage in biomass system, accumulators employed in power generation and carbon capture and storage technology used in the fossil fuel system(Foo and Tan 2016) (Kwon, Cho et al. 2017). It can also influence the impacts of other factors through various ways like the efficient and clean usage of fossil fuels , improving the energy efficiency, the development of new renewable energy and Sustainable transportation systems such as electric cars etc.(Cheng, Ren et al. 2019) (Hao, Cheng et al. 2017). The increasing recognition and benefits of the impact of TI toward energy consumption and CO2 reduction has motivated policymakers and governments to increase investment in Eco-friendly awareness initiatives and Sustainability, particularly in terms of sustainable energy usage and energy transition (Paramati, Apergis et al. 2017).

Technological innovation and green investment are some of the most efficient weapons for reducing environmental pollution, conserving power resources, contributing in economic growth and generating minimal carbon emissions. TI not only boosts the business output capacity, but also contributes to reduce environmental pollution. (Suki, Suki et al. 2022). Eco- innovations and technology is highly effective for countries to combat the global challenges of climate change, and reducing environmental degradation. (Li, Sampene et al. 2022). Whereas, conventional approach to industrialization, trading, and energy utilization is destructive for the health of our earth, causing environmental constraints for range of countries. (Jiang and Khan 2023) To effectively deal with this problem, we should adopt renewable energy resources and innovative technologies. Zhuang, Yang et al. (2022) too validated the findings from the Chinese viewpoint and disclosed that TI brings environmental sustainability. Porter's hypothesis advocates that environmental regulations facilitates the adoption of innovations and use of eco-friendly technologies, enabling companies to achieve a strategic advantage through cost savings, competitiveness, and market exploration (Gao, Wang et al. 2022). Major theories that shed light on the environment and energy efficiency in the perspective of climate change analyzed the extent, nature and importance of technological innovations. Promoting research and development (R&D) and breakthroughs in technology, contributes to minimized carbon emissions (Shahid, Ghaffar et al. 2022). That is why, among other strategies, TI has been recognized as the most powerful benchmark for mitigating environmental degradation, reducing power waste, and enhancing environmental quality (Usman and Makhdum 2021), (Ramzan, Raza et al. 2022). Though few contrary findings also reveal the adverse outcomes of technological innovation on the environment, as by promoting economic growth, TI increases the demand for energy, resulting a rise in carbon emissions and environmental degradations in the long term. (Freire-González 2011) . Research and development play a key role in introducing new products and production techniques but expenditures on R&D leads to increase carbon emissions (Shaari, Abdullah et al. 2016). Moreover, with technological progress the lifestyles of the people change, contributing a notable expansion in the usage of electronic products, resulting a marked increase in consumption of electrical energy and environmental degradation. (Wang, Zeng et al. 2019) (Huang, Chen et al. 2020) (Zhang and Chen 2021) differing from the findings of (Zhang and Chen 2021) and (Santra 2017) who explored that TI significantly improve carbon efficiency and reduce emissions. Advancements in technology and research breakthroughs have led countries to concentrate on power efficiency in both generation and consumption. These countries are also moving towards renewable energy consumption, and reducing harmful emissions. Multiple forums are established to determine the extent of technological change.

FDI over the past few decades has experienced significant increase worldwide, rekindling a longstanding debate among the scholars and policymakers regarding its benefits and costs. FDI has the potential to inject capital, foster technological advancements and boost economic growth (EG). The use of new skills and management practices, ultimately lead to increase productivity and competitiveness (Lee 2013). Literature on economic growth also unlocks the potential contribution of FDI in climate-resilient development of developing economies.(Tran, Phan et al. 2022) (Wang, Gao et al. 2022) But economic growth fueled by FDI has significant impact on the environment through energy-intensive activities like manufacturing, transportation and agriculture, resulting increased carbon emissions. Thus, if FDI is considered as a catalyst of economic growth in one study (Blonigen and Piger 2014), it has also been explored as the cause of environmental degradation, deteriorating air and water quality, having harmful impact on the ecosystem and human health. (Lawson and Nguyen-Van 2020). So there exist conflicting views among the scholars about the environmental impacts of FDI. Those who favor Pollution Haven Hypothesis (PHH), advocates the adverse outcomes of FDI on the environment, by revealing that foreign companies relocate their production practices in countries having lax environmental regulations, to cut expenses, as environment regulation costs at home outstrip non-compliance costs abroad.(Solarin, Al-Mulali et al. 2017) (Sarkodie and Strezov 2019, Ur Rahman, Chongbo et al. 2019). This triggers competitive environment among developing countries in providing the softest rules to attract more investment, resulting the stimulation of polluting FDIs inflow from developed countries, having strict environmental regulations to the developing worlds. The theory describes why some countries are more polluted than others, as companies search to escape severe laws and cut costs. (Abdo, Li et al. 2020). In contrast, the Pollution Halo Effect (PHE) reveals that FDI help reduce emissions in the host countries, as foreign investors share their eco-friendly innovations and sustainable practices with these countries, resulting decreased emissions and cleaner environment.(Sarkodie, Adams et al. 2020). Interestingly, FDIs appear to be a three headed monster that supports economic growth and development, decreases environmental degradations in some cases while increasing degradations, and contributes to ecological disruption in other. The environmental outcomes of FDI also differs by industry and country, and the effect of pollution haven and halo can occur at the same time too, highlighting the complexity of the issue.(Duan and Jiang 2021). U-shaped relationship between environmental efficiency and regional GDP per capita has also been explored, supporting PHE, that as regional GDP per capita increases, environmental efficiency initially decreases, but then improves, forming a U-shaped curve. (Repkine and Min 2020). Additionally, some countries with long-term increases in FDI have seen decreased carbon emissions in short-term as well as in long term.(Mert and Caglar 2020). These studies highlight that the environmental impact of FDI is not so simple and direct, rather is too widespread, complex, interconnected and influenced by multiple factors. But the interactive roles of these factors in the relationship between FDI and environmental degradation has remained a significant challenge for the policymakers in clear understanding the nexus between FDI and environmental outcomes, as each of these factors can either moderate or intensify the environmental impact of FDI. A deep understanding of the function of these influencing factors in the relation between FDI and environmental deterioration is essential to maximize its benefits and minimize its environmental costs. Surprisingly, the influence of these factors remains inadequately explored, hindering our ability to achieve sustainable development through FDI.

This study seeks to explore the impact of FDI on environmental degradation as well as the interactive role of TI together with FDI in influencing the environmental impact of FDI in the next eleven countries. The Next eleven countries comprise eleven emerging economies including, Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, Türkiye, South Korea and Vietnam. These group of countries have the ability and potential to become among the dominant countries of the world, as explored in 2005 by Goldman Sachs Investment Bank, and are also revealed to be the future new BRIC of the world (O'Neill and Stupnytska 2009). In these economies South Koria ranks among the highest income countries, Türkiye and Mexico in the upper middle income, whereas, Pakistan, Nigeria, Egypt, and Bangladesh, Philippines and Vietnam rank in the lower middle-income countries. (Mundial 2018). These countries constitute about a fifth of the world population and a tenth of the world trade,(Sandalcılar, Cihan et al. 2022) but are also among the top energy consumptions and carbon emissions countries. In the world leading twenty pollution emitter economies, six are from N-11 countries. (Statista 2024a). So, if on one side these economies are playing crucial roles in the world economy, their negative impacts on the environment are also adversely affecting environmental quality and sustainability. Figure-1 depicts the trend of territory- based carbon emissions (metric tons) in next eleven countries from 1990 to 2023. These countries have witnessed a consistent upward trend in carbon emissions for over three decades. To meet the Paris Agreement's goals, policymakers must set specific emission-reduction targets. Without adequate policy actions, emissions in these countries are expected to rise further.

