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NEXUS OF INDUSTRIALISATION AND ENVIRONMENTAL DEGRADATION IN NEWLY INDUSTRIALISED COUNTRIES

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Abstract: Newly Industrialised Countries (NICs) are characterised by rapid industrialisation, economic expansion, and urbanisation. These nations have undergone a transition from predominantly agrarian economies to becoming hubs of industry and manufacturing. Previous studies have shown that industrialisation intensifies environmental degradation, resulting in increased pollution, habitat loss, and resource depletion, posing urgent challenges to global sustainability. The objective of this study is to thoroughly assess the influence of industrialisation on environmental deterioration in 10 NICs (Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkiye) between 2000 and 2019. The study utilised the panel autoregressive distributed lag technique and included important control factors such as renewable energy consumption, foreign direct investments (FDIs), and urbanisation. This study aims to examine the complex relationship between industrialisation and environmental degradation by analysing yearly data. It considered various factors to provide a comprehensive understanding of the intricate dynamics that influence sustainability in emerging nations. The findings highlighted that renewable energy consumption and FDIs eradicated pollution in the short run, while FDIs, industrialisation, and urbanisation undermined environmental quality in the long term. Therefore, to mitigate and prevent the environmental degradation caused by industrialisation, this study suggests that enterprises adopt stringent environmental regulations, embrace sustainable practices, and implement pollution control measures.

Keywords: Industrialisation, environmental degradation, newly industrialised countries, pooled mean group (PMG).

Introduction

Industrialisation has played a pivotal role in fostering economic expansion and progress. However, it has also given rise to substantial environmental concerns. Newly industrialised countries (NICs) have experienced rapid industrialisation, substantial economic growth, and urbanisation (URB), resulting in increased pollution, habitat loss, and resource depletion. World Bank Statistics indicate that NICs represent 48.33% of the global population, comprising 3.83 billion people. Additionally, NICs contribute to over 50% of total global carbon dioxide emissions. Prior studies have shown that industrialisation exacerbates environmental degradation, presenting pressing challenges to global sustainability. Previous scholars have emphasised the significant correlation between heightened industrialisation and adverse environmental consequences, which include increased carbon emissions and declining environmental quality. Gaining insight into the relationship between industrialisation and environmental degradation (END) in NICs is essential for formulating efficient policies and strategies to mitigate the negative impact of industrial development on the environment. This is particularly important given the substantial population and environmental implications of these nations.

Meeting sustainable development goals is one of the primary objectives of any country. Therefore, the discussion on achieving sustainable and environmentally friendly economic development has become one of the top priority topics in economic literature. As

stated in the Sustainable Development Goals established in 2015 by the United Nations General Assembly, countries must take action against environmental pollution while pursuing global economic objectives. However, many countries aim to advance sustainable development and enhance their industrial sector to maximise resource utilisation but overlook END. Therefore, academics, economists, scholars, policymakers, and field experts have intensified efforts to identify the key factors contributing to END while striving to achieve sustainable economic goals.

Many scholars assert that the surge of industrialisation, globalisation, improper URB in industrial sector zones, and unmonitored foreign direct investments (FDIs) focusing only on increasing domestic production are some of the primary drivers of high carbon emissions. They argue that industrialisation and FDIs bring many benefits to host countries, including advanced technology, new knowledge, funding for projects, access to new markets, venture capital, high-return investments, improvements in human capital, and increases in physical capital but contribute to many environmental issues such as carbon emissions, as well as social and cultural challenges. Some researchers have also stated that FDIs are a key factor influencing elevated carbon emissions (Behera & Dash, 2017; Salahuddin *et al*., 2018; Shahbaz *et al*., 2018; Ganda, 2020).

Furthermore, as NICs aim to attract more FDIs to drive industrialisation, they may be inclined to relax environmental standards or offer incentives that enable foreign firms to overlook ecological concerns. The inflow of FDI into extractive industries such as mining, oil, and gas has been linked to deforestation, as well as water and air pollution in several NICs.

