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Role of Green Innovation Between the Relationship of Digital Transformation Strategy and Environmental, Social, and Governance (ESG) Performance: A Strategic Alignment Model

Dr. Pankaj Adatiya Tiwari*,

Associate ProfessorDepartment of Post Graduate Studies,
St Francis College, Koramangala, Bangalore, IndiaAdatiya.pankaj@gmail.com;
ORCID ID: 0000-0002-1426-1522

Abstract

In the age of the digital economy, digital technology opens up new avenues for business growth. Businesses' potential and degree of development are determined by how far they have digitally transformed. India's long-term low-carbon development goal is affecting the sector significantly. Based on the digitalization and sustainable development objectives of businesses, as well as the positioning of enterprise digital transformation level through the strategic alignment model (SAM), the relationship between digital transformation strategy and environmental, social, and governance (ESG) performance is examined. A sample of 145 respondents from medium-sized manufacturing companies provided data via a questionnaire survey, which was used for empiricaltesting using the Multiple Regression method. These are the findings of the empirical research -
(1) Enterprise ESG performance is positively and significantly impacted by digital transformation strategies. It is particularly evident in the two facets of the plan for digital transformation— platform and business digitalization—both of which significantly improve enterprise ESG performance. (2) To strengthen the association between enterprise ESG performance and digital transformation strategy, enterprise green innovation plays a vital intermediary function. (3) Green process innovation and green product innovation, the two facets of green innovation, both moderate the advancement of business digitalization and platform digitalization concerningcorporate ESG performance. In summary, through encouraging green processes and green product innovation, business. To establish conducive conditions for attaining sustainable growth, businesses should thus make clear the progression of their digital transformation strategy's development, strongly emphasize green innovation, and consistently enhance their ESGperformance.

Keywords: *Digital transformation strategy; Green Innovation; Process Innovation, Product Innovation, Environment Social Governance (ESG) Performance*

1. Introduction

Over the past two decades, India has emerged as a major player in the global economy, striving tobalance rapid industrial growth with sustainable environmental practices. In response to growing concerns about climate change and environmental degradation, the Indian government has introduced a range of policies aimed at achieving a sustainable future. The latest Indian Carbon Policy emphasizes the need to transition towards a low-carbon economy, targeting net-zero emissions by 2070. This commitment reflects India's dedication to global climate governance andits responsibility to mitigate climate impacts while fostering economic development. The integration of digital technology with traditional economic sectors has become essential in India's strategy to achieve its carbon goals. Digitalization, networking, and the use of intelligent systems are seen as crucial in reducing carbon footprints and enhancing operational efficiencies. This transformation, often referred to as "Industry 4.0," aligns with India's "double carbon" policy, which seeks to reduce carbon emissions through innovative technology solutions, optimized resource management, and sustainable industrial practices. Digital technologies are increasingly being leveraged to provide solutions that aid in carbon management and reduction, improve energyefficiency, and promote green innovations across various industries.

India's commitment to a sustainable development model is also reflected in its promotion of green manufacturing practices, which include green design, the establishment of green factories, and the creation of green industrial parks. These initiatives are supported by policies that encourage the integrated development of digital, intelligent, and green

industries. By investing in the technological upgrading of key sectors, India aims to drive the transformation from a factor-driven to an innovation-driven economy, thereby fostering a more sustainable and resilient industrial base. The focus on sustainability has led Indian enterprises to increasingly adopt Environmental, Social, and Governance (ESG) frameworks. ESG factors are now critical in evaluating corporate performance in terms of sustainability. Companies are encouraged to implement environmental protection measures, such as reducing their carbon footprint, enhancing energy management, and improving waste and water usage. Social responsibilities, including labor rights, diversity and inclusion, and supply chain management, are also integral to the ESG criteria. Good governance practices ensure that companies manage their environmental and social responsibilities effectively, maintaining transparency and accountability to stakeholders.