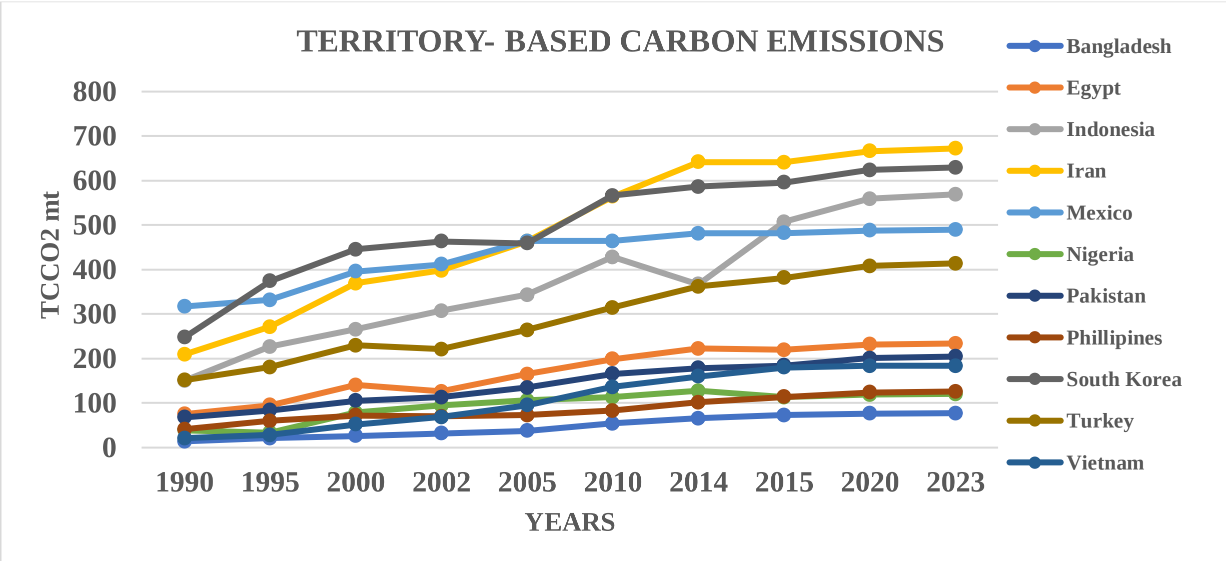



**Figure 1.1: Trend of TCO2 emissions in N-11 countries from 1990 to 2023**

Next-eleven countries offer an ideal context for analyzing the outcomes of this study. As these countries, in the developing world are not only confronted with significant environmental challenges but are also among the leading recipients of foreign direct investment.Figur-2 illustrates the trend of Foreign Direct Investment (FDI) in millions of US dollars across these countries from 1990 to 2023, highlights distinct growth patterns in FDI among these countries, marked by their unique economic profiles, levels of investment attractiveness, and the effects of international market fluctuations:

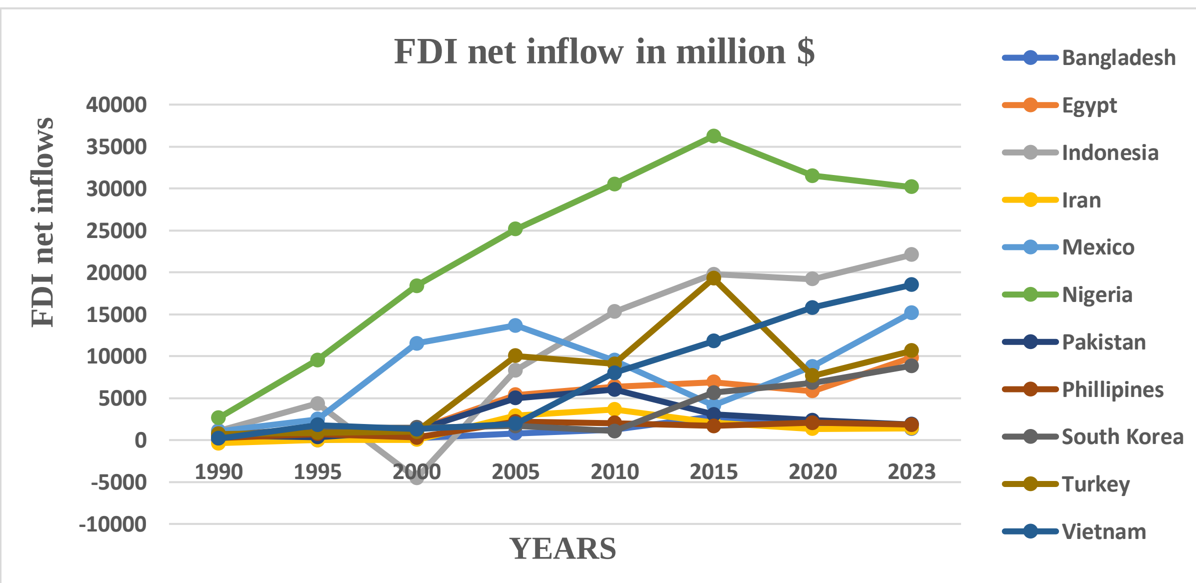



**Figure 1.2: Trend of FDI inflow in N-11 countries from 1990 to 2023**

Foreign direct investment is considered an essential and basic operator of economic growth, but its effect on environmental degradation has become a grave concern. Whereas, FDI can bring in advance innovations and capital, it can also cause increase in pollution and degradation of environment. But, the net outcome of FDI on environmental pollution varies across countries, with some facing extreme degradation, others have effectively reduced its adverse effects. Studies have illustrated that the range of environmental degradation resulted from FDI has been affected by multiple complementarity factors. This analysis seeks to explore the impact of FDI on environmental degradation, highlighting the interactive roles of technological innovations in the relationship, by utilizing database of eleven emerging economies. The study intends to provide useful information for policymakers to plan strategies, encouraging Eco-friendly economic growth while limiting environmental harms. The outcomes of the study will help policymakers of the selected sample countries, know whether technological innovations can shape the impact of FDI on environmental degradation and to what extent. Enhancing their sustainable decision-making abilities for achieving desirable economic growth. Using a panel data set ranging from 1990 to 2023, and employing key econometric techniques, the findings of this research are likely to yield a deeper insight into the complex interplays between FDI, complementarity factor, and environmental degradation, and equip decision-makers with valuable perspectives to make effective policy strategies for enhancing sustainable development

**REVIEW OF LITERATURE**

Foreign direct investment (FDI) makes a substantial contribution in sharing cutting-edge innovations to host countries, leading to increase productivity and economic growth via skilled workforce migration, technology transfer and diffusion, including the adoption of innovative management techniques (Cole, Elliott et al. 2008). The relation between FDI and environmental degradation in the context of CO2 emissions has been examined in numerous researches, rendering varied conclusions .Li (2023) explored no remarkable impact of FDI on environmental degradation in selected Asian countries. In contrast, Raghutla, Malik et al. (2024) revealed that FDI, combined with joint public-private initiatives and technological breakthroughs, mitigate CO2 emissions in Global trade zones. Salman, Razzaq et al. (2023) explored that FDI first reduces, then rises CO2 emissions in the manufacturing sectors of China, highlighting a possibly negative effect of FDI on environment. FDI has a statistically significant result on environmental degradation in Egypt, as specified by the study findings of (Rashdan and Ibrahim 2024),using quantitative risk analysis techniques for the time frame 1990-2021. The effect of FDI on carbon dioxide emissions differs, with quality of institutions having a significant impact (Boateng, Annor et al. 2024).