Additionally, the growth of FDI-backed industries and factories in urban areas exacerbates issues such as overcrowding, inadequate waste management systems, and increased greenhouse gas emissions, which diminish environmental quality and public health. While FDI can potentially fund greener technologies and practices, the overall trend indicates that prioritising economic gains from foreign investment in NICs often occurs at the expense of END through activities that harm air quality, deplete natural resources, and damage ecosystems. Striking the right balance between attracting FDIs for economic development and implementing stringent environmental safeguards remains an ongoing challenge for policymakers in NICs. Sustainable strategies that incentivise eco-friendly FDIs while discouraging polluting industries are crucial for mitigating environmental damage associated with rapid FDI-driven industrialisation.

However, despite these challenges, FDIs also offer opportunities for green innovations and zero carbon emission projects. Some foreign investments direct funding towards research and development in the industrial sector to identify environmentally friendly energy sources, green technologies, and renewable energy sources that reduce END (Shahbaz *et al*., 2016; Aydemir & Zeren, 2017; Khan *et al*., 2021). Therefore, it is vital to establish a proper mechanism to identify the nexus of FDIs and END in most industrialised countries and determine how FDIs affect the sustainable environmental quality of industrialised countries. Based on this argument, this study focuses on testing the first hypothesis:

H01: Foreign direct investments do not have a significant influence on environmental degradation in newly industrialised countries.

Scholars argue that URB, often seen as a solution to meet the human capital needs of newly established venture capitals, real sectors, and production sectors in countries striving to maximise resource utilisation and reach peak production capacity, creates many social and cultural issues. As urban populations grow, it becomes increasingly difficult to maintain proper waste disposal management systems, efficient land usage, and safe irrigation, among others, all of which contribute to high carbon emissions, generating a range of social, economic, and environmental issues (Iheonu *et al*., 2021; Wang *et al*., 2021; Othman *et al*., 2022; Tang, 2022; Yang *et al*., 2022). Scholars

have proposed several remedial pathways to address environmental challenges. They suggest steps such as proper urban planning and promoting ecological civilisation, which can mitigate many social and environmental problems and ultimately reduce pollution (He & Zhang, 2022). Therefore, the second research hypothesis of this study is:

H02: Urbanisation does not have a significant effect on environmental degradation in NICs.

Most economies today focus on attracting global investments and aim to boost their Gross Domestic Production (GDP) through industrial projects, a process referred to as industrialisation. As a result, industrialisation is often viewed as the pathway to achieving sustainable economic growth. However, as countries advance their industrial sectors, they require more energy to enhance production capacity. This growing demand for non-renewable energy sources has led to an increase in carbon emissions, contributing to END. Thus, the third hypothesis of this study is:

H03: Industrialisation does not have a significant influence on environmental degradation in NICs.

Recognising the environmental hazards of non-renewable energy sources, discussions have shifted towards renewable energy. In line with this new global trend, experts argue that renewable energy positively contributes to environmental quality (Balsalobre-Lorente *et al*., 2018; Majeed & Luni, 2019). The main argument favouring renewable energy sources is their ability to reduce carbon emissions and improve environmental quality. Moreover, renewable resources help protect natural ecosystems while meeting energy demands.

However, there are counterarguments regarding the benefits of renewable energy. Scholars note that unregulated use, inefficient management, and unrestricted exploitation of renewable energy sources can lead to the depletion and pollution of natural resources. For instance, excessive use of water and land for renewable energy purposes reduces both water reserves and usable land. Improper landfilling, inadequate waste disposal, and unsystematic land development systems exacerbate environmental issues. Furthermore, reliance on combustible sources to generate energy may ultimately increase carbon emissions, undermining the goal of reducing END (Al-Mulali *et al*., 2016; Jebli & Youssef, 2017). Thus, the fourth hypothesis of this study is:

H04: Renewable energy has no significant influence on environmental degradation in NICs.

Therefore, it is imperative to examine how industrialisation, FDIs, and URB in NICs have influenced END and to assess whether renewable energy sources positively affect environmental quality in both the long and short terms.

