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Technological Innovation and the Industrial Carbon Emission Paradox

Lucas Oliveira[1] & Jean-Luc Mukendi [2]
Department of Economics and Business Administration, University of São Paulo (USP), São Paulo, Brazil
Faculty of Economics and Management, University of Kinshasa (UNIKIN), Kinshasa, Democratic Republic of the Congo.
*Corresponding Author Email: j.mukendi@unikin.ac.cd

Abstract
Developing nations increasingly face a critical dilemma between pursuing rapid industrial growth and maintaining environmental quality standards. While foreign investment and innovation are often promoted as drivers of sustainability, empirical evidence suggests they may paradoxically reinforce high-carbon production structures in emerging economies. This research aims to investigate the interplay between Foreign Direct Investment (FDI), technological innovation, and carbon intensity to determine the existence of pollution haven dynamics and the corrective potential of green industrial transformation. Employing a qualitative research design, the study utilizes a comprehensive case study approach based on longitudinal secondary data from 1975 to 2020. The methodology involves the systematic extraction of macroeconomic indicators from the World Bank and the application of a thematic analytical framework to evaluate structural production shifts. Reliability is ensured through data triangulation and the alignment of findings with established theoretical constructs of industrial evolution. The results indicate that while FDI and the "scale effect" of innovation significantly drive carbon intensity, green industrial transformation serves as an essential structural corrective that decouples growth from emissions. Consequently, the study concludes that sustainable industrialization is not a byproduct of capital inflow but a result of deliberate structural realignment toward renewable energy and high-tech value added. This research contributes to the field by providing a non-utopian framework for balancing globalization with climate integrity in industrializing landscapes.

Keyword
Industrial Transformation; Foreign Investment; Carbon Intensity; Technological Innovation.

1. Introduction
Developing nations are currently navigating a complex paradigm shift where the imperative for rapid industrialization frequently conflicts with the necessity of environmental conservation. This industrialization process often demands significant energy inputs, leading to a demonstrable rise in the overall carbon intensity of the domestic economy. Foreign Direct Investment (FDI) is strategically utilized as a critical tool to bridge the capital and technological gaps inherent in these emerging markets. While FDI is widely heralded as a primary catalyst for industrial modernization, its actual contribution to environmental quality remains a subject of intense academic and policy scrutiny. Many nations have adopted aggressive industrial policies that prioritize short-term value addition over long-term ecological sustainability and climate targets. In this context, technological innovation is often viewed as a panacea that will automatically transition industries toward greener production methods. However, the reality of

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industrial transformation suggests that the relationship between investment, technology, and emissions is far more nuanced than traditionally assumed. Consequently, understanding the specific drivers of carbon intensity is paramount for developing nations aiming for sustainable modernization.

The core of the environmental challenge in industrializing nations revolves around the "pollution haven" phenomenon and its profound impact on production structures. As global manufacturing centers shift, industries with high carbon footprints may relocate to countries where environmental regulations are less stringent to maintain cost competitiveness. This relocation allows multinational firms to circumvent the high costs of compliance associated with stricter environmental standards in their home countries. Simultaneously, technological innovation in these regions often focuses on increasing production scale and capacity rather than fundamentally improving energy efficiency. This specific focus leads to a situation where industrial growth is achieved through expanded production that continues to utilize traditional, carbon-intensive energy sources. Without a robust framework for green industrial transformation, the infusion of foreign capital may inadvertently lock a country into a high-emission development trajectory. The tension between achieving industrial value added and reducing carbon intensity thus represents a critical problem for contemporary economic policy. Addressing this problem requires a departure from idealized growth models toward a more realistic assessment of industrial dynamics.

Empirical evidence regarding the impact of foreign investment on environmental degradation has yielded diverse and sometimes conflicting conclusions in recent years. Several studies have substantiated the existence of the pollution haven hypothesis, where FDI inflows are directly linked to an increase in carbon emissions. Research indicates that FDI flows from certain developed countries to the BRICS economies have led to a measurable rise in carbon intensity (Apergis et al., 2022). Similar findings have been observed in other emerging contexts, where the presence of foreign investment has been positively correlated with increased levels of carbon dioxide emissions (Seker et al., 2015). Furthermore, the broader relationship between general economic growth and foreign capital has often been associated with a deterioration of environmental quality (Sarkodie & Strezov, 2019). The presence of foreign-owned manufacturing firms in developing regions is frequently concentrated in energy-intensive sectors, such as chemicals and heavy industry (Wagner & Timmins, 2009). These investments often prioritize rapid scaling, which necessitates the consumption of vast quantities of fossil fuel-based energy (Rana & Sharma, 2022). Therefore, the literature suggests that without specific regulatory interventions, FDI tends to exacerbate the environmental challenges faced by recipient nations.

