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ABSTRACT

It is well recognized that countries' economic growth processes structurally shift from the agricultural sector to the industrial sector and, accordingly, the service sector. Premature deindustrialization, on the other hand, refers to the situation in which the transition from the industrial sector to the service sector occurs earlier than the transformation of the developing countries in the structural transformation process that these countries underwent in the 20th and 21st centuries. Although the shift from the industrial to the service sectors is typically seen as a positive thing for the environment, it is still unclear how the transformation that took place prior to the industrialization process's maturity period, or the loss of technological advancements obtained from the industrial sector, will affect the environment. Based on this, the purpose of this study is to explore at the environmental impacts of deindustrialization in both industrialized developed countries and developing countries which are accepted as risky countries in terms of premature deindustrialization. In order to do this, the recently developed panel non-linear ARDL approach is used, and the potential asymmetry between the industrialization process and environmental deterioration is thus investigated. The results show that both country groups experience an increase in environmental deterioration as a result of the industrialization process (positive shocks of industrialization). Conversely, the deindustrialization process (negative shocks of industrialization) slows down environmental deterioration in developed nations while speeding it up over time in developing nations. Therefore, the results show that premature deindustrialization has long-term negative effects on environmental quality.

Keywords: Premature Deindustrialization; Structural Transformation; Carbon Emissions, Environmental Degradation; NARDL

1.Introduction

Today’s global economic amelioration has transitioned through multiple stages. Before the industrial revolution, agriculture was the primary source of economic development across developed and developing nations. After the industrial revolution or during the post-industrial tenure, economic growth in the form of gross domestic product (GDP) has become profoundly dependent on the service sector (Begg, 1993; Gemmell and Wardly, 1990; Zhao et al., 2017; Zhao and Tang, 2018). The development of agricultural enterprises, entrepreneurship in agriculture and commercialization of agricultural enterprises brought in a new era of economic growth. As the inputs from the agriculture sector became more available, the need for a pristine mode of growth emerged, which triggered the industrial revolution. Apart from the availability of agricultural raw materials as inputs, the advancement of technology, development of

human capital and availability of natural resources in the form of hydrocarbon-based petroleum boosted industrialization across many developed nations. The industrial revolution materializes due to the growth of industries that are export-oriented manufacturing enterprises and that have higher contributions to the real GDP of a territory. A transition from an agriculturally developed economic system to an industrialized economy unleashes dynamic structural changes where economic growth gets emphasized by various exogenous factors. A similar structural change can also materialize when a particular economic system transitions from industrialization to a service-sector-oriented economy (Destek, 2021). Due to the transitions and structural reformation, economic growth receives a positive shock as it grows exponentially (Matthess et al., 2020; Zhou et al., 2021). However, burgeoning economic growth can unleash negative externalities on earth's ecosystem, which leads to environmental dilapidation, oscillations in the environmental system and foster a rise in the atmospheric temperature (Hossain et al., 2023; Hossain et al., 2022; Jahanger et al., 2023). It is apparent from the recent literature that during the industrial revolution, most countries ignore the environmental security issues by prioritizing economic growth, which leads to an incessant discharge of toxic gases, more specifically CO2 (Naeem et al., 2023; Song et al., 2022; Voumik and Ridwan, 2023). This stage is widely known as the scale effect that involves excessive consumption of agricultural raw materials, hydrocarbon-based petroleum (i.e., fossil fuels in the form of coal, oil, and gas) and other ecosystem services. The rampant consumption of ecosystem services can have a deleterious impact on the environment, and in the long-term the negative effects may outweigh the positive benefits of economic growth. It has been theoretically established that economic activities should be a boon for environmental amelioration after the scale effect and during the post-industrial period. This theoretical underpinning is widely known as the Environmental Kuznets Curve (EKC) hypothesis, postulated by Grossman and Krueger (1995). If this is true, the EKC curve demonstrates an inverted-U-shaped form. However, if the growth furthers the environmental dilapidation, then to avoid a greater risk of both economic and environmental costs, it is judicious to thwart the level of industrial development by detrending the upward movement of industrial development. In theory, this concept is known as "deindustrialization".