Despite these advancements, the relationship between digital transformation and sustainability in the Indian context remains complex. While digital technologies have the potential to enhance green innovation and reduce carbon emissions, there are also concerns about their limitations and potential environmental impacts. This research paper aims to explore the dynamics between digital transformation and carbon management in India, analyzing the impact of digital strategies on overall ESG performance in light of India's carbon policy commitments. The findings will provide insights into how Indian enterprises can navigate the challenges and opportunities of digitalization to achieve sustainable growth. The moderating effect of green innovation on the relationship between digital transformation strategy and ESG performance in India remains an under-explored area. While research on this topic is still in its nascent stages, the integration of green innovation as a moderating variable offers a valuable perspective, particularly within the context of India's commitment to carbon peaking and neutrality. Given India's unique economic and environmental landscape, this study aims to assess how green innovation influences the impact of digital transformation strategies on ESG (Environmental, Social, and Governance) performance in Indian enterprises. By focusing on the moderating role of green innovation, this research provides insights into how Indian companies can leverage digital transformation to enhance their ESG performance. The study aims to deepen theoretical understanding by highlighting the importance of green information technology in fostering sustainable development. It also seeks to broaden empirical research by demonstrating how digital transformation strategies, when aligned with green innovation, can drive ESG performance more effectively. Existing studies have primarily concentrated on the direct impact of digital transformation on economic value. However, there is a growing recognition of the importance of integrating green innovation to achieve broader non- economic objectives, such as enhancing corporate social responsibility and building a sustainable competitive advantage. This research fills a gap by proposing a model where green innovation moderates the relationship between digital transformation strategies and ESG outcomes, thus providing a more nuanced understanding of how digitalization can support sustainable practices in India.

By constructing a theoretical framework that positions green innovation as a key moderating factor, this study aims to open the "black box" of how digital transformation strategies can be tailored to improve ESG performance in Indian enterprises. The findings could guide companies in aligning their digital and green strategies to meet India's ambitious "double carbon" goals while fostering sustainable growth [1]-[25]. Hence the queries are, to assess the impact of Digital transformation strategy on Enterprise ESG Performance:

Research Question 1: What impact does Digital transformation strategy have on Enterprise ESG Performance?

Research Question 2: How does Enterprise Green Innovation influence both Digital transformation strategy and Enterprise ESG Performance?

2. Literature Review

Digital transformation strategy involves leveraging digital technologies to enhance business processes, improve customer experiences, and foster innovation. In the Indian context, digital transformation has become increasingly important due to rapid technological advancements and a push towards a more digitally integrated economy. Indian enterprises are adopting digital strategies to improve their operational efficiency, achieve sustainability goals, and create a competitive edge in the global market. A significant aspect of digital transformation in India is its role in enhancing sustainability and ESG (Environmental, Social, and Governance) performance. Digital tools such as big data analytics, artificial intelligence, and cloud computing enable companies to optimize their resource usage, reduce waste, and manage their environmental footprint more effectively. For instance, smart manufacturing and IoT (Internet of Things)

technologies help monitor and control energy consumption and emissions in real-time, thereby supporting green initiatives. Moreover, digital transformation is crucial for improving corporate governance and social responsibility. It enhances transparency, enables better decision-making, and facilitates greater accountabilitywithin organizations. Through digital platforms, companies can engage more effectively with stakeholders, including employees, customers, and investors, fostering trust and collaboration. While Indian enterprises are making strides in digital transformation, challenges such as infrastructure constraints, cybersecurity risks, and the need for digital skills remain. Nonetheless, with government initiatives like Digital India and increasing investment in technology, the momentum towards digital transformation is expected to grow, driving innovation, efficiency, andsustainability across various sectors in the country.

Environmental, Social, and Governance (ESG) performance has become a vital indicator of sustainable development in businesses globally, including in India. ESG criteria are used to evaluate a company's commitment to environmental stewardship, social responsibility, and governance practices, reflecting its ability to operate sustainably and ethically. The increasing focus on ESG performance in India is driven by growing awareness among investors, consumers, and regulators about the long-term benefits of sustainability and ethical business practices. In the environmental dimension, Indian companies are increasingly adopting green practices such as reducing carbon footprints, optimizing energy use, and managing waste effectively. This shift is motivated by both regulatory pressures and the desire to align with global sustainability trends. Socially, companies in India are focusing on inclusive growth, community engagement, and ethicallabor practices, aiming to foster positive relationships with stakeholders and enhance social equity. Governance is also a critical aspect of ESG performance in India, with companies striving for greater transparency, accountability, and ethical conduct. This involves adopting best practices incorporate governance, such as strong board oversight, effective risk management, and robust compliance mechanisms. Improved governance practices help build investor confidence and protect shareholder value. Despite these advancements, challenges persist, including inconsistent reporting standards, lack of awareness, and inadequate integration of ESG into core business strategies. However, with increasing regulatory support and investor interest, the emphasis on ESGperformance is expected to grow, encouraging more companies in India to embed sustainable and responsible practices into their operations, thereby fostering long-term economic and social benefits.