FDI has a substantial impact on greenhouse gas emissions in BRICS countries, emphasizing the requirement for Eco-friendly foreign investment (Sreenu 2024) TI also plays a game changing role in influencing the relationship between FDIs inflow and environmental degradation. Although FDI is often associated with increased carbon emissions, the availability of technological innovation can considerably decline these emissions. These findings imply that improving technological capabilities can reduce the environmental impact of FDI, making it important for policymakers to realize technological advancements when devising initiatives to protect environmental quality(Bakhsh, Yin et al. 2021). Salahuddin, Alam et al. (2018) investigated the impacts of FDI, economic growth and electricity consumptions on carbon emissions in Kuwait for the period ranging from 1980 to 2013, by employing time-series data and using ARDL model. The findings if ARDL revealed that FDI increase environmental degradation, and the results of VECM explored that FDI, economic growth and electricity consumptions, all aggravate carbon emissions. Sung, Song et al. (2018) analyzed the impact of FDI on carbon emissions in 20 industrial sectors of China by using panel data set for the period from 2002 to 2015 and explored that FDI reduces environmental degradation in the host nations. Amjad and Mehmood (2016) by using panel data set of 19 developing countries, analyzed the link between FDI, energy usage and technology on environmental degradation. The study explored that in the developing countries FDI accompanied by energy and technology usage are all key drivers of environmental degradation. The results suggest that without robust environmental laws and recognizing the competitive dynamic of the developing countries, the reduction in carbon pollution in these countries cannot be achieved through strategic investment in R&D or building energy efficiency. Halliru, Loganathan et al. (2021) examined the impact of FDI, economic growth, energy consumption and HC, on pollution emissions, in West African countries for the period from 1970 to 2017, employing long-run cointegration technique and panel quantile regression. The findings show U-shaped and N-shaped relationships between the variables and carbon emissions. The results show that FDI, energy consumption, and human capital are significant drivers of pollution across all quantiles. Ali, Phoungthong et al. (2022) studied the impact of FDI and green innovation on carbon emissions in BRICS countries by employing Augmented Mean Group estimator and using panel data spanning1990- 2014. The findings show that FDI, economic growth and energy consumption increase environmental degradation, whereas, green innovation has substantial negative impact. Ali, Phoungthong et al. (2022) examined the impacts of FDI and eco-innovations in BRIC countries on their environmental quality by using Augmented mean group estimation technique and utilizing panel data set ranging 1990-2014, explored that FDI, energy usage as well as EG, all are positively related with environmental degradation, whereas, eco-innovations have marked negative effects on the same. The study suggested that for promoting sustainable future, the BRIC countries must need to promote green innovations.

In another study made by Hao, Wu et al. (2020) examined the impact of FDI and TI on environmental degradation in China, by using panel data set of 30 provinces. The findings of the study supported the "pollution halo hypothesis" that increased FDI in China has decreased ED, and suggests that government should encourage FDI while also searching for investors that integrate environment-friendly practices with latest technologies. Another study on Belt and Road initiative regions conducted by Ali, Jianguo et al. (2023) utilized data set from 2001 to 2018, studied the relationship between financial inclusion, TI, natural resources, and ED. The findings highlight those natural resources and financial inclusion leads to increased environmental pollution, whereas, technological innovation, human capital and regulatory institutions help in decreasing ED. Another study made by Rauf, Ali et al. (2023) analyzed the impacts of FDI, renewable energy consumption and TI on the relationships between economic expansion and environmental sustainability in BRICS countries from 1990 to 2018. Employing robust statistical methods, the study found that FDI increases economic growth, Nonetheless, it has a negative impact on sustainability. Energy use was found to be directly linked with economic growth and CO2 emissions, while technological innovation had a direct association with EG and inversely relation with carbon discharge. Ketchoua, Arogundade et al. (2024)explored the relationship between FDI, technological innovation, and sustainable growth in OECD member economies. By employing Ordinary Least Squares (OLS) and GMM techniques, the results suggest that FDI impedes sustainable development, however TI plays a vital role in increasing it. Yu and Xu (2019) studied the impact of FDI and R&D on decreasing industrial pollution in China by utilizing data set ranging from 2000 to 2017 and employing Panel-Corrected Standard Error (PCSE) model. The findings reveal that at the national level FDI has significant negative impact on carbon emissions, with significant regional variabilities. But research and development both at regional and national level has significant negative impact on carbon emissions. The analysis explored that integrating FDI with technological development contribute to increase production-based carbon emissions, whereas, reduces consumer-based carbon emissions. and highlights the significance of technological innovation in reducing the effects of FDI on sustainable development Dam, Kaya et al. (2024) studied the link between TI, REC, natural resource rent (NRR), and CO2 emissions in E-7 countries (Brazil, China, India, Indonesia, Mexico, Russia, and Turkey) from 1992 to 2018. Employing ARDL approach, robustness test, and Dumitrescu-Hurlin panel causality test, the finding revealed that TI and REC enhance environmental sustainability by minimizing CO2 emissions. Exclusively, a 1% increase in TI and REC reduces CO2 emissions by 0.064% and 0.234%, respectively. On the other hand, NRR and GDP were explored to hinder environmental sustainability. The results advocate that policymakers should stress upon implementing sustainable innovations and increasing the share of REC to gain the environmentally friendly development objectives. Wang, Gao et al. (2022) explored the role of FDI and TI on CO2 emissions by employing quantile regression analysis and data set spanning 2000 to 2018 in China's high-tech industry. the findings highlight that FDI has a negative effect on CO2 emissions, while TI has a negative impact in the long-term but positive in the short term. The results advocate that FDI and TI have impacted energy consumption patterns in the high-tech industry, resulting fluctuations in CO2 emissions. The analysis suggests that policymakers recognize the heterogeneous effects of FDI and TI on CO2 emissions at different levels when designing carbon mitigation strategies. Siripi, Kuuwill et al. (2024) analyzed the links between FDI, TI, and CO2 emissions in Ghana, by using time-series data from 1980 to 2021 and employing the ARDL method, the findings show that in the long-run FDI follow pollution haven hypothesis and increases CO2 emissions but in the short-run FDI significantly reduces CO2 emissions. The research also validates EKC hypothesis, where CO2 emissions increase with increase in economic growth and then start decline at high growth level.

Abdul-Mumuni, Amoh et al. (2023) by employing the panel nonlinear autoregressive distributed lag (NARDI) technique, and using panel data set ranging 1996-2018, analyzed the asymmetric impact of FDI on pollution emissions in 41 sub-Saharan African countries explored that FDI has a heterogeneous effect on CO2 emissions, with negative shocks in the long-run decreasing emissions and positive shocks increasing emissions. A study made by Hunjra, Bouri et al. (2024) on 76 developing economies, examined the impacts of economic growth and FDI on environmental degradation. The study pointed out that economic growth brings about the utilization of sustainable technology and practices, resulting reduction of emissions. The study also found a direct link between FDI and carbon emissions, spotlighted the requirement for careful analysis of investment opportunities and policy frameworks. The study also explored that when high EG and large-scale FDI takes place at the same time, environmental degradation is escalated. Emphasizing the crucial role of situation-specific measures to gain balance between EG and environmental protection. Yang, Shafiq et al. (2024) analyzed the effects of energy consumption and technological innovation on carbon footprint in China. Employing panel data from 30 Chinese provinces from 1997 to 2021, the research employed the MMQR and BSQR to carry out empirical examination. The results highlighted that technological innovations have negative effect on ED whereas energy consumption is significant positive contributor of ED. that study also suggested that by sustainable energy initiatives and emission reduction efforts, the negative relationship between TI and ED can be further boosted. Though FDI could potentially lead to technological advancements and Sustainable manufacturing processes, decreasing carbon emissions, its overall impact is still unclear (Sarkodie, Adams et al. 2020) That is why, the relationship between FDI and environmental degradation in the context of technological innovation has remained a subject of heated debate among the scholars and policy makers for the past few years.

