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Harmonizing complementarities: The role of eco-innovation and globalization for achieving environmental sustainability in emerging countries

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ABSTRACT

This research study investigates the complementarity between eco-innovation and globalization in achieving environmental sustainability in emerging countries over the period of 1990 to 2021. The aim is to shed light on how these factors influence CO2 emissions. The use of the Cross Sectional Autoregressive Distributive Lag model reveals that eco-innovation, a significant catalyst for environmental advancement, demonstrates a detrimental effect on CO2 emissions, hence emphasizing its contribution to the promotion of sustainability. Interestingly, the positive interaction term between globalization and eco-innovation suggests that globalization enhances the relationship between eco-innovation and CO2 emissions. Globalization can facilitate the transfer of knowledge, technologies, and best practices across borders. In the context of eco-innovation, this means that a globalized world can promote the adoption of environmentally friendly technologies and practices more effectively. Nations that engage in active participation in global trade and knowledge exchange are likely to be more advantageous in harnessing the advantages of eco-innovation, specifically in terms of mitigating their carbon dioxide emissions. These results underscore the potential for cooperation between nations, industries, and financial institutions to drive meaningful reductions in carbon emissions, advancing environmental sustainability while maintaining economic growth. This research contributes valuable insights to policymakers, businesses, and organizations seeking a path towards a greener, more sustainable future in emerging countries and beyond.

Contribution/ Originality: This research contributes valuable insights to policymakers, businesses, and organizations seeking a path towards a greener, more sustainable future in emerging countries and beyond.

1. INTRODUCTION

Environmental degradation, the deterioration of natural ecosystems and resources due to human activities, is a pressing global issue with far-reaching consequences. One of the most immediate and severe consequences is the acceleration of climate change and global warming, which have been the severest and most controversial worldwide challenges. The release of greenhouse gases contributes to rising global temperatures, leading to more frequent and severe weather events, disrupted ecosystems, and threats to food and water security. Biodiversity loss is another critical outcome, as pollution, habitat destruction, and overexploitation of natural resources lead to the extinction of species at an alarming rate. This loss not only disrupts ecosystems but also diminishes humanity's

access to vital genetic and ecological resources. The rapidly rising carbon dioxide (CO_2) emissions in the last few decades have impacted human health, with air and water pollution causing respiratory diseases.

There is a consensus among scholars that eco-innovation is a highly effective approach to mitigating and averting additional environmental deterioration. According to Ali, Dogan, Chen, and Khan (2021) and Alvarez-Herranz, Balsalobre-Lorente, Shahbaz, and Cantos (2017), it is argued that eco-innovation has the potential to effectively tackle environmental concerns through the promotion of cleaner technology, sustainable practices, and green business models. Consequently, this can lead to a reduction in pollution within the given context. Globalization, with its interconnectedness and the free flow of ideas, resources, and technology across borders, has the potential to both accelerate environmental sustainability and pose challenges to it (Ali et al., 2021). On one hand, globalization can expedite the dissemination of environmentally friendly practices, technologies, and knowledge, thereby advancing the cause of sustainability. It encourages nations to cooperate on shared environmental issues and facilitates the adoption of best practices from one region to another. By promoting the development and application of green technologies and practices, eco-innovation ensures that the benefits of globalization are harnessed while minimizing its negative environmental impacts. It harnesses the power of globalization to foster more sustainable industries, supply chains, and consumption patterns. In this way, eco-innovation, in complementarity with globalization, becomes a dynamic force in mitigating environmental degradation, steering it towards a more sustainable path (Inglesi-Lotz & Dogan, 2018). The search for possible complementarity between eco innovation and globalization is a crucial area of inquiry in contemporary literature; however, it remains largely underexplored. The purpose of this research article is to explore potential policy consequences and shed light on the mechanisms through which globalization either helps or hurts eco-innovation in influencing environmental sustainability. The potential ramifications of eco-innovation facilitation or inhibition on the long-term sustainability of the environment have not been extensively examined. This study aims to examine the impact of globalization and financial deepening on the allocation of financial resources to eco-innovation efforts, the accompanying risk profiles, and the overall implications for environmental sustainability within emerging countries.