Green innovation, the development and implementation of environmentally sustainable practices and technologies, is increasingly crucial in addressing global environmental challenges. This fieldemphasizes creating solutions that reduce ecological footprints while enhancing economic and social benefits. Research highlights that green innovation encompasses several key areas: clean technologies, energy efficiency, sustainable materials, and waste reduction. Companies adopting green innovations often achieve significant advantages, including improved resource efficiency, reduced operational costs, and enhanced brand reputation. For instance, advancements in renewable energy technologies, such as solar and wind power, not only help in reducing greenhouse gas emissions but also offer long-term cost benefits and energy security. The role of green innovation is critical in achieving environmental sustainability goals. Innovations in recycling technologies and eco-friendly materials contribute to minimizing waste and conserving natural resources. Moreover, green innovations in processes and products can lead to lower energy consumption and reduced carbon footprints. However, challenges remain in the widespread adoption of green innovation. High initial costs, technological complexities, and limited access to financing can impede the implementation of green solutions, especially in developing regions. Toaddress these barriers, collaborative efforts between governments, industries, and research institutions are essential. Supportive policies, financial incentives, and investments in research anddevelopment can foster an environment conducive to green innovation. Overall, green innovation represents a vital strategy for advancing sustainability and meeting environmental targets. By focusing on developing and implementing green technologies and practices, businesses cancontribute significantly to environmental protection and sustainable economic growth [27] – [45].

3. Theoretical Background / Support

Enterprise digitalization in the Indian context involves integrating digital and intelligent technologies into every aspect of an organization's operations and business processes. Thisincludes enhancing areas such as research and development, production, sales, and customer service. The goal is to digitalize the entire development process of an enterprise,

thereby strengthening the value chain, innovation chain, and supply chain. As information technology rapidly evolves, the competitive landscape among Indian businesses intensifies, leading to increased investments in IT infrastructure year after year. Researchers have explored the concept of strategic alignment, emphasizing that a company's ability to maintain a competitive edge hingeson aligning its business plan (BP) with its information systems planning (ISP). One of the most influential frameworks in this area is the **Strategic Alignment Model** (SAM), developed by Henderson and Venkatraman. SAM outlines four key areas: business strategy, IT/IS strategy, organizational processes and infrastructure, and IT/IS processes and infrastructure. It suggests three types of alignment relationships: external alignment between BP and ISP in response to market competition; internal alignment focusing on the organization's management logic and structural design; and cross-domain alignment, which integrates strategic planning with architectural processes.

Four primary alignment patterns emerge from SAM, reflecting different paths of digital transformation. The first two are business strategy-driven, leading to "strategy execution" and "technology potential" models. The latter two are driven by IT/IS strategies, resulting in "competitive potential" and "service level" models. This study focuses on large manufacturing enterprises in India that have a foundation for digital transformation, examining how they developdigital strategies and reorganize corporate strategies to ensure sustainable development. The emphasis is on paths driven by digital strategies, where IT/IS digital strategies influence businessstrategies and organizational processes. This approach explores how new information technologies can provide Indian enterprises with competitive advantages, encourage innovative customer needs, and subsequently lead to new business strategies. Additionally, the service level path involves optimizing the positioning of IT/IS digitalization in external environments and leveraging advanced technologies to enhance user experience and organizational service functions. Integrating green information technology with digital transformation is crucial for Indian enterprises. It fosters collaboration, resource sharing, and value co-creation through digitalplatforms. Green information technology not only enhances business integration and information flow but also supports the development of dynamic platforms that facilitate rapid resource sharing.This study categorizes digital transformation strategies into two dimensions: business digitalization and platform digitalization. In practice, applying digital strategies to promote sustainable development highlights the importance of integrating green information technology, reflecting the synergy between digital innovation and environmental sustainability in the Indian context [46] – [65].