A comprehensive body of literature has investigated the relationship between FDI and environmental degradation and has offered mixed results, however, based on our current knowledge, no rigorous studies have been conducted on the interactive role of FDI and TI in influencing nexus between FDI and environmental degradation, particularly in Next eleven countries. Therefore, this study mainly investigates the complementarity role of TI together with FDI on the environment degradation in these eleven emerging economies.

**TRENDS AND STATISTICS IN KEY VARIALBES**

The N-11 countries, from the past three decades have undergone rapid economic growth and inflow of foreign direct investment. The accelerated economic growth, attributed largely by FDI, has raised the environmental concerns of such investments. A range of variables can affect the relationship between FDI and ED, including the type of investment, level of technological development, home country regulations and many others. So, the relationship is very much complex and multifaceted. Over the past few years, various steps have been taken by the policymakers of the selected countries to promote sustainable development and reduce environmental degradation. But despite many initiatives, environmental degradation continues as a key challenge for these countries. The subsequent section explores the trends and statistics of FDI, environmental degradation, and technological innovation, in the selected sample economies from 1990 to 2023. This analysis will lay the groundwork for the subsequent empirical investigations.

**Table 1:** Average values of key variables of the panel data set from 1990 to 2023

| Countries | Territory-Based Carbon Emissions (metric tons) | Foreign Direct Investment (net inflow in million US Dollars) | Technological Innovation |
|---|---|---|---|
| Bangladesh | 45.83794 | 959.8148 | 272.6765 |
| Egypt | 168.0881 | 4231.11 | 1658.206 |
| Indonesia | 381.3174 | 9742.284 | 5491.971 |
| Iran | 477.851 | 1760.503 | 7657.941 |
| Mexico | 435.0707 | 8947.156 | 13430.06 |
| Nigeria | 88.47278 | 23215.43 | 670.3235 |
| Pakistan | 141.8548 | 2953.141 | 976.8529 |
| Philippine | 84.05337 | 1577.635 | 2963.471 |
| South Korea | 491.1601 | 3646.632 | 141504 |
| Turkey | 289.969 | 8101.176 | 3694.794 |
| Vietnam | 104.6202 | 6721.981 | 2709.324 |

Source(s): World Development Indicators (WDI)

**Territory-based carbon Dioxide emissions (Environmental degradation)**

Carbon dioxide emissions have been an increasing issue since the Industrial Revolution, when non-renewable fuel burning became extensive, aligning with the growth of FDI in energy-hungry enterprises. The average territory-based carbon emissions in metric tons, for the N-11 countries presented in figure 3.1 shows that Bangladesh has the minimum carbon emissions in the list whereas South Korea tops the list. Pakistan's average carbon footprint stood at 141.85 metric tons, influenced by its growing energy demand and usage, comprising a combination of fossil fuels and renewable sources.

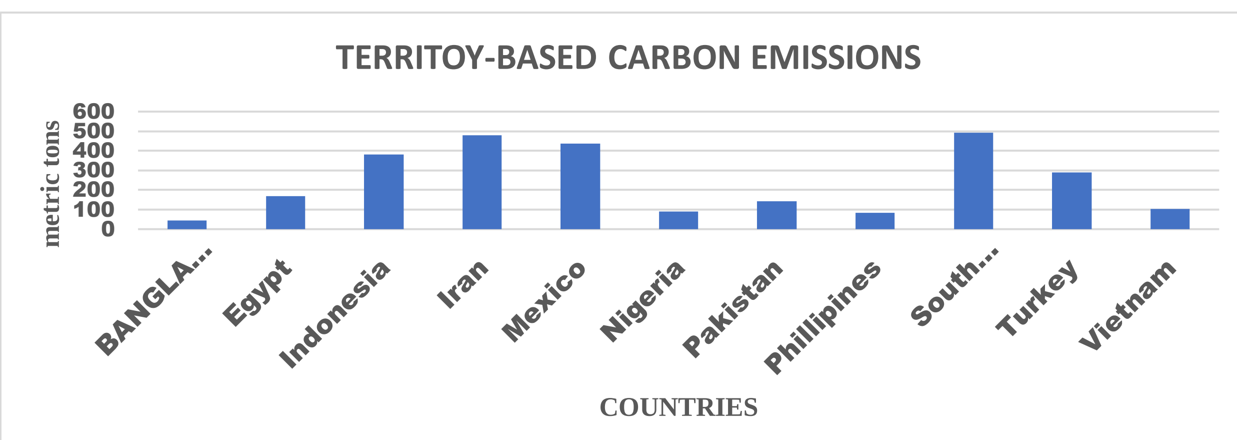


**Figure 3. 1:** TCCO2 emissions in next eleven countries from 1990-2023

As a whole, substantial differences in emissions are highlighted, with some countries still continue to rely heavily on fossil fuels while others showing potential for betterment through cleaner technologies and practices.

**Foreign direct investment net inflow**

As for as the average FDI net inflows in the sample countries are concern, Nigeria tops the list and Indonesia has the second number, highlighted in figure 3.2. Egypt is gaining from its tourism and energy sectors, while South Korea draws investment through its cutting-edge technology and industrial strength.

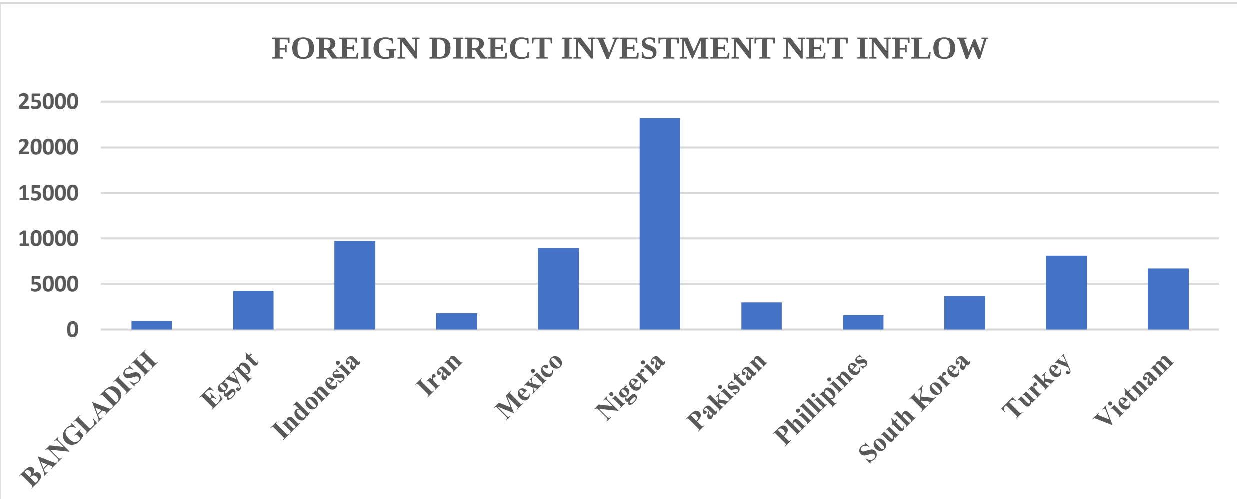



**Figure 3. 2**: FDI net inflow from 1990-2023

Pakistan, at the lower end of the scale, faces challenges of political instability, poor infrastructure, terrorism and many others. As a whole, significant disparities in FDI are observed across the sample countries.

**Technological innovations**

Technological innovation scores for a country demonstrate its dedication to research, development, and technological advancements. Here, in our selected list of countries, South Korea leads with a remarkable average score of 141,504, highlighted in figure3.3. Mexico has a score of 13,430.06, behind South Korea, whose TI is largely powered by its robust international trade partnerships, especially with the United States and by its manufacturing sector.