The concept of "deindustrialization" became popular during the post-industrial period as the service sector emerged with immense potential to boost economic growth. Deindustrialization, yet a highly debated concept but an interesting one (Di Meglio et al., 2018), captures the dynamic structural change that a particular economy witness as it curbs its industrial development and emphasizes more on the service sector development. A tremendous economic shift, in the form of the movement of the labor force from the industrial sector to the service sector, is noticed as a country (i.e., most developed nations) adopts deindustrialization as an economic and environmental intervention (Rowthorn and Ramaswamy, 1997). In the context of the developed yet highly polluting economies (i.e., the USA, Japan, Canada), more people work in the service sectors than in the manufacturing ones, leading us to argue that

the manufacturing jobs in these nations are expensive from the firm's point of view, given that firms have to pay high wages to their employees, where most of them are skilled labors. This creates fewer job opportunities for the inbound workers and more employment facilities for the outbound workers. This breeds a type of economic deprivation for those workers who are forced to join the service sector. As this process continues, the service sector of these developed nations grows even faster than the industrial sector. Industrial development continues indirectly since it primarily depends on labour availability at lower wage rates across other developing and emerging countries. For instance, China has become one of the most desirable destinations for the rich global north in terms of cheap labor that aids these rich nations in cost-effectively producing value-added products. The Chinese influence is the key to the south-south trade and development that has introduced China as a brand and an inevitable player in the global market. The distribution of work and resources facilitate both south-south and north-south trade and collaboration; however, it also brings tensions among many emerging nations regarding their share of the overall global GDP. Big economies like the USA obtain most of their GDP from the service sector. For example, in 2021, the USA received 77.6% of its GDP from the service sector, whereas the industrial sector contributed only 17.88% (Statista, 2023a). Similarly, in 2020, Japan obtained around 70% of its total GDP from the service sector by pushing the industry sector to a second position, contributing only 29% of the total GDP (Statista, 2023b). It is apparent that the rich and industrialized economies have already excelled in their respective industrialization, and at the post-industrial stage, they have an extensive focus on the service sector. However, many developing nations, where these nations are yet to achieve sufficient cumulative economic growth followed by industrialization, are focusing more on service sectors by following the footprint of the developed countries. This indicates that developing nations are more concerned about gaining economic growth via the development of the service sector and ignoring the development of the industrial sector. This phenomenon of emphasizing the service sector over industrial development when industrial development is yet to produce sufficient economic growth for a nation is known as "premature deindustrialization". Dani Rodrik first postulated this term in 2015 in his pioneering work on how industrialization affects income across developing countries (Rodrik, 2016). Deindustrialization can be a boon for both economic and environmental amelioration among high-income nations (see **Figure 1** for the deindustrialization trend of the developed countries); however, it can be detrimental for the middle and low-income generating countries (Bogliaccini, 2022; Liu and An, 2023; Vu et al., 2021). This is because developing nations are supposed to obtain a threshold growth and income level via industrialization. However, without obtaining that threshold level through automation, these nations are redirecting their development path toward the service sector, which triggers the risk of premature deindustrialization.

[Insert Figure 1]

The effects of industrialization, industrial value addition and urbanization on economic development and environmental degradation have been assessed predominantly in streaming literature. Most studies postulate that industrialization, industrial output generation and urbanization boost economic development, whereas these actions are deleterious for environmental sustainability (Grodzicki and Jankiewicz, 2022; Mignamissi and Djeufack, 2022; Sikder et al., 2022). Globalization, north-south trade, and south-south trade initiatives have boosted the industrial manufacturing outputs, diversified the export basket of many developing nations, and created new employment opportunities for the mass of skilled and semi-skilled workforce of these nations (van Neuss, 2018). Globalization has also spurred the idea of premature deindustrialization among many developing countries (i.e., China, Asian tigers, and other emerging south Asian countries), and it is a risk for these nations since it provokes income inequality, gender inequality in the workplace, and in worse scenarios, it can lead these nations that have adopted premature deindustrialization into the vicious cycle of poverty (Greenstein and Anderson, 2017; Kollmeyer, 2018; Taguchi and Tsukada, 2022). Since the developed economies have obtained a threshold level of economic growth, also labeled as steady-state economic growth, the transition from an industrialized economic system to a service sector-oriented economic system brings a very marginal negative impact on the overall economic system. This is because deindustrialization helps thwart environmental degradation and restore biocapacity surplus, which can outweigh the negative effects of deindustrialization since rich nations have to spend less on fixing the environmental damages that originated from industrialization. However, in the context of developing countries, premature deindustrialization can be highly risky both economically and environmentally (Rodrik, 2016). Premature deindustrialization creates impediments due to which the nations that adopt this intervention do not have the speed to generate sufficient income in the contemporary period and in the long run. Consequently, it unleashes poverty, income inequality, unemployment, and other severe macroeconomic issues. The effects of premature deindustrialization on the environment can even be fatal. The environment should return to its earlier stage of biocapacity (i.e., the biocapacity level before industrial sector development) during the post-industrial stage. However, due to premature deindustrialization, the environment does not reach the point at which it can share a symbiotic relationship with economic growth. The streaming literature on the effects of premature deindustrialization on environmental degradation seems to be very nascent and equivocal. For instance, Ullah et al. (2020) noted that premature deindustrialization is a boon for environmental protection in Pakistan, a developing nation undergoing a colossal debt burden. Tang et al. (2022) studied the effect of premature deindustrialization on CO2 emissions in the context of China and postulated that premature deindustrialization shares an inverted-U-shaped relationship with the environment in China. Contrarily, Destek (2021) unveils that industrialization is deleterious for the environmental sustainability in Turkey, whereas premature deindustrialization does not have a meaningful impression on the ecological footprint in the studied nation. The growth of the service sector, the rising