4. Hypotheses Development and Conceptual Framework

The concept of Environmental, Social, and Governance (ESG) factors as key indicators for measuring sustainable development was first introduced by the United Nations Principles for Responsible Investment (UN-PRI) in 2006. This framework encourages organizations to integrateESG factors into their operations, thereby achieving both economic and social value. In the Indiancontext, the ESG framework aligns well with the nation's growing emphasis on sustainable development and ecological progress, particularly under the broader goals of reducing carbon emissions and fostering green growth. Indian enterprises are increasingly recognizing the importance of incorporating ESG factors into their business strategies to achieve sustainable development goals. A key driver of this integration is digital transformation, which enhances an organization's ability to address environmental challenges. Through digital technologies and intelligent systems, businesses can quickly identify and respond to environmental issues, thereby enhancing their environmental responsibility. This technological capability not only supports regulatory compliance but also builds public trust and ensures long-term sustainability by enabling companies to monitor and manage their environmental impact more effectively. Furthermore, companies with strong ESG performance often demonstrate a significant commitment to social responsibility. This is evident in their willingness to make strategic decisions that prioritize societalwell-being, such as integrating sustainable practices within their supply chains. Digital transformation plays a crucial role in this process by enabling green integration both internally andexternally, fostering collaboration, and creating shared value across the entire supply chain. For instance, using digital platforms, companies can engage in real-time monitoring of supplier practices and ensure adherence to sustainability standards, thereby reinforcing their social responsibility commitments.

Corporate governance also plays a vital role in the digital transformation of Indian enterprises. Companies with strong governance frameworks are better positioned to drive digital initiatives that support sustainable development. Effective

governance reduces the principal-agent problem and mitigates financial constraints, enabling greater investment in digital technologies. This enhanced financial stability allows companies to adopt cutting-edge technologies that drive both business growth and ESG performance. In essence, good governance provides the foundation upon which digital transformation strategies can be effectively implemented, ensuring that theseinitiatives align with broader sustainability goals. The impact of digital transformation on ESG performance in Indian enterprises is multifaceted. It enhances environmental responsibility by leveraging technology for better resource management and compliance. It also supports social responsibility by promoting transparency and collaboration within supply chains. Lastly, strong corporate governance facilitates the adoption of digital strategies, providing the necessary oversight and resources to ensure that digital transformation efforts contribute to sustainable development. By integrating these elements, Indian enterprises can enhance their ESG performance and contribute to a more sustainable future. Existing research predominantly focuses on the impact of digital transformation on economic performance, particularly business value. There is a limited exploration of how digital transformation affects non-economic aspects, such as corporate social responsibility and ESG performance. This gap highlights the need for in-depth analysis of the complex relationship between digital transformation strategies and ESG outcomes. In the context of increased emphasis on social and environmental values, driven by advancements in digital transformation, enterprisesare increasingly recognizing the importance of integrating ESG principles to gain a competitive edge. Digitalization enhances transparency and reduces information asymmetry, leading to greaterstakeholder expectations for enterprises to address environmental and social responsibilities. Theability of businesses to meet sustainability goals often hinges on the effective governance of digital technologies across all operational levels. The theory of the innovation value chain suggests that digital transformation involves comprehensive innovation across the entire business ecosystem. Business digitalization encompasses the transition from conceptualization to practical application in collaboration with green supply chain partners through advanced technologies. This shift from traditional practices to dynamic, interactive processes fosters improved communication andcoordination among supply chain partners and internal departments.