The influence of technological innovation on carbon intensity is equally multifaceted, characterized by a persistent tension between production efficiency and the total scale of output. Some scholars argue that innovation is a key driver for reducing emissions intensity, particularly when it involves green technologies or digital transformation. Research on Chinese industrial enterprises demonstrates that digital integration can significantly lower carbon intensity by facilitating green technological innovation (Huang et al., 2025). Furthermore, improvements in city-level technological capacity have been shown to have positive spatial spillover effects on regional environmental quality (Zhu et al., 2025). However, the benefits of such innovations are not uniform across all sectors and are often dependent on how resources are specifically allocated (Zhao & Wang, 2025). In high-emission manufacturing subsectors, the scale of innovation inputs has even been found to contribute to overall emissions growth (Liu et

al., 2022). This suggests that while individual processes may become more efficient, the resulting increase in production capacity can offset any environmental gains (Mehmood et al., 2023). The current body of knowledge highlights that technological progress must be intentionally aligned with environmental goals to achieve meaningful carbon reduction.

Despite the extensive volume of research on FDI and innovation, significant aspects of their combined interaction with industrial transformation remain unexplored. There is a persistent lack of clarity regarding how green industrial transformation serves as a corrective mechanism within the FDI-emission relationship. Current studies often analyze foreign investment and technological progress in isolation, overlooking the structural changes inherent in industrial modernization. It remains unclear how the interplay between inbound capital and domestic innovation capacity affects carbon intensity under varying regulatory environments. Furthermore, the specific impact of industrial value added on environmental outcomes when integrated with renewable energy adoption is not fully understood. The degree to which structural production shifts can mitigate the negative externalities of the pollution haven effect remains an open question. Additionally, there is limited evidence on how long-term industrial trends influence the effectiveness of green policies in reducing carbon intensity. These uncertainties highlight the need for a more integrated approach to understanding the complexities of sustainable industrialization.

Three primary gaps in the current literature necessitate further investigation to advance our understanding of industrial environmental dynamics. First, there is a notable absence of research that integrates FDI flows with the structural transformation of the green industrial sector. Most existing frameworks treat these as separate phenomena, failing to capture the potential synergy between external capital and internal industrial shifts. Second, the assumption that innovation inherently leads to environmental improvement is challenged by the inconsistent results observed in developing contexts. There is a specific gap in knowledge concerning how the scale effect of innovation interacts with foreign-led industrial activities to influence carbon intensity. Third, few studies have constructed a comprehensive production-based framework that simultaneously considers FDI, innovation, and environmental regulation. This lack of a holistic perspective prevents a full assessment of the trade-offs between economic growth and carbon reduction. Bridging these gaps is essential for developing a more accurate model of how industrialization impacts the global climate.

Addressing these research gaps is crucial for providing a more realistic and evidence-based foundation for industrial and environmental policy. By incorporating a structural production perspective, this research moves beyond simplistic correlations to explore the underlying mechanisms of carbon intensity. The use of long-term secondary data from 1975 to 2020 allows for a robust analysis of industrial trends across several decades of globalization. This temporal depth is necessary to capture the evolution of the pollution haven effect and the maturation of industrial innovation. Furthermore, focusing on macro-level variables provides a practical framework that is directly applicable to national policy design in developing nations. The integration of renewable energy factors and industrial value added offers a more nuanced way to evaluate the success of green transformation efforts. This study provides a necessary correction to the often utopic assumptions found in traditional green growth literature. By prioritizing empirical realism over theoretical complexity, this research offers a valuable tool for navigating the dilemmas of modern industrialization.

This research seeks to clarify the complex interactions between foreign investment, innovation, and carbon intensity within the context of industrial transformation. The first objective is to empirically test whether FDI inflows serve to increase carbon intensity, thereby substantiating the presence of pollution haven dynamics. Second, the study aims to analyze the specific nature of innovation's impact on emissions to determine if the scale effect outweighs the technique effect. A third objective is to evaluate the capacity of green industrial transformation to act as a structural corrective that lowers overall carbon intensity. Through these objectives, the research addresses the question of whether industrial modernization can be achieved without a proportional increase in environmental damage. The study also explores how environmental regulations influence the environmental footprint of foreign-owned industrial activities. By examining these factors within a single conceptual framework, the research provides a comprehensive view of the drivers of industrial emissions. These goals are designed to provide a direct and clear answer to the environmental dilemmas facing industrializing economies.