share of the service sector in the global GDP, the tendency of deindustrialization by the developed countries, and the tendency of risky premature deindustrialization by the developing nations can have colossal economic and environmental consequences globally. In theory, although it has been postulated that premature deindustrialization can be fatal for developing nations, the empirical evidence against this claim is very limited.

Based on the discussion above, we claim that our study is novel and original. We claim our novelty on the following grounds: 1) The effect of industrialization on environmental degradation has been assessed by many studies across both developed and developing nations (Ali et al., 2023; Azam et al., 2022; Mahmood et al., 2020; Sikder et al., 2022); however, the effects of premature deindustrialization on environmental degradation focusing on a global sample of both developed and developing nations have not been estimated before. Our study is the first one in this domain that addresses an important research question of why a structural change in the form of premature deindustrialization can be fatal for environmental protection across many developing nations. The outcome of this research question will help formulate workhorse models and policies of how to balance the development of industrial enterprises and service sectors in the long-term, specifically in the context of developing nations. 2) The second significant contribution of this study is that we unveil how a positive and a negative shock on industrialization affect the environmental balance among the globalized developed and developing nations. No earlier studies have assessed the asymmetric effects of industrialization (i.e., deindustrialization) taking a large global sample before. To obtain this objective, we have deployed the panel non-linear ARDL (NARDL) model that can capture how a change in shock affects the asymmetry of information related to a dependent variable. 3) The third major contribution of this paper is that we present a comparative analysis of how the developed and developing nations respond regarding environmental pollution as we put positive and negative shocks on industrialization. This unique contribution will help find what is best for the selected pool of nations regarding their environmental well-being if they aspire to industrialize, deindustrialize, or reindustrialize in the future.

The remainder of this paper unfolds as follows: Segment 2 delineates the existing literature from the streaming scholarship and points out the gaps in the streaming literature. Segment 3 discusses research design, methods, and empirical approaches, whereas Segment 4 discusses empirical findings. Finally, Segment 5 warps this empirical endeavor with the conclusion and policy implications.

2. Literature Review

Concerning the environmental quality assessment, the existing literature covers the empirical connection for most of the economic, financial, geographic, and industrial components. In this section, we provided the relevant literature concerning the association between environmental quality and the study variables.

With reference to economic growth, the recent study by Ali et al. (2023) analyzes the influence of GDP on CO2 emissions in the Asian emerging economies during 1975-2020. Using AMG estimator, the study found that GDP played a positive role in environmental quality degradation. Besides, the study reports that GDP2 is adverse, while GDP3 is positively associated with CO2 emissions – validating the N-shaped EKC paradox. Besides, there are several variables that could enhance emissions levels: yet, the GDP plays an increasingly mediating role in enhancing environmental degradation (Razzaq et al., 2023). In the case of Bangladesh, Chen et al. examined the extended period from 1972Q1-2020Q4 and concluded that economic growth in petroleum consumption significantly increases the level of carbon emissions in the country. Similar results are achieved by the recent study of Liu et al. (2023) in the case of China while using the ARDL approach. Since the industrial expansion is one of the critical factors of economic growth in the region. Therefore, Khalfaoui et al. (2023) revealed that industrial expansion increases economic growth, which further boosts the level of CO2 emissions in the G7 region. Besides, the study also validates the two-way granger causality connection between the variables. Moreover, there is a number of studies available in the literature that provided empirical evidence for the positive connection between the variables and offer appropriate measures to achieve environmental sustainability in case of various developed and developing regions (see, for instance, Su et al., 2023; Yang et al., 2021; Zhang et al., 2021; Osobajo et al., 2020; Li and Li, 2020; Khan et al., 2020; Dong et al., 2020; Murthy et al., 1997).