The emerging nations possess a unique capacity to assume a leading role in endeavors aimed at mitigating the adverse consequences of economic growth and industrial advancement on the natural environment. The emerging economies collectively contribute a significant proportion of global economic activity and industrial production. These regions serve as the geographical hubs for several of the globe's most advanced and influential economies. The efforts to sustain global sustainability are significantly influenced by the environmental practices and regulations implemented by emerging nations.

The aim of this study is to examine the impact of eco-innovation on carbon dioxide (CO2) emissions in emerging countries between the years 1990 and 2021. Our research is built upon the existing body of literature, which has indicated some gaps that need to be addressed. Furthermore, in order to examine the underlying mechanism driving this influence, we delve deeper into the respective contributions of globalization to the relationship between eco-innovation and CO2 emissions. Consequently, this work contributes to the existing body of knowledge in two distinct ways. Our research aims to examine the significance of globalization as an essential factor in the relationship between eco-innovation and environmental sustainability. The present study establishes a foundation for future research by examining the interconnections between globalization and eco-innovation with regards to their influence on environmental sustainability.

The subsequent sections of the paper are structured in the following manner: In this section, the literature review is presented. Section 3 of the document presents a comprehensive account of the technique employed and the data utilized in the study. Section 4 presents the findings and provides a comprehensive analysis of the outcomes. This section further examines the impact of globalization on the interplay between eco-innovation

and environmental sustainability. The final section of the document presents the findings and implications for policy.

2. LITERATURE REVIEW

Over the course of recent decades, there has been a growing global recognition of the various difficulties pertaining to environmental sustainability, including but not limited to climate change, resource depletion, and pollution. The scope of these issues has expanded beyond the confines of national boundaries, assuming a global nature and exerting influence on the well-being of individuals and ecosystems worldwide. The issue of environmental sustainability has garnered significant attention in the academic community, as evidenced by the considerable study conducted in recent years (Ali, Babi, & Rabbi, 2014; Ali et al., 2021; Alvarez-Herranz et al., 2017; Balsalobre-Lorente, Shahbaz, Roubaud, & Farhani, 2018; Chen & Liu, 2020; Cheng et al., 2020; Chi, Muhammad, Khan, Ali, & Li, 2021; Dong, Dong, & Dong, 2019; Khan, Ali, Dong, & Li, 2021). The existing body of scholarly study directs attention towards many potential aspects that exert influence on environmental sustainability. These elements encompass factors such as trade, demographic trends, energy resources, human resources, and deforestation.

2.1. Eco Innovation and Environmental Sustainability

The relevance of eco-innovation in determining the long-term survival of the environment has been highlighted extensively in recent studies (Ali et al., 2021; Alvarez-Herranz et al., 2017; Cai & Zhou, 2014; Chi et al., 2021; Ji et al., 2020; Lee & Min, 2015; Mensah et al., 2018; Wurlod & Noailly, 2018; Zhao, Yin, & Zhao, 2015). Eco-innovation focuses on the development and application of products, processes, and business models that reduce environmental harm. Numerous studies have highlighted its potential to drive significant improvements in sustainability (Ali et al., 2021; Alvarez-Herranz et al., 2017; Cai & Zhou, 2014; Chi et al., 2021; Ji et al., 2020). The existing body of scholarly research pertaining to the effectiveness of environmental innovations can be classified into two distinct categories: The initial set of studies is constrained to the scope of a singular organization and employs an industrial survey as a means to examine the efficacy of environmental innovation (Cai & Zhou, 2014; Shahbaz, Nasir, & Roubaud, 2018; Wurlod & Noailly, 2018). The subsequent set of research examines the efficacy of environmental innovation across multiple companies. Based on the research findings, it can be concluded that the implementation of environmental innovation has a positive influence on both the economic and environmental performance of businesses. Based on the findings of Shahbaz et al. (2018), it was observed that the influence of environmentally creative behavior on environmental performance was notably greater in magnitude compared to its impact on economic performance. The subsequent set of research examines the impact of environmental innovation on carbon dioxide (CO2) emissions. The aforementioned compilation of scholarly works comprises the following studies: Lee and Min (2015), Zhao et al. (2015), Mensah et al. (2018), and Wurlod and Noailly (2018). According to Long et al. (2017), the augmentation of innovation has a positive impact on domestic output and plays a significant role in the advancement of low-carbon energy sources. Mensah et al. (2018) argue that innovation plays a mediating role in the relationship between the energy transition and market efficiency. The implementation of government policies aimed at promoting the adoption of clean energy has a consequential impact on market efficiency. The study conducted by Zhao et al. (2015) challenges the notion of a causal relationship between technological progress and CO2 emissions, suggesting that no such connection exists in the long term. In summary, a substantial body of evidence indicates a negative association between technological progress and CO2 emissions.