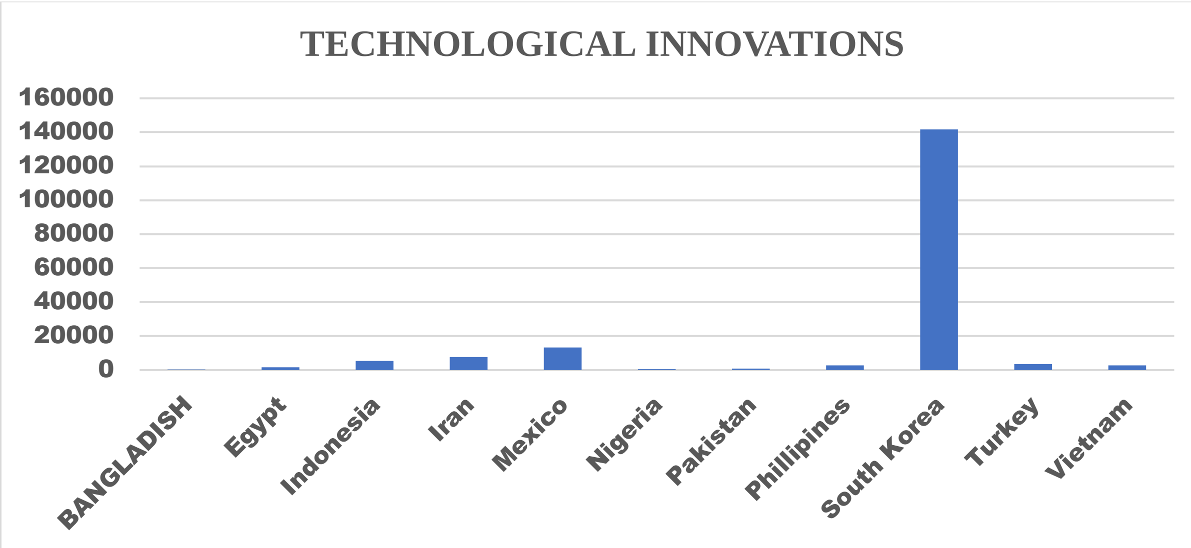


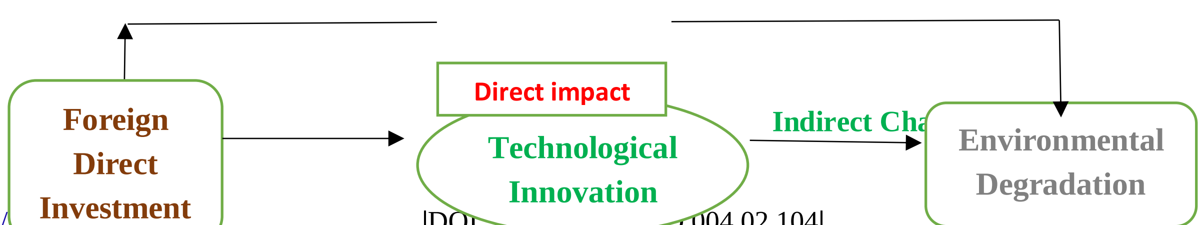

**Figure 3. 3:** TI score in next eleven countries from 1990-2023

Bangladesh, scoring 272.68, exhibits the lowest technological innovation score among these countries. Overall, these countries exhibit significant differences in their technological innovation capabilities.

**METHODOLOGY**

**Theoretical background**

The fastest growth of FDI across the globe during the last few decades, has raised worries about its environmental concerns, particularly, regarding climate change, global warming and environmental pollution. As countries struggle to achieve sustainable development aims, recognizing the intricate web of the relationship between FDI and environmental degradation become essential. technological innovations have been accepted as key factors in influencing environmental degradations. But FDI's impacts on environmental degradation in presence of this complementarity factor is still not clear, especially in the context of eleven emerging economies. This study attempts to examine the same by using panel data set of next eleven countries, and period spanning 1990 to 2023. The Next eleven countries offer a unique perspective for this study, due to their rapid economic growth, fastest inflow of FDI, and raising worries about increasing environmental degradation. By utilizing unique econometric techniques and extensive panel data set, this study aims to provide a detailed analysis of the issue, with the purpose of contributing policy outcomes that foster sustainable development in the chosen countries. Due to the increasing significance and distinctive attributes of the Next eleven countries in the global economy, the author decided to select these countries for this research.  These countries are projected to become influential entities in the global economy, shaped by their massive population growths, fast expanding economies, and strategic locations. Moreover, these countries provide diverse range of economic, political, and environmental contexts, providing a rich environment for examining the relationships between FDI, environmental degradation, and sustainable development. The issue under consideration is important because environmental degradation, particularly climate change, is a major concern worldwide today, needing urgent consideration.



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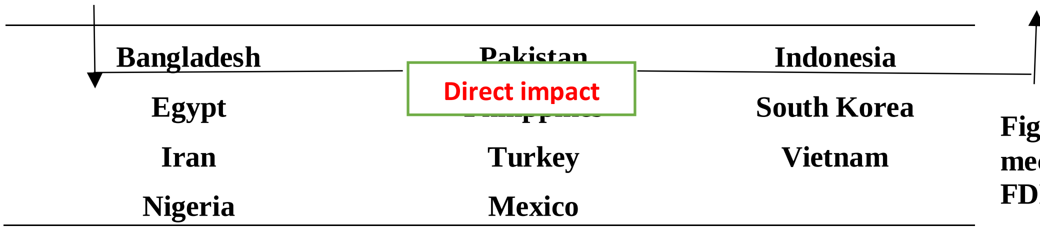


**Figure 3.1 The mechanism of FDI impact on environmental degradation, the complementarity role of technological innovation**

**Models Specification**

To determine the interactive role of TI with FDI in influencing environmental degradation, we specify our Model as:

$$\mathbf{ED_{i,t} = \lambda_0 + \lambda 1FDI_{i,t} + \lambda 2(FDI * TI)_{i,t} + \lambda 3X_{i,t} + \mu_1} \quad (1)$$

Where, 'i' and 't' denote country and time dimensions, respectively. Environmental degradation (ED), used as proxy for territory-based carbon emissions (TCCO2mt), Foreign direct investment (FDI), a set of Control Variables (X) including GDP per capita (GDPC) and Natural Resources Rent (NRR) and Population (pop). An Error Term ($u_1$) is presented in the model to capture unexplained variations. The inclusion of interactive term $(FDI * TI)_{i,t}$, in the model allows us to explore the complementarity role of TI in interaction with FDI on environmental degradation. where the coefficient $\lambda 2$ captures the marginal impact of TI when combined with FDI on environmental degradation.

**Data**

Secondary data is used to explore the interactive roles of TI in the relationship between FDI and environmental degradation. Environmental degradation is measured in matric tones and Territory based carbon emissions (TCCO2) is used as proxy for it. Territory-based carbon emissions, also called production-based carbon emissions including emissions from the combustion of fossil fuels like coal, gas, oil, industrial emissions during manufacturing processes, agricultural emissions from livestock and land cultivation practices, transportation sector emissions including emissions from vehicles etc. emissions from waste management activities like landfilling, and other relevant production processes. FDI is measured in US dollars and its net inflow is considered in the study, whereas, technological innovations are the score given for the use of modern technologies and production techniques. Moreover, World Data Bank is used as a source of data for all variables been selected in the study. Table 1 shows a detailed description of the variables, measuring units, data sources, and expected signs. The data were analyzed for the period 1990-2024. The sample countries for this study includes next 11 countries including Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippine, South Korea, Turkey and Vietnam.