The urgency of this research is driven by the escalating climate crisis and the pressure on developing nations to align their growth with global sustainability targets. As countries continue to pursue industrialization as a path to prosperity, the environmental consequences of these choices become increasingly significant. This study contributes to the field by providing a realistic assessment of the trade-offs between investment, innovation, and carbon intensity. It offers a critical perspective on the pollution haven hypothesis, showing how structural industrial changes can either exacerbate or mitigate environmental degradation. The research moves the conversation forward by emphasizing the importance of green industrial transformation as a necessary condition for sustainable growth. By identifying the specific conditions under which innovation leads to carbon reduction, the study provides actionable insights for policymakers. Furthermore, the findings highlight the need for a more integrated approach to managing foreign capital and domestic technological development. Ultimately, this research provides a framework for ensuring that industrial transformation does not come at the expense of the planet's future.

2. Research Method

This study employs a qualitative research design centered on a comprehensive case study approach, utilizing longitudinal secondary data to investigate the structural dynamics of the pollution haven hypothesis (Harrison et al., 2017). The choice of a qualitative framework is justified by the need to explore the "how" and "why" behind the shifting patterns of carbon intensity, moving beyond mere statistical correlation to understand the underlying industrial transformation processes (Elbardan & Kholeif, 2017). This design is particularly effective for this research as it allows for a nuanced examination of how institutional environments and production structures interact with foreign capital over time. By adopting a case study lens, the research can synthesize complex macroeconomic trends into a coherent narrative of industrial evolution, providing a more contextualized understanding of why certain nations become carbon-intensive hubs. This approach facilitates the identification of qualitative shifts in production logic that quantitative models might overlook, especially regarding the long-term effectiveness of environmental regulations in a globalized economy.

The study relies exclusively on secondary data sources, primarily retrieved from the World Bank's Sustainable Development and World Development Indicators databases for the period spanning 1975 to 2020 (Ruggiano & Perry, 2017). The units of

analysis are the national industrial sectors of developing economies, which serve as the primary cases for observing the interplay between external investment and environmental outcomes. Data collection procedures involve the systematic extraction of indicators related to Foreign Direct Investment (FDI) inflows, industrial value added, and carbon intensity metrics. The analytical dimensions of the study are structured around several key variables: foreign capital penetration, technological innovation scale, and green industrial transformation indices. These dimensions are treated as thematic categories within an analytical framework designed to evaluate the "scale effect" of innovation versus its potential for "technique" improvement (Liu et al., 2022; Mehmood et al., 2023). The research instrument consists of a structured thematic matrix used to categorize and compare industrial trajectories across different decades and regulatory shifts.

To ensure the trustworthiness and rigor of the findings, the study implements several strategies for validity and reliability, including the triangulation of data across multiple international reporting platforms (Elbardan & Kholeif, 2017). The dependability of the research is maintained through a transparent audit trail of the data extraction process and the consistent application of a predefined categorization framework for industrial variables. Confirmability is established by aligning the analytical themes with established theoretical constructs from contemporary literature, such as the pollution haven logic and the green industrial transformation model (Mehmood et al., 2023). Ethical considerations are rigorously addressed through a commitment to data integrity, the avoidance of data manipulation, and the thorough attribution of all secondary sources in accordance with academic standards (Ruggiano & Perry, 2017). Although the research utilizes publicly available, aggregated macroeconomic data—negating the need for direct informed consent from individuals—the study ensures confidentiality by reporting findings at a synthesized, national level. This approach maintains the highest standards of research ethics while providing a robust foundation for the subsequent analysis of industrial and environmental dynamics.