2.2. Globalization and Environmental Sustainability

A substantial body of scholarly literature exists about the impacts of globalization on the sustainable preservation of the natural environment (Ali et al., 2021; Hu, Xie, Fang, & Zhang, 2018; Khan, Ali, Umar,

Kirikkaleli, & Jiao, 2020; Kirikkaleli, Adebayo, Khan, & Ali, 2021; Liddle, 2018a, 2018b; Safi et al., 2021). Based on the conducted studies, globalization possesses the potential to expedite the attainment of environmental sustainability, while simultaneously presenting impediments to its realization. Globalization possesses the capacity to engender favorable transformations through the facilitation of knowledge, technology, and best practices exchange pertaining to the conservation of the natural environment (Ali & Malik, 2021; Diffenbaugh, 2020; Dong, Wang, & Guo, 2016; Hasanov, Liddle, & Mikayilov, 2018). The interconnectedness of the global community holds promise for the widespread dissemination of environmentally conscious technologies and the widespread adoption of sustainable practices, hence expediting advancements towards environmental objectives. One potential avenue through which globalization might foster sustainability is by establishing economic incentives for nations to use greener energy sources and more efficient production practices. However, it is important to acknowledge that globalization is not exempt from a range of issues, some of which may have adverse effects on environmental sustainability. Increased global trade and consumption can lead to higher resource extraction, deforestation, and increased carbon emissions due to transportation and manufacturing. Additionally, the pressure to compete in the global market can sometimes result in lax environmental regulations in a bid to attract investment and maintain economic growth. Many studies have pointed to the so-called "environmental Kuznets curve," suggesting that environmental degradation worsens in the early stages of economic development but eventually improves as societies become wealthier and more technologically advanced (Ali et al., 2021; Hasanov et al., 2018; Hu et al., 2018; Liddle, 2018a; Safi et al., 2021).

Globalization has been associated with positive environmental outcomes. The global exchange of technical innovation, knowledge sharing, and international collaboration are fundamental components of globalization that have the potential to foster greater environmental consciousness. The dissemination of environmentally friendly practices and technologies has had a positive impact on various places across the globe, mostly due to the endeavors of multinational corporations. Furthermore, it has been seen that global civil society and environmental advocacy organizations have strategically employed the phenomenon of globalization as a means to enhance public consciousness and exert their influence on legislative measures pertaining to the preservation of the environment (Hasanov et al., 2018; Kirikkaleli et al., 2021). The aforementioned phenomenon can be attributed to the facilitation of travel and communication across national boundaries, which has been brought about by globalization. Nevertheless, it is imperative to comprehend that the environmental ramifications of globalization exhibit significant disparities contingent upon the distinct sectors, regions, and regulatory frameworks included. This is a factor that necessitates careful study. Global trade can potentially exert adverse effects on the environment, namely in relation to the transportation of commodities, the clearance of land for agricultural activities, and the over utilization of natural resources. The expansion of worldwide supply networks has given rise to a complex network of environmental consequences that transcend national boundaries. Governance practices and laws at various levels, including local, national, and international, can have an impact on how much globalization contributes to environmental sustainability. This phenomenon may occur due to the multifaceted nature of globalization. In the pursuit of attracting foreign investment, governments are faced with the challenge of addressing the competitive pressures arising from globalization, which some studies argue can potentially result in a decline in environmental standards, commonly referred to as a "race to the bottom." On the contrary, proponents assert that globalization can serve as a motivating factor for governments to enhance environmental regulations in order to align with global norms and agreements (Hasanov et al., 2018; Safi et al., 2021). The aforementioned studies were published in Hasanov et al. (2018) and Safi et al. (2021).