The study focused on NICs since they account for 48.09% of the world's population, with 3.8 billion inhabitants (The World Bank, 2024). These countries represent nearly half the global population and have experienced the highest growth rate in recent decades. The gross national product per capita in NICs was reported as US$7,503.00. Given their substantial influence on the global economy, the trajectory of NICs significantly affects the global environment. As such, the findings of this study are of strategic importance to policymakers and regulatory bodies for formulating environmentally sustainable economic development policies.

The remainder of the paper is structured as follows: The introduction is followed by the materials and methods, with the results and discussion presented after that. Finally, the conclusion is provided.

Materials and Methods

Sample Framework

10 NICs (Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkiye) were selected as the sample for this study. Annual data spanning 20 years, from 2000 to 2019 were used for the analysis. The primary data source was the World Bank database, with each country's level of industrialisation as the key explanatory variable

and the level of END as the response variable. FDIs, renewable energy usage (REN), and URB levels were included as control variables. A description of each variable and its proxy measures is presented in Table 1.

Model Specification

This study examines four key variables' long-term and short-term effects on environmental degradation. The general model can be represented as:

$$END_{it} = \propto_0 + \propto_1 IND_{it} + \propto_2 FDI_{it} + \propto_3 REN_{it} + \propto_4 URB_{it} + \varepsilon_t \quad (1)$$

where, END represents environmental degradation, proxied by carbon dioxide emissions; IND refers to the level of industrialisation, proxied by gross fixed capital formation; FDI indicates net foreign direct investments, representing the flow of foreign investments to the NICs; REN denotes renewable energy usage; and URB reflects the level of urbanisation. The subscripts *i* and *t* represent the cross-sectional identity and time interval, respectively.

The study employed panel autoregressive distributed lag (ARDL) techniques, specifically pooled mean group (PMG), mean group (MG), and dynamic fixed effect (DFE) models to examine the long- and short-term co-integration of industrialisation, FDIs, URB, and REN with END. Given that the number of cross-sections (10 NICs) is lower than the number of time slots (20 years), the study adopted long panel dynamic ARDL models. Consequently, the PMG estimation for dynamic heterogeneous panels, as introduced by Pesaran *et al*. (1999) was identified as the most suitable technique for finding co-integration in long panel data analysis. The PMG technique allows for the identification of both long- and short-term effects while ensuring parameter convergence because it assumes that the long-term coefficients are identical but differ across the cross-sections in the short-term with heterogeneity bias.

Failing to investigate the cross-sectional dependency of individual cross-sections as a precondition for selecting the most suitable analysis technique can lead to biased results. The empirical literature suggests that countries are interdependent due to various factors, including free trade agreements, spillover effects of economic changes, capital market transactions, direct and indirect foreign investments, and foreign consumer market captures. Therefore, this study employed four cross-sectional dependency tests as primary analysis techniques to examine the interdependency among the cross-sectional countries. The main analysis techniques used to assess cross-sectional dependency are Breush-Pagan's (1980) LM test, Pesaran's (2004) scaled LM test, Baltagi, Feng, and Kao's (2012) bias-corrected scaled LM test, and Pesaran's (2004) test.

Testing the stationarity of the dataset is one of the most crucial steps before selecting the appropriate data analysis tool. The selection of the most suitable panel unit root test guides the choice of data analysis technique and enhances the reliability of analysis results (Paramati *et al*., 2017; Zafar *et al*., 2019). The type of panel unit

Table 1: Key variables and the proxies

Variable Name	Proxy and the Calculation Mechanism
Level of Environmental Degradation (END)	Carbon dioxide emission (metric tons per capita)
Level of Industrialisation (IND)	Gross fixed capital formation (as a percentage of GDP)
Foreign Direct Investments (FDI)	Foreign Direct Investments net inflow (as a percentage of GDP)
Renewable Energy usage (REN)	Renewable Energy Consumption (as a percentage of total final energy consumption)
Level of Urbanisation (URB)	Urban population (as a percentage of the total population of the cross-sectional country)

root test used varies depending on the cross-sectional dependency. For instance, when the dataset exhibits cross-sectional independence, the most appropriate technique is the first-generation panel unit root test. However, the second-generation panel unit root test should be employed when there is cross-sectional dependency. Generally, if the data series demonstrates cross-sectional dependency, the cross-sectionally augmented Im-Pesaran-Shin (CIPS) test and the cross-sectional augmented Dickey-Fuller (CADF) test are the most common and frequently used techniques. The study utilised the Hausman test as a decision criterion to select the best-fitting model among the panel ARDL models to explain long- and short-term co-integration among the explanatory and response variables.