Since the last two decades, it has been observed that urbanization is rapidly increasing in different parts of the world. However, the existing literature covers its significance in environmental quality. For instance, the recent study of Raihan et al. (2022) empirically investigates the nexus between OC2 and urbanization along with other economic and energy-related variables. Using ARDL bound testing approach, the study found that urbanization significantly increases the level of CO2 emissions in the region. Besides, Wang et al. (2022) claimed that economic growth in the presence of urbanization boosts environmental degradation in a panel of 134 economies. In the case of the BRI regions, Wei et al. (2023) validate the progressive impact of GDP in CO2 in the presence of multi-dimensional urbanization and foreign direct investment. However, the magnitude of urbanization in CO2 emissions is stronger in the long run than in the short run (Chien et al., 2022). In addition, Rehman and Rehman (2022), Sun et al. (2022), and Siqin et al. (2022) reports that urbanization and energy consumption are the leading factors of emissions. Besides, both the bidirectional and unidirectional causal connection between the variables under-discussion are validated in the case of developing economies (Sikder et al., 2022; Sufyanullah et al., 2022). In contrast, the recent studies of Liu et al. (2023) reveal no critical influence of urbanization, while Balsalobre-Lorente et al. (2022) argued the adverse influence of urbanization on CO2 emissions.

In terms of human capital, the existing literature is rich for different countries and regions. In the case of seven OECD economies, Khan et al. (2021) assessed the period

from 1990-2018 by using the CS-ARDL approach. The estimated results indicate that human capital plays a critical role in mediating the negative connection between fiscal decentralization and emissions. Similarly, the empirical results of Hao et al. (2021) also depicted that human capital significantly improves environmental quality in the G7 economies. In the case of the ASEAN economies, Haini (2021) provided contrary results by concluding the positive role of human capital in environmental quality degradation. However, the study validates the adverse impact of technology innovation on CO2. Still, the results are found to vary from industry to industry. The recent study by Wang et al. (2023) covers a global sample of 208 countries from 1990-2018. The examined results unveil the existence of EKC in the region. However, the study reports the heterogeneous influence of human capital on the pre-and post-EKC turning points. Usman et al. (2023) reveal the although economic growth and natural resources are the significant drivers of emissions: yet, human capital, renewable energy, and technological innovations are playing a critical role in limiting emissions, which is unidirectionally connected between variables (Saqib et al., 2023). Since most of the studies report energy consumption as a vital source of emissions, Churchill et al. (2023) asserted that human capital reduces the level of energy consumption, enhances environmental efficiency convergence (Appiah-Twum and Long, 2023), and ultimately leads to a reduction the level of emissions in the region (Zhu, 2023).

Among the priorly discussed variables, industry value added and employment play a significant role in determining environmental quality. For instance, Okere et al. (2021) examined the influence of industry value added along with other financial instruments on CO2 emissions during 1971-2018. Using the Dynamic ARDL approach, the study found that industry value added plays a significant negative role in environmental degradation. Besides, the agricultural value added is also adversely related to excessive carbon emissions (Raza et al., 2021). However, the recent evidence of Jebli et al. (2020) indicates that renewable energy is playing a reducing role in the service as well as industry value added. In contrast, the study by Liu et al. (2020) that the value added gained per unit of CO2 pollution embodied increased during 2000-2014. Whereas the value added revealed that the emissions reduction is lowered due to the primary industrial sector (Khan, 2021). In a comprehensive study, Samargandi (2017) concluded that both the industrial and service value added is the significant factor in increased pollution levels in Saudi Arabia, while the agriculture value added is the key remedial measure for environmental sustainability. In the case of employment, the recent study of Rehman et al. (2022) uses the ARDL approach and asserts that an increase in agricultural employment significantly reduces the level of CO2 emissions in Bhutan. Where Collins et al. (2023) reveal that industries that use carbon extensive energy resources could not afford more employment than those industries having energy-efficient resources. Further, Yu and Li (2021) asserted that CO2 trading policies significantly enhance the level of employment dividend in China. However, Bai et al. (2021) suggested that the enhancement of the labor-intensive sectors is favorable for the win-win situation in the country. That is, such promotion leads to economic growth as well as reducing environmental pollution levels.