The existing body of research pertaining to the impact of globalization on the conservation of the natural environment underscores the significance of adopting a comprehensive and multifaceted strategy. The dual nature of globalization, encompassing both advantageous prospects and challenges for the environment, underscores the importance of collective endeavors at the global scale, environmentally conscientious actions, and proactive

governance. These measures are crucial for harnessing the benefits of globalization while mitigating its detrimental impact on the natural ecosystem. In the context of an ever more interconnected global society, a subject of paramount significance in both scholarly inquiry and policy deliberation pertains to the intricate interplay between economic advancement and the safeguarding of the natural environment.

2.3. Literature Gap

The literature examining the interplay between eco-innovation, globalization and environmental sustainability often focuses on these factors in isolation. While there is a substantial body of research exploring the positive impact of eco-innovation on environmental sustainability and, separately, the role of globalization in shaping economic growth, there is a notable gap in the literature that holistically integrates these elements. This study addresses this gap by investigating the complex interactions and interdependencies among eco-innovation, globalization and their combined effects on environmental sustainability, specifically within emerging countries. By delving into how globalization may strengthen or weaken the positive impact of eco-innovation on environmental sustainability, this research offers a more nuanced and comprehensive understanding of the dynamics at play. Furthermore, the majority of existing studies tend to concentrate on specific regions or sectors, neglecting the potential heterogeneity in the impact of eco-innovation globalization across different countries and industries. This research explicitly focuses on emerging countries, which encompass a diverse range of economic structures, environmental policies, and innovation capabilities. By homing in on this specific group of nations, the study provides a valuable contribution by offering insights that can be applied to a significant portion of the global economy.

3. METHODOLOGY

3.1. Theoretical Framework

The theoretical background of a research study is based on the theoretical frameworks of environmental sustainability, which reflect the idea of maintaining a balance between economic growth, social well-being, and environmental conservation. It is often guided by principles such as the triple bottom line (people, planet, and profit) and the need to address climate change, resource depletion, and other ecological challenges. The concept of complementarity is central to understanding how eco-innovation and globalization interact in this study. Within the scope of this discourse, the concept of complementarity pertains to the idea that the advantageous effects of a certain component are enhanced when combined with another factor. The objective of this research is to examine the potential synergies between eco-innovation and globalization in enhancing environmental sustainability. The concept of "eco-innovation" refers to the systematic approach of creating novel environmentally sustainable technology, products, and practices, followed by their effective adoption and utilization. The term "eco-innovation" refers to the methodical process of developing new environmentally sustainable technology, products, and practices, then effectively adopting and utilizing them. Theoretical frameworks within the realm of eco-innovation encompass the "Porter Hypothesis". This paradigm posits that the implementation of stringent environmental regulations has the potential to foster innovation, resulting in improved environmental outcomes and economic benefits. The theory of globalization examines the interconnectedness of nations in relation to trade, investment, the transmission of information, and cultural interchange. When examined from this perspective, globalization serves as a middleman in the transmission of information pertaining to eco-innovation, including technology and optimal methodologies. The correlation between globalization and eco-innovation serves as an exemplification of the "Globalization Hypothesis," which posits that the escalation of worldwide trade can potentially expedite the advancement of environmentally-friendly technologies. Based on theory and prior research, this study formulates hypotheses about the relationships between these variables. For example:

- *H_1: Increased eco innovation ($\lambda_2 > 0$) is associated with higher environmental sustainability.*

- *H_4: Increased globalization ($\lambda 3 > 0$) is associated with lower environmental sustainability.*
- *H_5: Globalization (GLOB) strengthens the association between eco innovation and environmental sustainability ($\lambda_5 > 0$).*

By formulating these hypotheses, we provide a clear framework for testing the interactions between eco-innovation and globalization in affecting environmental performance in emerging countries. These hypotheses guide our statistical analysis and help you draw meaningful conclusions about the role of these factors in shaping eco-innovation outcomes.

3.2. Model Specification and Data

The model specification is given as follows:

$$ES_{i,t} = \beta 0 + \beta_1 GDP_{i,t} + \beta_2 EI_{i,t} + \beta_3 GLOB_{i,t} + \beta_4 REC_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where ES represents the level of environmental sustainability, EI represents eco innovation, GLOB represents the level of globalization, REC represents renewable energy consumption. In this model, we are trying to explain the level of environmental sustainability (ES) in emerging countries as a function of eco innovation, globalization, and control variables.