Consequently, digitalization supports real-time interactions and drives continuous improvement in ESG performance. Thus, the hypothesis is proposed that business digitalization positively impacts ESG performance, reflecting the significant role of digital strategies in enhancing corporate social and environmental outcomes. To effectively reduce carbon emissions, it is crucial to manage and oversee capital investments carefully. Enterprise digital transformation strategies involve substantial investments in technology, talent, and other resources to navigate technological advancements and market changes. As the global digital economy expands, businesses are rapidly evolving their digital strategies using cloud computing, big data, artificial intelligence, and blockchain, among other technologies. These digital tools are transforming development planningand organizational structures, allowing companies to adapt to a fast-paced competitive landscape. Digital platforms are becoming the central organizational framework in industry practices, offering significant advantages through various types of platforms. The dynamic capability theory underscores the importance of platform digitalization in driving comprehensive digital transformation. It involves creating digital innovation networks to integrate resources and establish connections between green supply chain partners and internal departments. This integration facilitates the sharing of knowledge, data, and technology, thereby fostering collaborative growth within the green supply chain and contributing to improved ESG performance. Thus, the hypothesis is proposed that platform digitalization positively influences ESG performance, as it enhances the integration and collaboration necessary for advancing environmental and social goals. Hence proposed:

Hypothesis 1 (H1). Digital transformation strategy has a positive impact on enterprise ESG performance.

Green innovation involves developing new renewable or non-toxic materials and products to enhance energy efficiency, protect the environment, and promote the use of renewable resources.This approach is crucial for enterprises aiming to achieve sustainable development and is increasingly acknowledged across various sectors. By actively engaging in green innovation, companies can strengthen their environmental image and gain a competitive edge. Under India's "double carbon" policy, green innovation has become central to business operations. In the digital era, the impact of digital transformation on ESG performance is significantly mediated through green innovation. Firstly, from an environmental responsibility perspective, actions such as adopting advanced technologies, enhancing environmental governance, and reducing pollution are increasingly reliant on digital and intelligent technologies. Investment in digitalization often catalyzes green innovation within enterprises. Secondly, in terms of ESG performance, corporate

social responsibility is reflected in how well companies address stakeholder needs and foster strong relationships. This encourages resource sharing and enhances green integration within the supply chain, further driving green innovation. Lastly, regarding corporate governance, enterprises must align their digital transformation strategies with green innovation efforts to meet carbon neutrality goals by 2060. Effective green innovation, which is grounded in scientific principles, supports these objectives by providing a clear pathway to reduce greenhouse gas emissions and mitigate climate change impacts. Thus, green innovation not only supports environmental goals but also ensures long-term business sustainability and growth.

The "double carbon" policy emphasizes the need for enterprises to invest in low-carbon, zero- carbon, and negative-carbon technologies. Influenced by such policies, businesses are increasingly channeling resources into information technology, capital, and talent, thereby enhancing their ability to lead in digital strategy and green innovation. Green information technology, a crucial aspect of digital transformation, is both a driver of economic development and a strategic tool for fostering enterprise green innovation within the framework of the "double carbon" goals. Green innovation, supported by digital strategies, helps manufacturing firms improve their ESG performance, bolstering corporate reputation and social recognition. Effective ESG practices can reduce barriers to innovation, with government and investor support fostering a virtuous cycle thatprovides strategic resources and builds competitive advantages. Green innovation plays a pivotal role in balancing economic growth with environmental protection, supporting India's green transformation and the "double carbon" objectives. With the rise of the digital economy, the intersection of digital strategies and green innovation has gained academic attention. Technologiessuch as big data, the Internet of Things, and blockchain have enhanced green innovation by improving collaboration between enterprises and stakeholders. Digitalization accelerates the exchange of information and optimizes resource allocation, fostering more green innovation activities. Thus, digitalization and green innovation are crucial strategic choices for enterprises, each influencing the other. Digital investment directly supports green innovation, forming a chain that connects digital strategy to improved ESG performance.