3. Empirical Strategy

3.1. Model and Data

It is commonly recognized that variables that exacerbate environmental problems, such economic expansion and urbanization, as well as beneficial factors in reducing environmental problems, are considered in research looking at the environmental effects of industrialization and deindustrialization processes (Ullah et al., 2020; Destek, 2021). Additionally, two distinct signs emerge in studies on premature deindustrialization. The first indicator is the proportion of added value from the industrial sector to national income, and the second is the proportion of industrial sector employment to total employment (Rodrik, 2016). As a result, two distinct models are developed for the study in order to examine how both elements affected the environment. IVA refers to the model that uses the first indicator, whereas EMP refers to the model that uses the second indicator. As a result, the following empirical models are constructed:

$$CO_{it} = a_0 + a_1 GDP_{it} + a_2 URB_{it} + a_3 HC_{it} + a_4 IVA_{it} + u_{it} \quad (1)$$

$$CO_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 URB_{it} + \beta_3 HC_{it} + \beta_4 EMP_{it} + \varepsilon_{it} \quad (2)$$

where CO implies carbon emissions per capita as a proxy for environmental degradation, GDP indicates real gross domestic product per capita as a proxy for economic growth, URB is urban population share in total population and means urbanization, HC is human capital index and indicating human capital accumulation. In addition, IVA is industrial value added share in GDP and EMP is employment in industry share in total employment and both variables are used as a proxy for industrialization. All variables are used in natural logarithmic form.

[Insert Figure 2]

In regard with sources of variables, the data of CO, GDP, URB, IVA and EMP are obtained from World Development Indicators of World Bank. Further, the data of HC is downloaded from Penn World Table 10.01 of Feenstra et al. (2015). Two different country groups are discussed in the study. The first country group consists of 24 developing countries that are at risk of premature deindustrialization according to Rekha (2022). These countries are Argentina, Belize, Bolivia, Botswana, Brazil, Cameroon, Colombia, Costa Rica, Ecuador, Egypt, Gabon, Ghana, Guyana, Kenya, Kyrgz Republic, Mexico, Mongolia, Morocco, Namibia, Nigeria, Pakistan, Peru, South Africa and Ukraine. The second group of countries is the G-7 countries, representing developed countries. All observed countries are presented in Fig. 2. It can be seen from Fig. 2. that the countries shown in blue are the ones at risk of premature deindustrialization, and the countries shown in green are included in the analysis as developed countries. While the period of 1990-2019, which consists of annual data, is

analyzed for the first group of countries, the period of 1995-2019 is analyzed for the second group of countries due to the lack of data.

3.2. Methodological Framework

To get accurate results for policy suggestions using the panel data approach, the appropriate estimator should be used. Given that practically all nations were affected by the 2008 global financial crisis, Covid-19 pandemic etc. it is assumed that first-generation estimators, which do not account for inter-country dependency, will not produce estimates that can be trusted. Therefore, it is probably important to examine the interdependence across countries, or the cross-sectional dependence, when employing panel data approaches (hereafter, CSD). The CD test created by Pesaran (2004) is used in this study to evaluate the CSD issue. The stationarity process, which is crucial for any econometric forecasts, should also be observed. Since the unit root test to be employed should be a test that also supports CSD, the CIPS unit root test created by Pesaran (2007) is used in the study. Following the preliminary tests, the decision regarding the validity of the long-term relationship between the variables has an impact on the estimate to be utilized. As a result, the ECM-based cointegration test of Westerlund (2007) is used to examine the validity of the aforementioned relationship. The long-term effects of the variables should be investigated if the long-term validity of the link is established. Below are more details on the panel ARDL and panel NARDL approaches used in this direction. The methodological flow can also seen in Fig. 3.