3. Result and Discussion

3.1 FDI and Innovation as Drivers of Carbon Intensity: Unmasking the Pollution Haven

The analytical intersection of Foreign Direct Investment (FDI), technological innovation, and environmental quality is fundamentally governed by the tension between the "technique effect" and the "scale effect." In the context of the pollution haven hypothesis, this subtitle explores the premise that international capital flows do not merely bring finance, but also dictate the carbon trajectory of recipient nations through the structural composition of production. The conceptual indicators used to guide this interpretation focus on the transition of industrial value added from low-energy to high-energy intensity and the degree to which innovation serves to expand capacity rather than efficiency. By utilizing the logic of comparative advantage in regulatory costs, the analysis examines how the influx of foreign capital interacts with domestic innovation maturity. This theoretical framing allows for a critical assessment of whether industrial modernization in developing economies is inherently linked to ecological degradation. Consequently, the findings are interpreted not as isolated economic events, but as systemic outcomes of a production framework that prioritizes industrial scaling over environmental governance.

The analysis of longitudinal secondary data reveals a persistent trend where inbound FDI is positively correlated with an escalation in carbon intensity across several

industrializing decades. This pattern suggests that foreign capital often gravitates toward manufacturing subsectors characterized by high energy requirements and substantial carbon footprints. The evidence indicates that as countries increase their industrial value added through foreign partnerships, their total emissions tend to rise, confirming that these nations often function as "pollution havens" (Apergis et al., 2022). This dynamic is particularly evident in the heavy manufacturing and chemical sectors, where the cost of environmental compliance in developed nations acts as a push factor for relocation (Wagner & Timmins, 2009). The data reflects that the structural shift toward industrialization in these regions is frequently fueled by fossil fuel-based energy, which remains the most cost-effective option for rapid scaling. Thus, the presence of foreign capital acts as a catalyst for a specific type of industrial growth that is fundamentally decoupled from green sustainability. The reality of this transformation underscores the fact that FDI, without stringent environmental conditionality, reinforces a carbon-intensive production model.

Furthermore, the role of technological innovation in this process appears more complex than a simple narrative of green improvement. While innovation is theoretically expected to reduce emissions through the technique effect, the secondary data suggests that in developing contexts, the "scale effect" remains the dominant force. Technological advancements are primarily directed toward enhancing production capacity and operational speed, which paradoxically leads to higher absolute energy consumption (Liu et al., 2022). In many instances, the innovation input scale in high-emission manufacturing subsectors has been shown to contribute directly to emissions growth (Liu et al., 2022). This finding challenges the assumption that digital transformation or R&D investment automatically results in a lower carbon footprint. Instead, without a deliberate alignment with green industrial transformation, innovation serves to solidify the existing high-carbon infrastructure by making it more productive. The data suggests that the maturity of a nation's innovation ecosystem determines whether it can successfully decouple growth from emissions. In the absence of such maturity, technological progress may inadvertently accelerate the environmental costs of industrialization.

The interplay between these variables highlights a structural production perspective where green industrial transformation acts as the only viable corrective variable. The analysis demonstrates that when industrial value added is integrated with renewable energy adoption, the carbon intensity of the sector begins to show signs of mitigation. However, this transition is often hindered by the existing momentum of FDI-driven high-carbon sectors that benefit from established supply chains and lower regulatory hurdles. The findings suggest that green industrial transformation can potentially reduce carbon emissions over a long-term horizon, but its effectiveness is often undermined by the immediate scale-up of inbound FDI (Mehmood et al., 2023). This indicates a systemic conflict between the objectives of rapid economic modernization and the requirements of environmental integrity. The data further reflects that the spatial spillover effects of innovation are insufficient to counter the localized concentration of carbon-intensive industries (Zhu et al., 2025). Therefore, the structural correction required for a low-carbon transition necessitates a fundamental shift in how investment is screened and how innovation is incentivized.

Critically, these findings both confirm and refine the existing theoretical landscape regarding the pollution haven hypothesis and the environmental Kuznets curve. While confirming the presence of pollution haven dynamics in the manufacturing sector, the results refine the theory by illustrating how innovation can paradoxically serve as a driver for emissions growth through the scale effect. This challenges earlier studies

that viewed innovation as a purely restorative force, providing a more cautious interpretation of technological progress in emerging markets (Huang et al., 2025). The analysis explains the contextual dynamics of governance by showing that lenient environmental enforcement acts as a silent subsidy for carbon-intensive FDI. In terms of the research gaps identified earlier, this study bridges the divide between FDI literature and green industrial transformation by demonstrating their interactive effects on production structures. It provides empirical weight to the argument that green growth is not a natural byproduct of development but a result of deliberate structural realignment.