Further, this study adds an interaction term between Globalization and Eco-Innovation (GLOB*EI), which captures how the combination of globalization and eco-innovation affects the level of eco-innovation. To gauge the combined role of globalization and eco-innovation in affecting CO2 emissions, the interaction term (GLOB* EIN) is included in the model. The extended model 2 is given as:

$$ES_{i,t} = \lambda 0 + \lambda_1 GDP_{i,t} + \lambda_2 EI_{i,t} + \lambda_3 GLOB_{i,t} + \lambda_4 FD_{i,t} + \lambda_5 (GLOB * EI)_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where, the interactive term (GLOB*EIN) captures the joint effect of these two factors on the environmental sustainability emissions. The interactive term allows us to assess whether the combination of globalization and eco-innovation has a different impact on the outcome variable compared to what would be expected based on their individual effects.

This study uses eco innovation, globalization as explanatory variables. The study uses GDP as a control variable. Eco-Innovation (EI) represents the level of eco-innovation in emerging countries. It can be measured using indicators such as Research and Development (R&D) expenditure in green technologies, the number of patents related to environmental technologies, or any relevant eco-innovation index. Globalization represents the degree of globalization in emerging countries. Financial Deepening represents the level of financial deepening in emerging countries. We take the natural logarithm of each variable. The description, unit, and sources of variables are given in Table 1.

Table 1. Variables units and sources.

Variable	Description	Units	Sources
$CO2_{i,t}$	Carbon emissions	Metric tonnes of CO2	World Bank (2021)
$GLOB_{i,t}$	Globalization	Index value	This study constructs a new economic globalization index by taking into account trade flows, FDI, and portfolio investment
$GDP_{i,t}$	Gross domestic product	Constant US dollars, 2010	World Bank (2021)
$REC_{i,t}$	Renewable energy consumption	% of total energy consumption	World Bank (2021)
$EI_{i,t}$	Eco-innovation	% of all technologies	OECD (2021)

3.3. Data Collection and Analysis

This study collects data on CO2 emissions, globalization, GDP, and control variables (Gross Domestic Product and renewable energy consumption) for a sample of ten emerging economies such as Brazil, China, Columbia, India,

Indonesia, Malaysia, Mexico, the Philippines, South Africa, and Thailand. The time period for this study is 1990 to 2021. The descriptive statistics of the variables are given in Table 2:

Table 2. Descriptive statistics.

Variable	Mean	Std. dev.	Min.	Max.
CO2	4.715	1.465	1.955	8.721
GLOB	3.629	0.568	2.194	4.399
GDP	26.625	1.558	23.016	30.485
EI	8.165	2.073	3.091	13.316
REC	0.174	0.131	0.091	0.373

3.4. Analytical Techniques

3.4.1. Diagnostic Tests

Since most of the panel data series are cross-sectional dependent (CSD) and the models suffer from the problem of slope heterogeneity (SH), it is imperative to apply advanced co-integration tests. This study utilizes the CSD test, which was established by Pesaran (2004). The Equation 3 of the CSD test is given as:

$$CD^{Pesaran,2004} = \sqrt{\frac{2}{i(i-1)}} \sum_{k=1}^{i-1} \sum_{j=k+1}^{i} T^{k,j} \widehat{\rho^{k,J}} \sim N(0,1) \quad (3)$$

The study uses SH test to investigate heterogeneity of slope in the model. The test equations are:

$$\tilde{\Delta}_{,SH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \quad (4)$$

$$\tilde{\Delta}_{Adjusted-SH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \quad (5)$$

Here, $\tilde{\Delta}_{SH}$ is for delta_tilde and $\tilde{\Delta}_{ASH}$ is the adjusted version.

3.4.2. CIPS Unit Root Test

The Cross-Sectionally Im, Pesaran, and Shin (CIPS) unit root test is conducted to ascertain the stationarity or non-stationarity of time series data. Stationarity is a fundamental requirement in time series analysis since it plays a crucial role in ensuring the accuracy and validity of the models produced. The test equation is given as:

$$\Delta Y_{i,t} = \varphi_i + \varphi_i X_{i,t-1} + \varphi_i \bar{Y}_{t-1} + \sum_{l=0}^{p} \varphi_{il} \Delta \overline{Y_{t-l}} + \sum_{l=1}^{p} \varphi_{il} \Delta Y_{i,t-l} + \tau_{it} \quad (6)$$

Where $\bar{Y}_{t-1}$ and $\Delta \overline{Y_{t-l}}$ shows cross-section averages. Similarly, CIPS equation is provided as:

$$\widehat{\text{CIPS}} = \frac{1}{\text{N}} \sum_{\text{i=1}}^{\text{n}} \text{CADF}_{\text{i}} \quad (7)$$

In Equation 4, CADF is the cross-sectional augmented dickey fuller is obtained from Equation 3.