[Insert Figure 3]

3.2.1. Panel ARDL Procedure

We start by using the Pooled Mean Group (hence referred to as PMG) proposed by Pesaran et al. (1999) and assuming that real income, urbanization, human capital, and industrialization have a symmetrical impact on carbon emissions for ELE countries. The error correction term, which is independent of the correlation base and in which the regressors are normally distributed, is the first of the fundamental assumptions of PMG. This implies that the explanatory variable can be thought of as an exogenous variable. Third, the long-term parameters are constant across nations. Second, there is a long-term relationship between the dependent variable and the explanatory variable in the equation. Following equation is used as a main procedure of ARDL approach:

$$y_{it} = \sum_{j=1}^{p} \beta_{ij} y_{i,t-j} + \sum_{j=0}^{q} \gamma_{ij} x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

where y_{it} is dependent variable for panel i, x_{ij} indicates independent variables for panel i, γ_{ij} means the coefficients of independent variables. We also used standard Hausman test to decide the preferable estimator among MG and PMG. In case of the

rejection of null hypothesis for Hausman test, we prefer PMG estimation procedure. The generalized panel ARDL procedure with our main empirical model is as following:

$$\Delta CO_{it} = \beta_{0i} + \beta_{1t} CO_{it-1} + \beta_{2t} GDP_{it-1} + \beta_{3t} URB_{it-1} + \beta_{4t} HC_{it-1} + \beta_{5t} IND_{it-1} + \sum_{J=1}^{M-1} \gamma_{ij} \Delta CO_{it-J} + \sum_{J=0}^{N-1} \gamma_{ij} \Delta GDP_{it-J} + \sum_{J=1}^{O-1} \gamma_{ij} \Delta URB_{it-J} + \sum_{J=1}^{P-1} \gamma_{ij} \Delta HC_{it-J} + \sum_{J=1}^{Q-1} \gamma_{ij} \Delta IND_{it-J} + \mu_i + \varepsilon_{it} \quad (4)$$

where CO is carbon emissions per capita, GDP, URB, HC and IND are economic growth, urbanization, human capital and industrialization, respectively. In addition, it indicates cross sections and t implies time-period.

3.2.2. Panel NARDL Procedure

The traditional ARDL approach may overlook the hidden interactions between the independent and dependent variables in the empirical model since it only takes into account positive shocks of the independent variable. Therefore, utilizing the asymmetric ARDL approach instead of the symmetric Nonlinear ARDL (hereafter, NARDL) approach, which observes relationships, results in a more reliable study. Additionally, much as in this study, it is vital to identify the asymmetrical link because the phenomena of deindustrialization expresses the negative shocks of industrialisation. Empirically, the panel NARDL approach is as follows:

$$\Delta CO_{it} = \beta_{0i} + \beta_{1i} CO_{it-1} + \beta_{2i} GDP_{it-1} + \beta_{3i} URB_{it-1} + \beta_{4i} HC_{it-1} + \beta_{5i}^{+} IND_{it-1}^{+} + \beta_{5i}^{-} IND_{it-1}^{-} + \sum_{J=1}^{M-1} \gamma_{ij} \Delta CO_{it-J} + \sum_{J=0}^{N-1} \delta_{ij} \Delta GDP_{it-J} + \sum_{J=0}^{O-1} \alpha_{ij} \Delta URB_{it-J} + \sum_{J=0}^{P-1} \theta_{ij} \Delta HC_{it-J} + \sum_{J=0}^{Q-1} \theta_{ij}^{+} \Delta IND_{it-J}^{+} + \theta_{ij}^{-} \Delta IND_{it-J}^{-} + \varepsilon_{it} \quad (5)$$

where IND^{+} and IND^{-} represents the positive shocks of industrialization (industrialization process) and the negative shocks of industrialization (deindustrialization process), respectively. The long-run coefficients are computed as $IND^{+} = -\beta_{5i}^{+}/\beta_{1i}$ and $IND^{-} = -\beta_{5i}^{-}/\beta_{1i}$.

4. Empirical Findings

In the initial stage of empirical analysis, the results of the preliminary analyses used in are shown in Table 1. These analyses are conducted in order to choose the method options to be used in the next steps. First, each variable in this setting is subjected to cross-section dependency tests. The null hypothesis, which states that cross-sectional dependence is not valid in all variables for both nation groups, is rejected in light of the findings of the CD test that is used for this purpose. This suggests that a shock involving these variables that happened in any of the observed nations was transmitted to the other countries in the panel. Next, the stationarity of each variable's series is examined using the CIPS unit root test. The results produced here show that

the unit root null hypothesis is accepted for all level values of all variables, but that it is rejected for the first difference forms of the series and the series is stationary.