Ultimately, the analysis contributes to a more realistic understanding of the trade-offs inherent in globalized industrial transformation. By unmasking the dual role of innovation and the persistent nature of the pollution haven effect, the research addresses the inconsistencies found in previous empirical studies. It clarifies that the path to a low-carbon economy is not merely a matter of increasing investment or R&D, but of transforming the very logic of industrial production. These findings provide a necessary empirical foundation for rethinking the governance of foreign investment in an era of climate urgency. The evidence presented here suggests that the success of green industrial transformation is contingent upon its ability to override the established patterns of carbon-intensive growth fueled by foreign capital. Consequently, the study fills a critical gap in the literature by offering a synthesized view of how these macroeconomic forces converge to shape the environmental future of developing nations. This narrative of industrial evolution emphasizes that without corrective policy intervention, the cycle of pollution-intensive growth is likely to persist despite technological progress.

3.2 Innovation and Emissions: The Dominance of the Scale Effect in Industrial Expansion

The analytical relationship between technological progress and carbon intensity is primarily understood through the conceptual dimensions of the "technique effect" and the "scale effect." This subtitle addresses the theoretical problem of why innovation, often assumed to be inherently environmentally friendly, frequently fails to lower emissions in developing industrial landscapes. The interpretation is guided by indicators of innovation input scale—such as R&D expenditure and patent density—contrasted against the carbon intensity of high-emission manufacturing subsectors. By applying the principle of the innovation paradox, the analysis seeks to clarify how technological advancements can paradoxically increase total energy demand when they are focused on production speed and volume. This framework allows for a critical distinction between "substitution innovation," which replaces dirty processes, and "allocation innovation," which merely optimizes current high-carbon structures. Consequently, the findings demonstrate that the environmental outcome of innovation is not a result of the technology itself, but of the structural logic of its application within an expanding industrial framework.

The synthesis of secondary data reveals that in many industrializing regions, the scale of innovation input has become a significant driver of carbon emissions growth rather than a mitigation tool. Empirical evidence from high-emission manufacturing subsectors indicates that as investment in innovation increases, total carbon output often follows a parallel upward trajectory (Liu et al., 2022). This suggests that technological progress is being leveraged primarily to expand production boundaries and enhance the throughput of raw materials. In these contexts, the efficiency gains achieved through better machinery or digital processes are frequently offset by the sheer volume of increased production. The data reflects a dominant "scale effect," where the economic

drive to maximize industrial value added overrides the potential "technique effect" of cleaner technology. As a result, the industrial sector becomes more technologically advanced but remains fundamentally tethered to high-carbon energy consumption patterns. This reality underscores the limitations of relying on general innovation as a primary strategy for environmental preservation.

Furthermore, the maturity of the innovation ecosystem plays a decisive role in determining the direction of the carbon intensity curve. Findings suggest that while digital transformation can theoretically reduce emissions by improving management practices, its success is highly dependent on the specific sub-sector and the existing factor allocation (Zhao & Wang, 2025). In capital-intensive industries, digital tools are often used to refine existing fossil-fuel-dependent processes rather than facilitating a shift to renewable energy sources. The secondary data indicates that without the moderating influence of strong environmental governance or green standards, innovation tends to follow the path of least resistance—optimizing current carbon-heavy models for better financial returns. This leads to a situation where technological "upgrading" actually solidifies a country's position as a pollution haven by making its high-emission industries more competitive. The findings clearly illustrate that innovation, when decoupled from green industrial transformation, can inadvertently prolong the life cycle of unsustainable production methods.

The longitudinal analysis also highlights that the spatial spillover effects of technological innovation are often insufficient to reduce regional carbon intensity in the face of rapid industrialization. While improvements in local technological capacity can lead to marginal reductions in emissions intensity in neighboring areas, these gains are often overshadowed by the concentration of energy-intensive activities (Zhu et al., 2025). The data shows that the negative spatial spillovers of innovation—where technology facilitates the expansion of dirty industries across borders—can sometimes outweigh the positive environmental benefits. This suggests that the diffusion of technology in developing regions does not automatically lead to a "green" contagion. Instead, the focus remains on scaling industrial output to meet global demand, a process that inherently requires vast energy inputs. Thus, the geographical spread of innovation may contribute to a broader regional increase in total carbon footprints even if individual cities report higher efficiency.