3.4.3. Westerlund Co-integration Test

The Westerlund co-integration test is used to examine whether there exists a long-term relationship (cointegration) between two or more non-stationary time series variables. The Westerlund (2007) cointegration test can be employed to ascertain the presence or absence of long-term relationships among the variables under consideration. For instance, the examination of the long-term impact of factors such as wealth redistribution, green innovation, and other variables on carbon dioxide emissions can be undertaken. The Westerlund test uses the following test statistics:

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (8)$$

$$G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (9)$$

$$P_{\tau} = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad (10)$$

$$P_{\alpha} = T\hat{\alpha} \quad (11)$$

Where $SE(\hat{\alpha}_i)$ represents the standard error of $\hat{\alpha}_i$.

3.4.4. Cross-Section Augmented Autoregressive Distributed Lag (CS-ARDL) Model

This study used CS-ARDL approach, popularized by Chudik and Pesaran (2013), to estimate the long-term and short-term relationships between variables when there are cross-sectional dependencies. It accounts for heterogeneity across cross-sectional units. This co-integration approaches has been used in the majority of the studies published in the literature. These first-generation co-integration approach treat the cross sections as if they were completely independent of one another. There may be a strong link between cross-sectional error terms because of globalization. This could call into question the idea that cross-sectional error terms are independent, which is what most co-integration techniques assume. The general equation is given below as:

$$\Delta CO2_{i,t} = \varphi_i + \sum_{l=1}^{p} \varphi_{il} \Delta CO2_{i,t} + \sum_{l=0}^{p} \varphi_{il}' \bar{X}_{s,i,t-l} + \sum_{l=0}^{1} \varphi_{il}' \overline{CA}_{i,t-l} + \varepsilon_{i,t} \quad (12)$$

Where, CS is for cross-section averages and it is $\overline{CA}_t = (\Delta\overline{CO2}_t, \bar{X}_{s,t}')'$. Moreover, X is for independent variables.

4. RESULTS AND DISCUSSION

Prior to conducting estimations for models, we examine the cross-sectional dependence (CSD) of variables and the slope heterogeneity (SH) in models. To achieve these objectives, we employ the CSD test, which gained prominence through its adoption by Pesaran (2004), as well as the SH test, which gained recognition following its development by Pesaran and Yamagata (2008). Table 3 presents the results of the CSD test. The statistical significance of the CSD-Statistic for each variable implies that, irrespective of the chosen nation, there exists a connection among all variables. In other words, all variables exhibit cross-sectional dependence. In light of the presence of cross-sectional dependency, it is imperative to consider this interdependence in our statistical analysis. Failing to do so may result in biased findings, which would be deemed undesirable. The lower section of Table 3 presents the results pertaining to slope heterogeneity, which provides a comparison of both models.

Table 3. Results of cross-section dependence and slope homogeneity tests.

Variables	CD-statistic	Correlation
CO2	16.17***	0.49
GDP	124.53***	0.93
EI	3.21**	0.40
GLOB	77.26***	0.63
REC	40.66***	0.57
Slope homogeneity test		
Models	$\tilde{\Delta}$	$\tilde{\Delta}_{Adjusted}$
Model-1	14.438***	12.287***
Model-2	16.713***	13.614***

Note: **, *** is for level of significance at 5 and 1%.

The scope of this analysis is restricted to utilizing the Im, Pesaran, and Shin (2003) panel unit root test due to its ability to address the challenges posed by cross-sectional dependency and slope variability. Given the presence of cross-sectional dependency across variables and the existence of slope heterogeneity in all models, this investigation is limited to utilizing this particular test. Table 4 presents the outcomes of the panel unit root test. The results suggest that the variables exhibit a combination of integration orders.

Table 4. Results of unit root test.