Hence proposed:

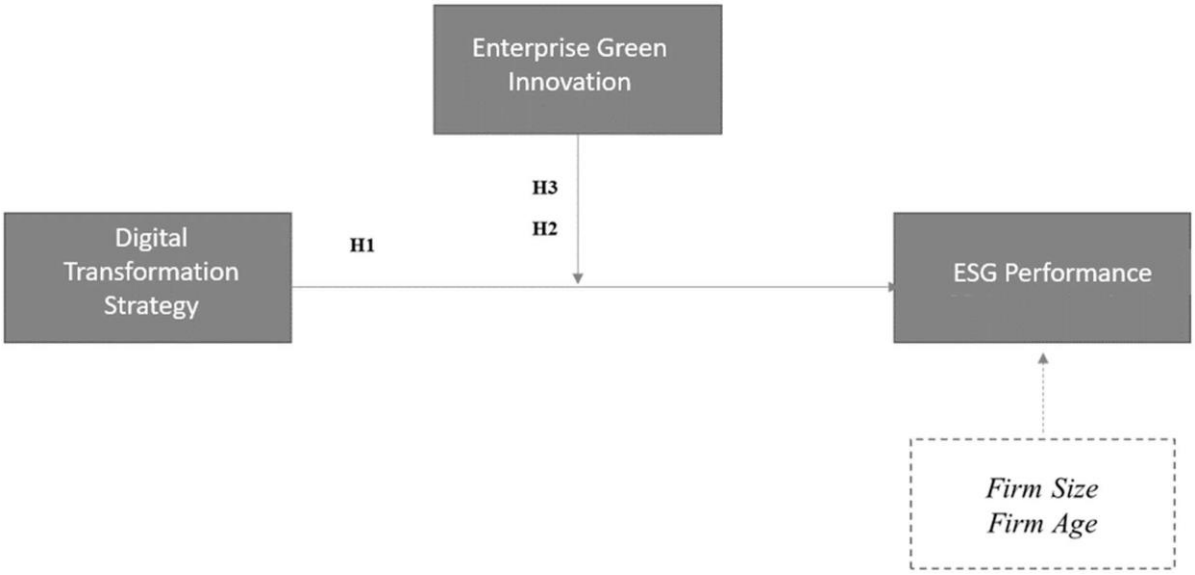
Hypothesis 2 (H2). Enterprise Green Innovation has a significant impact on ESG Performance.

Existing research identifies two key dimensions of green innovation: green process innovation and green product innovation. Green process innovation focuses on minimizing environmental impacts during production, while green product innovation targets the design of products with inherently lower environmental impacts. Digital technologies play a crucial role in enhancing both dimensions. They facilitate the optimization of processes and integration of green supply chains, positively influencing enterprise ESG performance. Green process innovation involves reducing the environmental burden of business operations by designing processes that consume less energy,use fewer raw materials, and produce recyclable products. To boost ESG performance, enterprisescan leverage platform digitalization to enhance resource exchanges with suppliers of green materials and environmental technologies. Digital technologies such as the Internet of Things and big data enable businesses to gather and analyze customer data, improving market demand identification and optimizing institutional innovation processes. Platform digitalization supports green process innovation by enhancing customer satisfaction and building a positive enterprise reputation, which, in turn, impacts ESG performance. Similarly, digital platforms provide valuable insights for decision-making, with resources managed via cloud computing and big data analytics demonstrating strong management potential. Advanced technologies like neural algorithms and machine learning help product developers access and utilize tacit innovation knowledge, enriching the enterprise's knowledge base for green innovation. This transition from experience-driven to data-driven green product innovation highlights the role of platform digitalization in improving innovation quality and its effect on enterprise ESG performance. Thus, green process and product innovations mediate the relationship between business digitalization and ESG performance.

Hence proposed:

Hypothesis 3 (H3): Enterprise Green Innovation moderates the relationship between Digital Transformation strategy and ESG Performance.

To sum up, the theoretical model of this study is as shown in Figure 2.



5. Research Methodology

Sampling and procedure: A sample of 145 respondents from medium-sized manufacturing companies in Bangalore, provided data via a questionnaire survey, which was used for empirical testing using the Multiple Regression method. SPSS was used to analyze descriptive and inferential statistics including hypotheses and moderation testing. The survey yielded a response rate of 26.8%.

Measures: All measures are based on a five-point Likert scale. All item scales' validity was verifiedby applying PCFA, followed by CFA. The PCFA was accomplished to examine all items loaded in one factor. Cronbach's alpha (α) appropriate values were found to be greater than 0.7 for the scale reliability. A confirmatory factor analysis (CFA) was carried out for measurement model validation. The measurement model is considered satisfactory at CMIN/DF = 2.807, CFI = 0.916,RMSEA = 0.071, and SRMR = 0.029.