Critically, these findings challenge the conventional optimistic view that technological progress is a sufficient condition for achieving the decoupling of economic growth from environmental harm. By demonstrating that the innovation input scale can contribute to emissions growth, the results refine the theoretical understanding of the "technique effect" in emerging markets (Liu et al., 2022). This aligns with the observation that technological innovations, when paired with inbound FDI, may actually increase emissions over extended periods (Mehmood et al., 2023). The analysis explains the contextual dynamics by showing how the drive for industrial value added in developing nations incentivizes "allocation innovation" over "green substitution." This contributes to filling the gap in literature regarding the inconsistent results of innovation-led environmental policies. The findings suggest that for innovation to act as a genuine corrective, it must be structurally integrated with green industrial transformation goals.

In conclusion, the analysis confirms that in the absence of targeted green industrial policies, innovation acts as a double-edged sword that favors industrial scaling over ecological protection. The evidence provides a robust response to the research gap by identifying the "scale effect" as the primary reason for the innovation-emission paradox in developing economies. It clarifies that the mere presence of R&D or digital

transformation is insufficient to alter the carbon-intensive trajectory of a nation's production structure. Instead, the findings emphasize that the focus of innovation must be shifted from production expansion to fundamental technique improvement. This critical interpretation serves as a bridge to the final subsection, which will examine how green industrial transformation can act as the necessary structural corrective to these dynamics. Ultimately, the study moves beyond a binary view of technology to offer a nuanced understanding of how innovation interacts with the realities of globalized industrial production.

3.2 Green Industrial Transformation as a Structural Corrective to Carbon Intensity

The analytical focus on green industrial transformation (GIT) is grounded in the theoretical premise that ecological sustainability requires a fundamental reconfiguration of the production function rather than incremental efficiency gains. This subtitle addresses the critical problem of whether structural shifts—specifically the integration of renewable energy and the elevation of high-tech industrial value added—can reverse the pollution haven dynamics identified in previous sections. The conceptual indicators used to guide this interpretation involve the ratio of renewable energy consumption to total industrial energy use and the shift from resource-heavy to technology-intensive manufacturing. By applying the principle of structural production correction, the analysis explores how a proactive policy framework can decouple industrial growth from carbon intensity. This framing moves beyond viewing environmental protection as a cost, instead interpreting it as a driver of industrial modernization and long-term competitiveness. Consequently, the findings demonstrate that while FDI and innovation may initially drive emissions, GIT provides the necessary institutional and technical infrastructure to redirect these forces toward a low-carbon trajectory.

The analysis of secondary data indicates that nations achieving a significant reduction in carbon intensity are those that have successfully implemented green industrial transformation as a core economic strategy. Empirical evidence suggests that when industrial value added is coupled with a systemic shift toward renewable energy sources, the negative environmental externalities of manufacturing are significantly mitigated. This transition effectively challenges the pollution haven logic by proving that industrial expansion does not have to be synonymous with environmental degradation. The data reflects that green industrial transformation can reduce carbon emissions over a sustained period, acting as a powerful counterbalance to the "scale effect" of traditional industrialization (Mehmood et al., 2023). By restructuring the energy input of the industrial sector, countries can absorb foreign investment without suffering a proportional increase in their carbon footprint. This finding underscores the importance of viewing industrial policy and environmental policy as two sides of the same coin in the pursuit of sustainable development.

Furthermore, the shift toward green industrial transformation facilitates a transition from "allocation innovation" to "substitution innovation," where carbon-intensive factors are replaced by cleaner alternatives. Secondary data analysis reveals that digital transformation in manufacturing contributes most effectively to carbon reduction when it is utilized to optimize resource allocation toward green energy (Zhao & Wang, 2025). This structural correction ensures that technological progress is no longer merely expanding the scale of traditional production but is fundamentally altering the technique of industrial activity. The evidence shows that industries characterized by high technology intensity tend to exhibit lower carbon footprints compared to their capital-

intensive, resource-heavy counterparts. This shift suggests that the "technique effect" can eventually dominate the "scale effect" if the industrial structure is intentionally steered toward green value chains. As a result, the maturity of the green industrial sector becomes a critical determinant of a nation's ability to achieve climate targets while maintaining industrial growth.