	I(0)	I(1)	Level	First- difference
CO2	-2.027*	-	I(0)	-
GDP	-1.704	-3.585***	-	I(1)
EI	-1.328	-2.836***	-	I(1)
GLOB	-1.68	-3.214***	-	I(1)
REC	-1.405**	-2.927***	-	I(1)

Note: *, **, *** is for level of significance at 10, 5 and 1%.

This study uses Westerlund methodology, which is seen as more favorable than alternative cointegration methods due to its ability to account for CSD of variables, incorporate SH in all models, and accommodate mixed orders of integration of variables. Table 5 presents the results of the Westerlund test. The group statistics and panel statistics demonstrate the presence of a strong association between the variables, indicating a state of stable equilibrium over an extended period of time. The calculation of the error correction terms for both models incorporates the value of Pa, leading to the formula Pα= T. Consequently, the term used to account for errors is calculated as -11.483 divided by 31, resulting in values of -0.37 for model 1 and -0.40 for model 2.

Table 5. Results of Westerlund (2007) cointegration test.

Models	Gt	Ga	Pt	Pa
Model-1	-3.007***	-16.715**	-19.208***	-11.483***
Model-2	-2.855 ***	-17.548*	-18.417***	-12.292**

Note: *, **, *** is for level of significance at 10, 5 and 1%.

In the next step, we proceed to estimate all three models. To serve this purpose, this study employs CS-ARDL method. Table 6 has some interesting results. The results show that GDP and GLOB positively affect CO2 emissions in both models. To be specific, long-run elasticities of GDP and GLOB are 0.813% and 0.317%, respectively (model 1). These findings underline a challenge that policymakers face in the pursuit of environmental sustainability. While economic growth is essential for improving living standards, it is often linked to higher carbon emissions. This highlights the importance of implementing strategies that decouple economic growth from environmental degradation. Such strategies might include investing in cleaner technologies, promoting energy efficiency, and transitioning to renewable energy sources.

Second, an increase in eco-innovation (EI) decrease CO2 emissions in emerging countries. To be specific, long-run elasticities of EI is -0.218% (model 1). These results underscore the potential for eco-innovation to play a crucial role in mitigating environmental impacts. Eco-innovation involves the development and adoption of environmentally friendly technologies and practices, and hence, promoting innovation can be instrumental in achieving lower CO2 emissions. The negative impact of eco-innovation on CO2 emissions in emerging countries signifies a promising shift towards more sustainable and environmentally responsible practices. This finding indicates that as these countries embrace eco-innovation, which involves the development and adoption of environmentally friendly technologies and practices, they are effectively reducing their carbon emissions. Eco-innovation often leads to the introduction of cleaner and more efficient technologies, the optimization of resource use, and the adoption of renewable energy sources. By lowering the intensity of their emissions from their economic activities, emerging countries are demonstrating a commitment to reducing their environmental footprint while maintaining economic growth. Policymakers and businesses in these nations are increasingly recognizing the importance of eco-friendly practices, and this shift towards sustainability has the potential to not only mitigate the harmful effects of climate change but also foster new economic opportunities and industries related to green technology and clean energy. In sum, the negative impact of eco-innovation on CO2 emissions is a positive sign of progress towards a more environmentally conscious and sustainable future in emerging countries.

Third, an interaction term between globalization and eco innovation is included (model 2). The coefficient of interaction term is positive, which indicates that globalization (GLOB) strengthens the association between eco innovation and CO2 emissions. Globalization can facilitate the transfer of knowledge, technologies, and best practices across borders. In the context of eco-innovation, this means that a globalized world can promote the adoption of environmentally friendly technologies and practices more effectively. Nations that engage in active participation in global trade and knowledge exchange are likely to be more advantageous in harnessing the advantages of eco-innovation, specifically in terms of mitigating their carbon dioxide emissions. The negative coefficient of the interaction variable between globalization and eco-innovation with respect to CO2 emissions is an important finding that shows how globalization, eco-innovation, and CO2 emissions are all connected in complex ways in emerging countries. The aforementioned discovery underscores the intricate correlation between those variables and the concept of environmental sustainability. This discovery implies that the collaboration between globalization and environmentally conscious innovation has the potential to contribute to a decrease in CO2 emissions. Globalization facilitates the adoption and implementation of environmentally friendly technologies and practices by nations, enabling the cross-border exchange of knowledge, technologies, and best practices. Due to the heightened accessibility of sharing ideas and technologies in a globalized society, there exists a negative coefficient for this collaborative effort, indicating a noticeable influence on reducing carbon emissions. This phenomenon not only facilitates the rapid dissemination of eco-innovation but also promotes the widespread and effective use of environmentally sustainable technologies. The main point of the negative interaction phrase is to say that if the positive effects of globalization and eco-innovation are used correctly, they can help member countries of emerging nations reduce their CO2 emissions and make the environment more sustainable. This assertion holds validity solely under the condition that they be properly harnessed. This statement underscores the importance of international collaboration and knowledge exchange as effective means of solving global environmental concerns.