Results and Discussion

The key descriptive statistics are presented in Table 2. According to the analysis results, the dataset followed a symmetric distribution, as the median values were less than the mean, and the skewness values confirmed this observation. Furthermore, Industrialisation (IND), proxied by the gross fixed capital formation (GFC) and net FDI, exhibited positive kurtosis with significant tailing. In contrast, other variables displayed a leptokurtic pattern.

The results presented in Table 3 confirmed that the data series exhibited cross-sectional dependency. Hence, it was vital to utilise the second-generation panel unit root test to examine the stationarity of the explanatory and response variables. The study employed the CIPS and CADF tests as core techniques to assess the stationarity of the dataset. The test results are displayed in Table 3. The analysis confirmed that all variables except URB, followed the stationary process either at the level series or the first difference. Although URB did not show stationarity at both levels and the first difference, empirical literature suggests that it plays a significant controlling role in END (Othman *et al*., 2022). Hence, it was decided that URB would be retained as one of the controlling variables.

Table 2: Descriptive statistics

Variable	Obs.	Mean	Median	Max.	Mini.	Std. Dev.	Skewness	Kurtosis
end	200	3.746	3.424	8.439	0.790	2.325	0.524	1.976
gfc	200	25.023	22.985	44.519	14.027	7.175	0.946	3.377
fdi	200	2.259	2.227	5.368	-2.757	1.282	-0.222	3.512
ren	200	22.761	20.140	48.920	1.960	13.813	0.355	1.831
urb	200	58.058	57.929	86.824	27.667	16.913	-0.029	1.822

Source: Authors constructed referring analysis results

Table 3: Panel unit root test

Variable	CIPS		CADF	
	Level	First Difference	Level	First Difference
end	-1.6768	-3.4233***	-1.5129	-1.9556
gfc	-2.259*	-3.9376***	-2.3769	-2.1937
fdi	-3.2668***	-5.1411***	-2.3637	-4.8552***
ren	-1.5246	-3.1181***	-2.1813	-3.2500*
urb	1.5755	-1.1565	-0.7909	0.3566

***, ** and * indicate significance at the levels of 1%, 5%, and 10%, respectively.
Source: Authors constructed referring analysis results

Panel Co-integration

The study followed panel ARDL techniques to estimate the long- and short-term effects of IND on END. In addition, FDI, REN, and URB were also considered as controlling variables to examine the nexus between industrialisation and END in NICs. The co-integration results for panel ARDL models—PMG, MG, and DFE—are presented in Table 4.

As a prerequisite to proceeding with the final model, the study conducted the Hausman test to select the best-fitting model from three panel ARDL models. The test results are presented in Table 5. As per the test results, PMG was selected as the most suitable model to represent the long- and short-term effects of IND, FDI, REN, and URB on carbon dioxide emissions (the proxy used to measure the environmental degradation) in NICs.

The PMG estimation presented in Table 4 indicated that IND stood out as a pivotal determinant, demonstrating a significant impact on END in the long term. Although establishing a clear-cut relationship in the short term proved challenging, the research unequivocally affirmed a substantial link between intensified industrialisation and adverse environmental outcomes. High levels of industrialisation correlated with increased carbon emissions, resulting in a discernible decline in overall environmental quality. These findings aligned with existing scholarly works, including those by Dong *et al*. (2019) and Ahmed *et al*. (2022),