**Table 3. Data sources and variables.**

| Variables | Symbols | Measurement unit | Source |
|---|---|---|---|
| Territory based carbon emissions | ED | metric tons of TCCO2 | World Bank (2024) |
| Foreign direct investment | FDI | Net inflow in million $ | World Bank (2024) |
| Technological Innovations | TI | | |
| GDPC | GDPC | | |

| | | | |
|---|---|---|---|
| Natural Resources Rent | NRR | | |
| Population | pop | Population total | World Bank 2024 |

**The descriptive statistics**

The descriptive statistics of the selected panel data set is presented in table 4, with natural log transformation applied to the considered variables in the analysis, for meaningful interpretation. The average territory-based carbon emission in the sample countries is 5.15, which is significantly high, indicating that the sampled countries environmental situation is relatively very poor and needs to be saved from further degradation. The standard deviation value for the same variable is 0.931, indicating that there are large differences in emissions levels in different countries. However, FDI exhibits a negative mean -1.1618 suggesting diminished or potentially negative FDI on average, with standard deviation of 0.43, showing moderate variation around the mean. The average value for technological innovations in the sample countries is 7.9279, with a standard deviation of 1.71, indicating that there are obvious differences in technological innovation capacity in different countries. GDPC has an average value of 26.408, and standard deviation of 0.94064. The minimum and maximum values from the table indicate that territory-based carbon emissions vary between 2.6445 and 6.5307, while FDI between -2.1386 and -0.1410. The means and standard deviations for most variables suggest a relatively normal distribution, although outliers may be present in case of FDI and NRR fields. Overall, the mean and standard deviation of variables are normal, having certain level of dispersions, but meet the requirements for further testing.

**Table 4** Descriptive statistics of variables.

| Variable | No. of Samples | Mean | St. Dov | Min | Max |
|---|---|---|---|---|---|
| lntcco2mt | 374 | 5.1464 | 0.93138 | 2.6445 | 6.5307 |
| lnfdi | 374 | -1.1618 | 0.42714 | -2.1386 | -0.1410 |
| lnti | 374 | 7.9279 | 1.72717 | 4.1271 | 12.2723 |
| lngdpc | 374 | 26.408 | 0.94064 | 24.1062 | 27.9281 |
| lnnrr | 374 | 0.7584 | 1.88714 | -4.4861 | 3.55409 |
| lnpop | 374 | 18.419 | 0.45832 | 17.5737 | 3.5541 |

**Analytical Techniques**

To investigate the model-based links between variables presented in model-1, a systematic procedure is used in the study, represented stepwise as: (i) To examine cross-sectional dependence among the variables, Pesaran CD (PCD) is employed (ii) For slope heterogeneity check, SH test advocated by Pesaran and Yamagata (2007 is used (iii) For unit root tests, Pesaran CADF and Pesaran CIPS panel unit root tests are used, and (iv) For the long-run estimations, the AMG estimator is used whereas (v) for robustness analysis the CCEMG estimator employed.

**Test for cross sectional dependence (CSD):**

In case of panel data set, it is essential to check the CSD, before estimating the model. As in case of too much interdependence among variables i.e. countries in our study, the computed results of traditional unit root tests and long run estimates may be incorrect and misleading. For the purpose of checking CSD, Pesaran (2004) test is used to confirm the correctness of our ahead findings. The equation of the test is formulated as:

$$CD^{Pesaran,2004} = \sqrt{\frac{2}{i(i-1)}} \sum_{k=1}^{i-1} \sum_{j=k+1}^{i} T^{\hat{k}j} \rho^{k,j} \hat{N}(0,1) \quad \textbf{(2)}$$

Where the mean value and variance are assumed to be zero and constant, respectively.

**Test for slope heterogeneity (SH):**

SH is another important problem that confront in panel data set, that can affect the unbiasedness & consistency of the estimates. So, it is essential to check this issue. This study employed the SH test advocated by Pesaran and Yamagata (2007) to ascertain the presence or absence of SH in the models under investigation. A variety of factors contribute to existence of SH in panel data, including demographic and structural factors. The Pesaran and Yamagata SH test is prioritized above other types of heterogeneity tests, due to its applicability to a larger sample size. Rendering it more practical. The Pesaran and Yamagata test equation is formulated as:

$$\Delta_{SH} = (N)^{\frac{1}{2}} (2K)^{\frac{-1}{2}} \left(\frac{1}{N}S - K\right) \quad \textbf{( 3)}$$

$$\Delta_{SH} = (N)^{\frac{1}{2}} \left(\frac{2k(T-K-1)}{T+1}\right)^{-\frac{1}{2}} \left(\frac{1}{N} S - 2K\right) \quad \textbf{(4)}$$

$\Delta_{SH}$ and $\Delta_{ASH}$ represent delta tilde and adjusted delta tilde, respectively.

**Panel unit root test:**

To confirm stationarity of the variables, we apply Pesaran Augmented Dickey–Fuller (CADF) and the Pesaran cross-sectionally Augmented Im, Pesaran, and Shin (CIPS) tests. Pesaran (2007) developed these tests. These are second-generation unit root tests, where the cross sections are augmented so as to avoid the problems of SH and CSD. The equation of CADF can be presented as:

$$X_{it} = a_i + b_i\bar{y}_{i,t-1} + c_i y_{t-1} + \sum_{j=0}^{k} d_{ik} \Delta\bar{y}_{t-j} + \sum_{j=1}^{k} d_{ik} \Delta y_{i,t-j} + \varepsilon_{it} \quad \textbf{(5)}$$

where $y_{i,t-1}$ and $\Delta y_{i,t-j}$ shows the first differences of each unit and the mean of lagged level cross-sectional values. After calculation of CADF, we can estimate the CIPS statistics as follows:

$$CIPS = \frac{1}{N} \sum_{N-1}^{N} t_i(N, T) \quad \textbf{(6)}$$

where ti(N, T) shows t-statistics in the CADF test define in Equation (5)

**Augmented Mean Group test (AMG)**

To estimate the interactive role of TI with FDI in influencing environmental degradation, this research employs the Augmented Mean Group test selected by (Eberhardt and Bond 2009). It is a panel data estimation technique that facilitates the estimation of dynamic heterogeneous models. This technique is used for estimating long-run relationship in panel data set. It tackles issues such as cross-sectional dependence and heterogeneity among groups in the data (Destek and Sarkodie 2019). Moreover, it is free from stationarity issue too (Hussain, Khan et al. 2020) The AMG approach essentially strengthens traditional mean group estimators by including lags of cross-sectional means to enhance the robustness and efficiency of the parameter estimations, especially when analyzing dynamic panel data models. By using the AMG approach, this research aims to offer a detailed understanding of the nexus between FDI and environmental pollution, and to explore the interactive role of technological innovation with FDI in influencing the effect of FDI on environmental deterioration. A two-steps estimation technique can be employed for it as:

First step:

$$\Delta y_{it} = a_i + b_i \Delta z_{it} + c_i\, f_t + \sum_{t=2}^{T} d_i \Delta Q_t + \mu_{it} \qquad \textbf{(7)}$$

Second step:

$$\hat{b}_{AMG} = N^{-1} \sum_{i=1}^{N} \hat{b}_i \qquad \textbf{(8)}$$

Here, $a_i$ denotes the intercept, $\Delta$ indicates the differenced operator; $b_i$ represents coefficients of country-specific estimations; $f_t$, the unobserved common factor having heterogeneous factor; yit and $z_{it}$ define observables; $d_i$ shows the coefficient of standard dynamic process and time dummies; $\hat{b}_{AMG}$ denotes "the mean group estimator" for AMG and $\mu_{it}$ the residual term of the model.

**Robustness Check**

To conform robustness of our AMG estimators, the technique we used is the CCEMG estimation approach. This technique provides excellent results in even in the presence of panel data heterogeneity and multifaceted residual terms. Hence, the linear combination of group averages of common effects and variables is used (Dong, Hochman et al. 2018),(Atasoy 2017). The following regression is used to calculate the CCEMG estimator:

$$Mit = \emptyset_{1i} + r_1 Z_{it} + \sigma_i P_t + \beta_i \bar{M}_{it} + v_i \bar{Z}_{it} + \mu_{it}$$

Here $\emptyset_{1i}$ is the constant term of the model, $M_{it}$ and $Z_{it}$ are observable variables, $\mu_{it,}$ the error term and $P_t$ the common unobservable factor with heterogeneous coefficients, $r_1$ is the coefficient of country-specific estimates, respectively. The same procedure has also been used by other researchers including (Hussain, Khan et al. 2020) and (Ali, Phoungthong et al. 2022)for robustness checks of AMG estimations.