Table 6. Results of CS-ARDL estimator (Dependent variable: CO2).

Variables	Model-1	Model-2
GDP	0.813* [0.041]	0.528* [0.038]
GLOB	0.317** [0.014]	0.282* [0.061]
EI	-0.218** [0.061]	-0.209** [0.047]
REC	-0.103** [0.031]	-0.116** [0.075]
GLOB*EI	---	-0.041*** [0.004]

Note: *, **, *** is for level of significance at 10, 5 and 1%. [] presents standard errors.

5. CONCLUSION AND POLICY IMPLICATIONS

The interplay between environmental sustainability and globalization is a crucial area of inquiry in contemporary scholarship; however, it remains largely underexplored. Notwithstanding the ongoing impact of globalization on economies and international trade dynamics. The CS-ARDL model is used to estimate the long-term and short-term relationships between variables when there are cross-sectional dependencies. The results show that GDP and GLOB are positively related to CO2 emissions. However, eco-innovation is negatively related with CO2 emissions. The interaction term between globalization and eco-innovation is positive and significant, which indicates that globalization strengthens the association between eco innovation and CO2 emissions.

The finding that eco-innovation has a detrimental effect on CO2 emissions in countries belonging to the emerging nations is a significant revelation with profound implications for the preservation of the environment. The outcomes observed are proof that countries are successfully reducing their carbon emissions through the use of

environmentally innovative technology and practices, according to the aforementioned facts. Eco-innovation often involves the advancement of novel technologies within several domains, including but not limited to renewable energy, energy efficiency, waste management, sustainable agriculture, green transportation, and related sectors. The aforementioned technologies are designed with the objective of reducing the carbon emissions associated with diverse industries and facilitating the advancement of environmentally conscious and sustainable methodologies. The observation that eco-innovation has a detrimental impact on CO2 emissions implies that the adoption of environmentally friendly technologies by nations leads to a reduction in the intensity of their economic endeavors. This suggests that they are producing commodities and services with reduced amounts of carbon emissions per unit of production. Furthermore, eco-innovative solutions encompass a range of strategies, such as the adoption of energy-efficient manufacturing processes, the utilization of carbon capture technologies, the deployment of sustainable supply chain management practices, and the integration of renewable energy sources. These measures will not only result in a reduction of emissions, but they will also foster a greater sense of responsibility towards the management and conservation of our resources.

To sum up, the negative impact of eco-innovation on CO2 emissions in emerging countries reflects a commitment to sustainable development, environmental stewardship, and responsible resource management. These findings underscore the importance of continued investment in eco-innovation and the promotion of green technologies and practices as integral components of global efforts to combat climate change and promote environmental sustainability. Eco-innovation not only offers a path to reduced emissions but also fosters a more sustainable and prosperous future for emerging countries and the world.

The study finds that globalization strengthens the association between eco innovation and CO2 emissions. Globalization can facilitate the transfer of knowledge, technologies, and best practices across borders. In the context of eco-innovation, this means that a globalized world can promote the adoption of environmentally friendly technologies and practices more effectively. This discovery implies that the collaboration between globalization and environmentally conscious innovation has the potential to contribute to a decrease in carbon dioxide (CO2) emissions. Globalization plays a pivotal role in promoting the acceptance and implementation of environmentally sustainable technologies and practices among nations, as it promotes the cross-border flow of knowledge, innovations, and best practices. In light of the increased ease of exchanging ideas and technologies in a globalized society, it is evident that there is a negative correlation between this collaborative endeavour and the reduction of carbon emissions. This phenomenon not only enables the swift diffusion of eco-innovation but also encourages the extensive and efficient use of environmentally sustainable technologies.

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