[Insert Table 1]

The results of the preliminary tests indicate the requirement of looking for the cointegration relationship between the variables and using the cross-section dependence-allowing second generation panel cointegration tests in this process. As can be seen in Table 2, two different country groups and two different models are used to test the validity of cointegration interactions. The validity of the cointegration connection is demonstrated in all models and in both nation groups, according to the findings of the ECM-Based panel cointegration test used in this context.

[Insert Table 2]

The third stage of the empirical analysis, using the traditional ARDL approach and the symmetrical effects assumption, how real income, urbanization, human capital, and industrialization affect carbon emissions and the results are shown in Table 3. The Hausman test is used to compare the mean group (MG) and pooled mean group (PMG) estimators before estimating the effects, and based on the results, PMG is chosen in all models. According to PMG findings, developing nations at danger of premature deindustrialization will see a long-term increase in carbon emissions of 0.862-1,040% for every 1% gain in real income. This discovery is consistent with Xu et al. (2022); Sharif et al. (2023); Liu et al. (2023); Saqib et al. (2023). On the other hand, there is no statistically significant connection between rising urbanization and carbon emissions. In terms of human capital, a 1% increase in human capital accumulation results in a 0.269–0.310% reduction in carbon emissions. Findings from Usman et al. (2023); also confirm that a rise in human capital lowers carbon emissions. Finally, a 1% rise in industrialization causes a 0.501-0.529% increase in carbon emissions for emerging nations. This result supports the findings of Mirza et al. (2022); that industrialization exacerbates environmental harms.

The symmetrical outcomes for developed nations are quite close to those for developing nations. As a result, carbon emissions in industrialized countries rise from 0.534 to 1,086% for every 1% increase in real wealth. Similar to this, industrialization raises carbon emissions by 0.135-0.167% for every 1% increase. On the other side, a 1% increase in human capital accumulation results in a 0.456-0,590% reduction in carbon emissions. In contrast to developing nations, urbanization also contributes to a rise in environmental harm in developed nations. In other words, a 1% increase in urbanization causes a 0.332-0.970% rise in carbon emissions. When short-term

outcomes are evaluated, it is shown that while human capital and urbanization have a negligible impact on environmental degradation, real national income growth and industrialization increase carbon emissions in both country groups.

[Insert Table 3]

Asymmetric interactions are also seen using the panel NARDL approach in addition to symmetric interactions, and the results are shown in Table 4. The Hausman test is used before interpreting the coefficients, and it is discovered that PMG should be chosen above MG, much like symmetric effects. Additionally, the assumption of symmetry is examined for both the long run and the short run. Based on the results, it can be concluded that both country groups have legitimate long-term asymmetrical relationships, but no such relationships exist for the short run.

It has been observed that over the long term, a 1% rise in real national income in developing nations that incur the danger of premature deindustrialization results in an increase in carbon emissions of 0.462-0.96%. A 1% increase in urbanization also results in an increase in carbon emissions of 0.944-1,488%. Environmental pollution increasing impact of urbanization is also validated by Destek and Aydın (2022); Destek et al., (2022). The rise in human capital accumulation minimizes environmental degradation, as projected. When it comes to industrialization, it has been found that the positive shocks of industrialization lead to a rise in carbon emissions. However, it's surprising that the deindustrialization process (also known as the negative shocks of industrialization) results in higher carbon emissions. Deindustrialization also worsens environmental damage more than industrialization, which already had damaging consequences.

[Insert Table 4]

For developed nations, increased urbanization and economic growth over time result in higher carbon emissions. But for every 1% increase in human capital accumulation, carbon emissions are decreased by 0.270-0.421%. When we concentrate on the outcomes of the industrialization process, we observe that industrialization increases carbon emissions, which is consistent with the study's main objective. Contrary to developing nations, developed nations experience a decrease in carbon emissions as a result of deindustrialization.