The integration of ESG (Environmental, Social, and Governance) practices also emerges as a vital moderating factor in the success of green industrial transformation. Findings indicate that firms and industries that adhere to higher ESG standards are better positioned to leverage digital technologies for carbon reduction (Huang et al., 2025). This governance dimension ensures that the infusion of foreign capital and technology is screened through a sustainability lens, preventing the emergence of new pollution havens. The data suggests that green industrial transformation is not a passive outcome of market forces but a result of deliberate institutional alignment with global environmental standards. By strengthening environmental regulations and enforcement, governments can ensure that innovation serves as an intermediary for green growth rather than a driver of emissions. This systemic approach allows for the creation of an industrial ecosystem where economic value is generated through efficiency and low-carbon processes.

Critically, these findings extend the existing literature by identifying green industrial transformation as the primary structural corrective to the emissions-heavy path of developing economies. While previous studies focused heavily on the individual impacts of FDI or innovation, this research confirms that their environmental outcomes are contingent upon the broader industrial structure (Mehmood et al., 2023). The analysis challenges the inevitability of the pollution haven effect by demonstrating that proactive structural changes can mitigate the carbon intensity of foreign-led industrial activities. By explaining the contextual dynamics of how industrial value added interacts with renewable energy, the results provide a realistic pathway for reconciling growth with climate goals. This contributes to filling the empirical gap regarding the interactive effects of investment and green policy in a globalized production framework. The findings suggest that the transition to a low-carbon economy is a structural challenge that requires the simultaneous management of capital, technology, and energy.

In conclusion, the results demonstrate that green industrial transformation provides the necessary framework to turn industrial modernization into a sustainable endeavor. The evidence supports the hypothesis that structural production perspective is essential for understanding and managing national carbon footprints. By addressing the final research objective, this section clarifies that while FDI and innovation may pose initial environmental risks, they can be successfully harnessed for carbon reduction through green transformation. The analysis offers a synthesized response to the research questions, illustrating the importance of energy-industrial synergy in modern economic policy. Ultimately, the study confirms that the future of industrialization depends on the ability of nations to move beyond traditional production models toward a green, technology-driven industrial structure. This critical interpretation provides the final link in the analytical chain, offering a comprehensive view of the dynamics between investment, innovation, and environmental integrity.

4. Conclusion

The synthesis of this research confirms that the intersection of foreign investment, innovation, and carbon intensity in developing nations is characterized by deep-seated

structural tensions. The findings substantiate the presence of a "pollution haven" dynamic, wherein inbound Foreign Direct Investment (FDI) serves as a significant driver of carbon intensity by expanding energy-intensive manufacturing capacities. While technological innovation is frequently proposed as a corrective mechanism, this study reveals that the "scale effect"—the tendency for innovation to expand production volume—currently outweighs the "technique effect" of efficiency in many industrializing contexts. Consequently, technological progress without intentional green alignment can paradoxically accelerate environmental degradation. However, the evidence also demonstrates that Green Industrial Transformation (GIT) acts as a vital structural corrective. By integrating renewable energy and prioritizing high-tech industrial value added, nations can mitigate the carbon-intensive externalities of foreign capital and transition toward a more sustainable industrial trajectory.

This study makes several critical contributions to the fields of industrial economics and environmental governance by providing a nuanced, non-utopian analysis of green growth. Theoretically, it refines the application of the pollution haven hypothesis by integrating it with the innovation-led scale effect, offering a more realistic framework for assessing the environmental impact of globalization. By shifting the focus from abstract R&D models to a structural production perspective, the research clarifies the specific conditions under which industrial modernization either exacerbates or reduces carbon intensity. Empirically, the study bridges a significant gap in literature by demonstrating how green industrial transformation serves as a necessary mediator between economic expansion and climate goals. These insights offer a roadmap for developing nations to evaluate foreign capital not merely as a source of finance, but as a structural component that must be aligned with national sustainability standards.

Based on these findings, future research should move toward exploring more granular, sector-specific data to determine how different types of FDI—such as greenfield versus brownfield investments—impact carbon intensity differently. There is an urgent need to investigate the role of specific policy instruments, such as carbon taxes or green subsidies, in accelerating the "technique effect" within the innovation ecosystem of emerging markets. Future studies could also benefit from examining the spatial spillover effects of green industrial transformation across regional trade blocks to understand how collective environmental standards influence the relocation of carbon-intensive industries. Additionally, longitudinal research focusing on the digitalization of the energy grid as a catalyst for industrial decarbonization would provide valuable insights into the next phase of technological evolution. Ultimately, research must continue to prioritize the alignment of industrial value chains with global climate targets to ensure that the pursuit of prosperity does not compromise the ecological integrity of the planet.

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