Study Variables: All study variables were tailored from existing literature to ensure both content and construct validity, with varying item counts for each variable category:

Digital transformation strategy. Digitalization is a complex dynamic process, that is extremely difficult to quantify; therefore, the digitalization degree is introduced to measure the implementation level of enterprise digitalization relative to static and measured using 10 items [67], [68].

Enterprise ESG performance (ESG), six items of enterprise environmental responsibility, and seven items were chosen to measure Social and Governance in this study. *Intermediary variable:Green innovation* was measured using the eight items developed by [69].

Control variable: Based on existing research results, Firm Size and Firm Age were selected as themain control variables. This is because Firm size is closely related to the ability of firms to implement digital transformation strategies, and firms belonging to different industries often experience different impacts on their ESG performance.

Descriptive Statistics: The values for mean, standard deviation, and correlation coefficient of the study variables are shown in Table 1.

6. Research Findings

In this study, SPSS 25 statistical software was used to verify the research hypothesis through hierarchical regression. This method was applicable in this study because the advantage of the hierarchical regression method was that the degree of influence of each factor at each layer on theresult was quantified, very clear, and definite [70].

By providing not only an appropriate theoretical basis in the literature review but also logical reasoning for the sequence of predictor variables during variable selection, the scientific validity of applying this method was guaranteed [71].

The results of regression analysis are shown in Table 2.

Table 1: Descriptive Analysis

		Variables	0	1	2
		Mean	3.574	3.152	3.043
		Std. Dev.	1.153	1.318	1.233
		Reliability	0.875	0.798	0.882
Kendall's tau_b	**0**	ESG Performance	1		
	1	Digital Transformation Strategy	0.563***	1	
	2	Enterprise Green Innovation	0.459***	0.399***	1
Spearman's rho	**0**	ESG Performance	1		
	1	Digital Transformation Strategy	0.634***	1	
	2	Enterprise Green Innovation	0.439***	0.397***	1
*** Correlation is significant at the 0.01 level (2 tailed)					

Table 2: Regression Analysis (Moderation)

Variables	ESG Performance					
	Model 1		Model 2		Model 3	
Control Variable						
Firm Age	0.125***	0.011	0.112***	0.021	0.026***	0.012
Firm Size	0.115***	0.013	0.109***	0.023	0.016***	0.014
Independent Variable						
Digital Transformation Strategy	0.818***	0.026	0.498***	0.017	0.225***	0.089
Moderating Variables						
Enterprise Green Innovation			0.282***	0.025	0.242***	0.098
Interactions						
Enterprise Green Innovation * Digital Transformation Strategy					0.221***	0.092
-2 log likelihood	457.968		452.771		472.771	
Likelihood ratio (Chi-Square)	89.256***		114.636***		126.283***	
Pesudo R^2 Cox and Snell	0.532		0.558		0.678	
Notes: N = 145 1. Unstandardized regression coefficients and standard errors are shown.						
2.***Significance at 0.001 level (2-tailed).						

7. Discussion

The intersection of enterprise digital transformation and ESG performance is gaining increasing attention, yet existing research on how digitalization influences ESG outcomes and the mechanisms involved remains limited. While some studies have explored the impact of digitalization on governance (G) and social (S) aspects of ESG, with findings suggesting that digitalization lowers agency costs and enhances goodwill, its effect on environmental (E) performance remains underexplored [72]-[89]. Additionally, research that has investigated green innovation as a mediator between digital transformation and ESG performance has often relied onnarrow indicators, such as the number of green invention patents, which does not fully capture thebreadth of green innovation [90]. This study contributes to filling this gap by empirically examining various dimensions of green innovation and digital transformation strategies within large manufacturing enterprises. By broadening the scope to include multiple variables and focusing on both the direct and indirect effects of digital transformation on ESG performance, this research enriches the theoretical framework and provides a more comprehensive understanding of the interplay between these elements. At a macro level, the study highlights the crucial role of digital transformation in enhancing ESG performance under the “double carbon” strategy, illustrating its importance for building sustainable competitive advantages.