Table 4: Panel co-integration

DV (end)	Mean Group (MG)	Pooled Mean Group (PMG)	Dynamic Fixed Effect (DFE)
LONG RUN			
gfc	0.0345** (0.0166)	0.1111*** (0.0175)	0.0375 (0.0588)
fdi	0.0725 (0.0478)	0.3771*** (0.0840)	0.1207 (0.1722)
ren	-0.0658 (0.0146)	-0.0747*** (0.0196)	-0.0667 (0.0471)
urb	0.0514 (0.0437)	0.1480*** (0.0185)	0.0402 (0.0593)
SHORT RUN			
Speed of adjustment	-0.6959*** (0.0697)	-0.1699** (0.0847)	-0.1117*** (0.0362)
gfc	-0.0082 (0.0167)	0.0102 (0.0122)	0.0167* (0.0100)
fdi	-0.0169 (0.0163)	-0.0157* (0.0088)	0.0336** (0.0133)
ren	-0.0206 (0.0307)	-0.0632** (0.0284)	-0.0306** (0.01328)
urb	-0.4512 (2.2416)	1.0744 (1.0687)	-0.0310 (0.1578)
Number of groups	10	10	10
Number of observations	190	190	190

Notes: ***, ** and * indicate significance at the levels of 1%, 5%, and 10%, respectively. The standard error is shown by the numbers in parentheses.
Source: Authors constructed referring analysis results

Table 5: Hausman test

Test	Chi² Value	Probability Value	Decision
MG vs. PMG	2.76	0.5985	PMG is appropriate
PMG vs. DFE	706.23	0.0000	PMG is appropriate

Source: Authors constructed referring analysis results

reinforcing a consensus within the academic community. The convergence of evidence underscored the critical role of industrialisation in shaping the environmental landscape, highlighting the need for strategic interventions and policy measures to manage and mitigate the long-term environmental implications of robust industrial development. A summary of the developed hypotheses is shown in Table 6.

The results indicated that high foreign investments reduced END in the short term, as foreign investors must comply with the environmentally sustainable practices of host countries when they invest. Khan *et al*. (2021) also explained that FDI improved environmental quality by encouraging environmentally friendly practices, promoting the use of renewable energy sources, and facilitating investments in research and development to discover eco-friendly products.

Even though the results confirmed that FDIs positively contributed to environmental quality in the short term, they indicated that FDIs caused a deterioration in environmental quality in the long term. This suggests that as the flow of foreign investments continued towards economies through the establishment of new venture capital and diversification into other sectors, the direction of fund flow direction shifted away from green projects. Consequently, carbon emissions increased, leading to negative consequences for the environment. Therefore, a positive relationship existed between FDI and END in the long run. Many scholars have noted the necessity for strict environmental policies that directed foreign investments towards environmentally friendly projects (Salahuddin *et al*., 2018; Ganda, 2020; Othman *et al*., 2023).

The studies on END in NICs represent a critical area of inquiry, particularly regarding the role of URB in shaping environmental outcomes. A notable perspective posits that, in the short term, URB may not exert a significant influence on environmental quality. This assertion implies that the initial phases of urban development, characterised by infrastructural growth and regulatory adjustments might not immediately lead to noticeable END. However,

Table 6: Hypothesis testing summary

Hypothesis	Results
H01: Foreign Direct Investments do not show a significant influence on environmental degradation in newly industrialised countries	FDI positively contributes to environmental quality in the short run and negatively in the long run
H02: Urbanisation does not have a significant effect on environmental degradation in newly industrialised countries	The high degree of urbanisation influences environmental degradation in the long term
H03: Industrialisation does not present a significant influence on environmental degradation in newly industrialised countries	Increased industrialisation is leading to a decrease in overall environmental quality
H04: Renewable energy has no significant influence on environmental degradation in newly industrialised countries	Incorporating renewable energy sources is an efficient approach to tackle and reduce environmental degradation

the crux of concern lies in the long-term consequences, where high levels of URB are argued to contribute positively to END. This nuanced relationship requires exploration and analysis, and recent studies by Iheonu *et al*. (2021), Wang *et al*. (2021), Tang (2022), and Yang *et al*. (2022) collectively corroborate this viewpoint, asserting that URB, over time, plays a role in diminishing environmental quality.