## RESULTS AND DISCUSSIONS

This section summarizes the main results of our four-steps analysis, described earlier, for our sample of eleven emerging economies.

**Results of Cross-Sectional Dependency (CD) and slope Heterogeneity (SH) Tests**

The outcomes of our CD test presented in Table 5 show strong correlation among cross-sectional units for all variables, with p-values uniformly significant at 0.000, pointing conclusive evidence against the null hypothesis of no cross-sectional dependence, at a 1% level, and justifies cross-sectional dependence in our study panel. The CD test statistical values spanned from 21.26 (TI) to 43.11 (POP), indicating significant interdependence among countries. The results suggest that country-specific shocks may have widespread repercussions on other countries, highlighting the need for a multifaceted technique for our panel data analysis that accurately captures these complex relationships. Table 5 also presents the outcomes of our slope heterogeneity test. The results show that our model suffer from slope heterogeneity. The findings of the test are authenticated by $\Delta$ and $\tilde{\Delta}$adjusted values (denoted by *** for 1% significance) signifying marked differences in slope heterogeneity coefficients across sample countries, where the p values 0.000, indicate the failure to accept null hypothesis of no slope heterogeneity in the model. The finding reveals that technological innovation interacts with FDI to influence the FDI-induced environmental degradation, with country-specific differences in its performance. That shows the importance of suited technological innovations to resolve environmental challenges.

Due to the presence of cross-sectional dependence and slope heterogeneity problems, this study is confined to employ Pesaran (CADF) and Pesaran (CIPS) 2nd generation unit root tests to verify the stationarity of variables, as the traditional unit root tests would provide misleading results.

**Table 5**. Results of Cross-sectional Dependency (CD) and Slope Heterogeneity (SH) tests:

| Variables | CD-Test | Correlation |
|---|---|---|
| TCCO2mt | 41.03***[0.000] | 0.949 |
| FDI | 29.48***[0.000] | 0.682 |
| TI | 21.26***[0.000] | 0.604 |
| GDPC | 42.55***[0.000] | 0.984 |
| NRR | 22.08***[0.000] | 0.511 |
| POP | 43.11***[0.000] | 0.997 |
| FDI*TI | 29.96***[0.000] | 0.693 |
| | **SLOPE HETEROGENITY TEST** | |
| | **values** | **p-value** |
| **SH ($\tilde{\Delta}$ test)** | 14.334*** | 0.000 |
| **SH ($\tilde{\Delta}$ adj test)** | 16.391*** | 0.000 |

**Results of Panel Unit Root Tests**

The results of Pesaran (CADF) and (CIPS) unit root tests presented in Table -6 indicate that most of the variables, namely TCCO, FDI, TI, GDPC and POP, are stationary at level, with statistically significant test statistics. The *** and ** Symbols denote non-acceptance of the null hypothesis of a unit root at the 1% and 5% significance levels, respectively. This validates that these variables are integrated of order zero, I (0), and do not require transformation. The stationarity of these variables suggests that their present values are influenced by their past values, and they can be employed in their existing format in subsequent analyses. In contrast, NRR show non-stationarity at level. Meanwhile, upon first differencing, this variable also become stationary. This transformation is essential for correcting for non-stationarity and ensuring the reliability and correctness of afterward analyses. The order of integration has significant implications for modeling and data analysis, guiding the selection of relevant specifications and transformations to guarantee accurate conclusions.

**Table 6. Results of CADF and CIPS unit root tests:**

| Variables | CADF | | |
|---|---|---|---|
| | **Level** | **First Difference** | **Integrated Order** |
| TCCO2mt | -2.518*** | ----- | I(0) |
| FDI | -2.430 * | ---- | I(0) |
| TI | -2.456*** | ---- | I(0) |
| GDPC | -2.174* | ---- | I(0) |
| NRR | -1.590 | -4.924*** | I(1) |
| POP | -3.456*** | ---- | I(0) |

| | CIPS | | |
|---|---|---|---|
| TCCO2mt | -2.805*** | ----- | I(0) |
| FDI | -2.900 *** | ---- | I(0) |
| TI | -3.122*** | ---- | I(0) |
| GDPC | -2.320** | ---- | I(0) |
| NRR | -1.989 | -6.095*** | I(1) |
| POP | -2.003*** | ----- | I(1) |

**Note**: Asterisks denote a significance level of 10% (*), 5% (**) and 1% (***).

**Results of panel AMG estimates**:

This study used AMG estimator to explore the interactive role of technological innovations and foreign direct investment in influencing environmental degradation in the selected countries. The estimation results of Panel AMG are presented in Table-7. The empirical findings reveal that FDI has a positive and significant impact on environmental degradation, with a coefficient of 0.1615**, revealing that a 1% increase in FDI results a 0.1615% increase in environmental degradation. This outcome is statistically significant at the 5% level. Also, a 1% increase in TI is linked with a 0.2044% increase in environmental degradation, indicating that technological advancements have also a direct and statistically significant impact on the environmental degradation. However, the interaction term between FDI and TI (-0.0216*) indicates a key finding. When FDI is accompanied with technological innovation, the environmental degradation resulting from FDI is reversed. Precisely, for every 1% increase in TI, the environmental degradation caused by FDI is reduced by approximately 0.0216%. The result is significant at 1% level. As for as the control variables of the model are concerned, the coefficient of GDPC, 0.7671 indicates that a 1% increase economic growth, measured in GDPC is connected with 0.7671% increase in environmental degradation, highlighting that economic growth has a significant positive impact on the environmental pollution. Natural resources rent (NRR) has also a positive and significant impact on environmental degradation in the next eleven countries with a 1% increase is coupled by 0.0253% increase in the environmental pollution. Similarly, higher level of population growth rate is directly associated with environmental degradations, although the result is statistically insignificant in the model. A 1% increase in population (pop) is accompanied by 0.3126% increase in the environmental degradation.

The results of AMG estimations portray that FDI has a significantly direct impact on the environment degradation in the N-11 countries and is potentially harmful to their natural environment. The result is consistent with Pollution haven hypothesis, confirmed in numerous past studies (Solarin, Al-Mulali et al. 2017, Justice, Seth et al. 2021, Ali, Phoungthong et al. 2022) who reveals that weak environmental regulations in developing countries invite polluting FDIs. Contrary to conventional views, we propose that FDI, in the next eleven countries, by accelerating economic growth, stimulating economic activities and wealth, resulted increased demand for energy-reliant goods. Thus, the escalating demand for energy-intensive products coupled with growing transportation requirements may have contributed to the direct relationship between FDI and environmental degradation in these countries, as these economies still heavily rely on fossil fuels for energy their requirements. Our arguments align with the findings of (Luo, Ran et al. 2022, Oladipupo and Ajide 2024) but are contrary to the findings of (Ekwueme, Obiora et al. 2021) Furthermore, the empirical findings of our study demonstrate that technological innovation adversely affect environmental health. This result diverges from the technological spillover hypothesis, which suggests that technological innovation led to decreased emissions, a trend evident in various regions worldwide, including OECD countries (Ganda 2019) and China (Liu, Zhao et al. 2022). Our reservations are grounded in the fact that technological innovations in developing countries may not always prioritize environmental protection, particularly when environmental regulations are poorly enforced. In many emerging economies such as the next eleven countries, where environmental regulations are weak, technological innovation may prioritize economic competitiveness over sustainability. Technological innovation in these economies may boost production and consumption, and consequently, increase emissions. This implies that new technologies introduced in emerging economies like next eleven, may prioritize economic growth and might not be designed with renewable energy utilization or emissions reduction as a top priority. Our analysis aligns with the results of (Khan, Chenggang et al. 2021, Ali, Phoungthong et al. 2022) (Su, Xie et al. 2021) who also identified identical outcomes where technological innovation failed to yield emission reductions. In contrast to (Ganda 2019, Ofori, Bekun et al. 2024) and many others who explored inverse relation between technological innovation and environmental degradation in BRIC countries. The interaction term (FDI*TI) captures the combined effect of FDI and TI on environmental degradation, where