While prior research primarily centered on economic value, this study extends the strategic alignment model to explore how digital transformation can generate non-economic value, offeringnew insights into its potential for improving ESG outcomes [91]. On a micro level, the research establishes the link between green information technology and sustainability, offering a nuanced view of the complex relationship between digital transformation and ESG performance. It also addresses the "double-edged sword" effect of digital transformation, affirming its potential to both promote and challenge ESG performance across different dimensions. The theoretical model proposed—linking digital transformation strategy to enterprise green innovation and ESG performance—provides valuable managerial implications by integrating internal and external factors. This model serves as a foundation for further research and policy recommendations aimedat leveraging digital transformation for enhanced ESG performance.

In conclusion, this research confirms that a higher degree of digital transformation strategy correlates with improved ESG performance in large manufacturing enterprises, aligning with recent studies [89,90]. The findings underscore the critical role of digital transformation in enhancing ESG outcomes. Internal and external factors collectively drive digital transformation, setting a solid foundation for advancing ESG performance. Crucially, green innovation plays a significant role in this process. By integrating process and product innovations, enterprises can enhance the quality of their green initiatives, leading to steady improvements in ESG performance.This highlights the need for enterprises to strategically implement digital transformation toeffectively achieve and sustain high ESG standards.

Implications

Government departments play a crucial role in advancing the "double carbon" goals and guiding enterprises toward enhanced ESG performance. To foster high-quality development in the manufacturing sector, governments should bolster investments in intelligent, high-end, green, anddigital technologies. This support is essential for driving a new wave of industrial-technological transformation. Specific policy initiatives should target key sectors such as information systems, integrated circuits, automotive and new energy, biomedicine, and green petrochemicals. Additionally, enhancing the industrial base by supporting enterprise growth, scaling up operations,and encouraging industrial cluster development is vital. Government efforts should also focus on promoting the digital transformation of enterprises by creating intelligent digital application scenarios and advancing the shift toward green and service-oriented industries. Establishing innovation platforms will further support technological advancements and the application of newproducts.

For enterprises, improving ESG performance through digital transformation and green innovation involves several strategic actions. Enterprises should prioritize digitalization and the development of digital platforms, leveraging strategic consistency to integrate these technologies into their business ecosystem. This approach will facilitate the transition from digital strategy to comprehensive business and organizational processes, ultimately driving competitive advantage and organizational efficiency. Additionally, enterprises need to harness digital technologies to advance green innovation. By fostering an innovation-centric culture and incorporating effective green information technologies, businesses can enhance their green innovation capabilities. This includes promoting green processes and product

innovations and creating a supportive internal andexternal environment for ESG implementation.

8. Limitations and Recommendations for Future Research

While the findings of this study offer valuable insights into improving ESG performance throughdigital transformation strategies, several limitations must be noted.

Firstly, the study utilizes a questionnaire-based approach to assess multi-dimensional constructs, which may introduce subjective bias. The reliance on participants' perceptions could impact the consistency and accuracy of the results. Additionally, the challenges associated with collecting first-hand data from Indian enterprises—such as high research costs and limited sample sizes— may affect the robustness of the findings.

Secondly, the study's sample is drawn from a limited geographical context, and the insights may not fully represent the diversity in digital transformation strategies and ESG performance across different regions in India. Future research should broaden the scope to include a wider range of enterprises from various states and sectors in India to validate and refine the findings, enhancing their generalizability.

Thirdly, while the research examines different strategic routes of digital transformation, it lacks an in-depth analysis of how these strategies specifically drive green innovation. Future studies should delve deeper into the mechanisms by which digital transformation strategies can foster green innovation, particularly through the integration of green supply chains within the Indian context.

Lastly, although the hypotheses have been empirically validated, the study does not thoroughly explore practical methods for enterprises to effectively improve their ESG performance. Future research should investigate potential moderating variables and provide actionable strategies for enterprises to enhance their ESG practices. A more comprehensive examination of these aspects will contribute to a better understanding of how Indian enterprises can address their ESGresponsibilities.

Addressing these limitations and expanding research in these areas will lead to a more nuanced understanding of the relationship between digital transformation, green innovation, and ESG performance in India.

9. Conflict of Interest

None.

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