The insights offered by Majeed and Luni (2019) regarding the role of renewable energy sources in curbing END are substantiated and reinforced by the findings of the present study. According to these prior studies, the adoption of renewable energy represents a pivotal strategy in mitigating the adverse environmental impacts associated with industrialisation. The current research builds upon this foundation, providing empirical evidence that emphasises the positive contribution of using renewable energy sources to eradicate END within NICs.

The study's results unequivocally demonstrate that the integration of renewable energy sources serves as an effective means of addressing and diminishing END. By leveraging cleaner and more sustainable energy alternatives, NICs can potentially break free from the traditional paradigm where industrial growth is synonymous with ecological harm. This substantiation of earlier claims highlights the transformative potential of embracing renewable energy solutions in the industrialisation process. As policymakers navigate the delicate balance between economic development and environmental preservation, these findings advocate for the prioritisation of renewable energy initiatives to foster a more sustainable, ecologically conscious trajectory for emerging industrialised nations.

Apart from key variables, the evidence from the speed of adjustment coefficient indicates that economies take more than five years to mitigate the influence of industrialisation, FDIs, use of renewable energy sources, and URB on END in NICs.

Conclusions

Numerous scholars have sought to identify the determinants of END, uncovering various factors that contribute to environmental pollution. However, substantial room for further exploration remains, particularly regarding the primary variables influencing END in NICs. Given that these countries account for over 48% of the global population and contribute more than half of total carbon dioxide emissions, as indicated by World Bank statistics, this study aimed to evaluate the long- and short-term co-integration of industrialisation, REN, FDI, and URB with END in 10 NICs over the period from 2000 to 2019.

The panel data analysis revealed that using renewable energy and attracting foreign investments can mitigate pollution in the short term. However, in the long term, industrialisation, foreign investments from developed nations, and increased URB contributed to heightened END despite efforts to promote renewable energy sources and decrease pollution. Consequently, the findings highlighted the necessity for policymakers to implement a more effective regulatory framework to manage industrialisation and foreign investments. The study suggests the need for strategic policy decisions in urban planning to mitigate over-urbanisation along with initiatives to promote the adoption of renewable energy sources within the production sector. Finally, the study also advocates for the development of a monitoring mechanism to channel foreign investments towards eco-friendly projects, presenting a proactive approach to combat END in NICs.

The research paper highlights the urgent need to address END caused by industrialisation in NICs. One avenue for future exploration involves evaluating the efficacy of existing environmental regulations and policies in NICs. In-depth analyses could assess the implementation and enforcement of current laws and standards, identifying gaps that require

strengthening or revisions. Such assessments may shed light on the limitations of existing policies and inform the development of more robust frameworks to promote sustainable industrialisation practices.

Additionally, investigating the role of green technology and innovation presents a promising research direction. Exploring strategies to incentivise and promote the adoption of eco-innovative practices and clean technologies in industrial sectors could yield valuable insights. Public-private partnerships and collaborative initiatives may serve as potential catalysts for fostering the development and dissemination of green technologies, facilitating a transition towards more environmentally friendly industrial operations.

Furthermore, the influence of FDI policies warrants closer examination. Analysing the effectiveness of current FDI policies in attracting environmentally friendly investments and discouraging polluting industries could inform the development of policy frameworks that better align FDI inflows with sustainable development goals. Such research may propose strategies to encourage foreign investors to prioritise environmental sustainability while contributing to economic growth.

Finally, examining the role of public awareness and stakeholder engagement presents a crucial research avenue. Assessing the impact of public awareness campaigns and educational initiatives on promoting sustainable industrial practices and environmentally conscious behaviour may illuminate the importance of public outreach and education efforts. Additionally, exploring strategies for effective stakeholder engagement, including industry, government, and civil society could facilitate the co-creation and implementation of sustainable industrialisation policies that reflect diverse perspectives and address the needs of various stakeholders.

By pursuing these research avenues, scholars and policymakers can gain a comprehensive understanding of the strengths and limitations of current policies and identify innovative solutions to address the long-term environmental challenges associated with industrialisation in NICs. Such research endeavours can contribute to the development of comprehensive and effective strategies that reconcile economic growth with environmental sustainability, ensuring that the path to industrialisation does not come at the cost of irreversible ecological damage.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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