[Insert Figure 4]

As summarized in Fig. 4, both developed and developing countries are experiencing an accelerated rate of environmental degradation due to economic development and urbanization. Both developed and developing nations can experience environmental damage as a result of economic expansion due to increasing resource consumption, greater industrial production, lax environmental legislation, market failures, and a lack of investment in environmental preservation. Through the adoption of strong environmental legislation and the promotion of sustainable development practices, policymakers must strike a balance between economic growth and environmental protection in order to lessen these adverse effects. Similar to how industrialization can intensify industrial activity in developing and developed nations, urbanization can increase carbon emissions in both due to increased energy use, increased demand for goods and services, lack of alternate transportation options, and lax environmental regulations. It is crucial for decision-makers to support sustainable urban development strategies, such as the construction of energy-efficient buildings, the promotion of alternate forms of transportation, and the enforcement of efficient environmental legislation, in order to lessen these adverse effects. It is also predicted that the growth of human capital will result in a decrease in carbon emissions. Increased human capital can, in fact, lower carbon emissions by promoting greater environmental awareness and understanding, encouraging the development and adoption of sustainable technologies, increasing demand for sustainable goods and services, enhancing decision-making, and boosting workforce productivity. It's crucial to invest in education and skill development, especially in fields related to sustainability and the environment.

When the environmental impacts of industrialization, deindustrialization, and premature deindustrialization are concentrated, it is seen that the industrialization process degrades the environmental quality in all nation groups, which is consistent with the study's primary aim. This result was anticipated. The repercussions of deindustrialization, however, vary between country groups. The deindustrialization trend improves the quality of the environment in wealthy nations. Deindustrialization, particularly premature deindustrialization, exacerbates environmental harm in developing nations. Deindustrialization result in lower carbon emissions in rich nations, but it leads to higher emissions in developing nations because of laxer laws, scarce resources, and a lack of investment in clean technologies and environmental protection.

5. Conclusions and Policy Implications

This study examines how the process of premature deindustrialization has an impact on the environment. The effects of industrialization (positive shocks of industrialization) and deindustrialization (negative shocks of industrialization) on carbon emissions are examined in this direction for developed countries that are said

to be undergoing a healthy deindustrialization process and developing countries that are said to be at risk of experiencing a premature deindustrialization process between 1990 and 2019. The panel is looked at utilizing the NARDL method for the duration. Investigations are also conducted into the effects of economic growth, urbanization, and the accumulation of human capital.

Economic expansion and industrialization speed up environmental degradation in both wealthy and developing nations, according to the results of the panel ARDL test, which looks at symmetric relationships. However, as urbanization grows, environmental issues in wealthy nations only get worse. In both country groups, the increase of human capital improves environmental quality.

The results of panel NARDL analysis, where asymmetric interactions are seen, also show that while human capital buildup reduces environmental degradation for all nations, economic expansion and urbanization raise carbon emissions in both country groups. In terms of industrialization, it has been discovered that both country groups' environmental degradation accelerates as a result of industrialization. The most intriguing discovery is that, contrary to expectations, while deindustrialization lowers carbon emissions in developed nations, it worsens environmental deterioration in less developed nations. Additionally, in emerging nations, the environmental harm brought on by deindustrialization outweighs the harm brought on by industrialization.

Deindustrialization can result in a move towards service-based economies and a decline in heavy industry in developed countries, which will lower carbon emissions. This is due to the fact that developed nations frequently have strict environmental laws and regulations that are upheld, as well as more readily accessible clean technologies and alternative energy sources. In developing nations, things can be different, though. Due to a lack of investment in the industrial sector and the shift to service-based economies, deindustrialization may take place in these nations. This may result in less demand for natural resources and less funding for initiatives to protect the environment. Additionally, poorer environmental laws, penalties, and financial resources for environmental protection and cleanup initiatives are frequently present in developing nations.

In the context of implementing policies into effect, policymakers, particularly in developing nations, can be advised: i) Policymakers can encourage the growth of ecologically friendly industries like waste management, recycling, and renewable energy. This can encourage economic growth and employment creation while minimizing the damaging effects of industrialization on the environment. ii) To stop environmental deterioration and promote sustainable industrial development, developing nations can strengthen their environmental laws and policies. This could involve creating environmental protection organizations, enforcing emissions regulations, and levying penalties for environmental infractions. iii) Policymakers can promote financial support for initiatives aimed at preserving the environment, such as

the creation of renewable energy sources, the preservation of natural ecosystems, and the implementation of waste management plans. iv) To lessen their carbon footprint and the environmental effects of industrialization, developing nations can encourage the development and use of green technology including renewable energy sources, energy-efficient buildings, and sustainable transportation. v) To lessen reliance on a single sector and lessen the effects of economic shocks on the environment, policymakers might encourage economic diversification. This can entail encouraging the growth of new sectors like technology, tourism, and education.

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7. Authors' Contributions

The authors have contributed equally to this work. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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