| Variables | AMG (p) | CCEMG (p) |
|---|---|---|
| FDI | 0.1615** (0.025) | 0.2326* (0.075) |
| TI | 0.2044*** (0.000) | 0.2017** (0.040) |
| GDPC | 0.7671*** (0.009) | 0.3886*** (0.010) |
| NRR | 0.0253*** (0.000) | -0.0210 (0.506) |
| POP | 0.3126 (0.975) | -1.4109 (0.717) |
| FDI*TI | -0.0216*** (0.005) | -0.0283**(0.046) |
| Observations | 374 | 374 |
| groups | 11 | 11 |
| Wald $\chi$-statistics (Prob > $\chi^2$) | 60.84(0.000) | 18.49(0.0051) |
| RMSE | 0.0483 | 0.0353 |

its negative coefficient signifies that this interaction has a pronounced negative effect on pollution emissions. Hence, combining FDI with advanced technological innovation results decrease in environmental pollution that surpass their individual contributions. The finding highlights a significant complementarity link between FDI and technological innovation that can lead to reduction in environmental degradation.(Bakhsh, Yin et al. 2021, Ali, Phoungthong et al. 2022, Siripi, Kuuwill et al. 2024)

**Table 7.** Results of panel AMG and CCEMG estimators

**Robustness Analysis**

To Authenticate and verify the robustness of our panel AMG estimation results, the CCEMG technique is employed, that provide us a more detailed understanding of the relationships between variables in our panel data set. The results are shown in Table-7. The CCEMG estimations give us nearly identical findings as AMG estimator, where in both the models foreign direct investment, technological innovations and economic growth, all have direct and significant impacts on environmental degradation, indicated by their positive coefficients, with slight difference in their magnitude of impacts. In contrast, the natural resources rent, though has positive and significant impact on environmental degradation in the AMG model but insignificant coefficient in CCEMG, revealing that its impact is not robust across the two models. In both models the coefficient of the interaction term between FDI and TI have negative values, signifying that FDI in interaction with TI results a decrease in environmental degradation in the selected sample countries. So, the CCEMG findings further authenticate the moderating effect of technological innovation, indicating that the interaction between FDI and technological innovation contribute to emissions reductions. The uniformity of the findings in both AMG and CCEMG methods enhance the reliability of our results and lend further support to the conclusion that FDI combined with technological innovation have far-reaching effects on environmental sustainability.

**CONCLUSION AND POLICY IMPLICATIONS**

In response to the escalating threat of climate change, the global community has increasingly focused on cutting carbon emissions as a key strategy to reduce its adverse effects on human well- being and natural environment. In this regard, we examined the complex interplay between FDI, TI and environmental degradation (ED) in next eleven countries, in the presence of control variables, economic growth (GDPC), natural resources rent (NRR) and population (pop), for the period 1990-2023, shedding light on the environmental cost of economic growth. Latest econometric techniques were employed for empirical analysis of the study. Firstly, the cross-sectional dependence test was conducted, whose results indicate marked cross-sectional dependence among the panel variable's set. Then we checked slope heterogeneity of the panel and the findings confirmed the existence of slope heterogeneity problem in the data set. Upon confirmation of slope heterogeneity among variables, we used the second-generation unit root tests, CADF and CIPS to check stationarity of the panel and found that the variables are integrated of mixed orders. Due to cross-sectional dependence, slope heterogeneity and mixed order of integration in our panel, the best choice with us was to employ AMG technique to assess dynamic nexus between the study's variables and verify the results by CCEMG estimation technique. Our findings highlight that FDI is positively associated with environmental degradation, validating the notion of pollution haven hypothesis. Based on insights from the next eleven countries, our results suggest that weak environmental regulations in most of the developing countries attract FDI that prioritize pollution-intensive practices over environmental sustainability. The individual effect of TI on environmental degradation of our findings contradicts the conventional wisdom hypothesis that technological innovation help mitigate carbon emissions, instead suggest that it may actually contribute to increased degradations. This highlights that technological innovation in the next eleven countries, similar to other emerging economies, may prioritize economic competitiveness at the expenses of environmental quality. Interestingly, our findings underscore a new perspective into the ways in which TI can be utilized to offset the harmful environmental consequences of FDI. Specifically, the results indicate that TI in interaction with FDI can offset the unfavorable environmental consequences associated with FDI, as our findings reveals that the interaction between FDI and TI, (FDI*TI) significantly reduce environmental degradation, suggesting that FDI paired with ecofriendly technological innovation effectively balance economic growth and environmental sustainability. The research suggests that FDI can contribute as catalyst for sustainable development in the selected countries, provided that policymakers carefully and effectively address complementarity factors.

Based on our findings presented in this study, policy makers and businesses in the N-11 countries are urged to adopt proactive measures that promote sustainable development and decrease environmental degradation. Decision-makers should develop and implement strategies that facilitate and encourage the interaction between FDI and TI, to drive sustainable development. Policymakers in the next eleven countries should prioritize attracting, encouraging and incentivizing those foreign investments who give preference and importance to environmentally sustainable practices. By offering incentives in the form of tax holidays, other tax concessions, simplified licensing procedures, subsidies etc. to those investors who adopt environmentally friendly practices in their production operations, this goal can be optimally realized. Moreover, public-private partnership, including, foreign investors, government and local investors should be established, where government can offer certain incentives, concessions, support, recognition, protection as well as rewards for adopting sustainable practices, foreign investors can promise to adopt sustainable practices, share expertise, technologies, sustainable infrastructure as well as business knowledge with local investors. A proper framework for observing and reviewing the effect of these partnerships should also be established. Last but not the least, Global cooperation and unity are crucial for fostering sustainable growth and mitigating environmental degradation from the planet. A collective effort by Governments. International organizations, local communities, businesses and NGOs, is important for ensuring sustainable FDI, and attaining a cleaner and greener tomorrow.

### 6.2 Limitation and Future Research

Although this study has made significant contributions, it has certain limitations, that should be acknowledged. Firstly, the study is based on secondary data, which may not fully capture the depth of the research issue. Second limitation is the limited geographical scope of the study. As the research focus on the Next Eleven countries, which might restrict the applicability of the findings to other countries, having different economic, social, and environmental frameworks. Third limitation is that the study relies on territory-based carbon emissions as an indicator and proxy for environmental degradation, that may not fully capture the complexity of environmental degradation and may neglect other significant environmental concerns including deforestation, air and water pollution, land degradation, conservation crises etc. Fourth limitation is about methodology of the study. The AMG technique is utilized in the study for obtaining estimate of the study. This test may not fully capture the complex link between FDI, complementarity factors and environmental degradation.

Opportunities for future research may include expanding the analysis to a comparative study between develop and developing countries or expanding the geographical scope of the study by including more countries in the analysis. Utilizing alternative indicators for ED including air and water pollution could also be used to capture a broad spectrum of ED. Furthermore, future study could explore the impact of FDI on broader range of environmental indicators, including habitat loss, water pollution etc. could also be carried out. The role of international trade agreements and institutional factors in influencing the relationship between FDI and ED could also be explored in future studies. Latest econometric techniques could also be employed to investigate the complex linkages between FDI and ED and complementarity factors

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