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The Role of Green Financing and Technological Innovation in Enhancing Corporate Environmental Performance Among Manufacturing Companies in India

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ABSTRACT

This study examines the relationship between technological innovation, green financing, and environmental performance in Indian manufacturing companies. While green finance and technological innovation are found to be good for the environment, their direct impact on the environmental performance of companies requires further investigation. Using the partial linear scale model of structural equation modeling (PLS-SEM), this research assesses these effects and their interactions. The findings indicated that technological innovation significantly improves environmental performance and contributes to overall corporate success. Green financing, which includes environmental, financial, and social aspects, also has a positive impact on environmental performance. However, the economic factors do not exert a significant impact. The study presents empirical evidence of the interaction between green finance and technological innovation, offering valuable insights for policymakers and industry leaders within the Indian manufacturing sector. The findings can aid in formulating effective strategies for integrating green finance and technological innovation, thereby driving sustainable business practices and promoting environmentally responsible business models for long-term success.

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1. Introduction

In recent years, the global community has witnessed unprecedented environmental awareness and sustainability concerns (World Economic Forum, 2020). As a result, businesses encounter growing pressure to recognise their environmental impact and take proactive measures to mitigate it. Green financing and technological innovation were found to be critical factors in enhancing corporate environmental performance. This dynamic relationship between finance and technology can drive transformative change across industries, leading to more sustainable and environmentally responsible business practices.

Green financing, a concept rooted in environmental sustainability, involves allocating financial resources to support projects, initiatives, and businesses with a beneficial ecological impact (G20 Green Finance Study Group, 2016). It allows manufacturing companies to secure funding for eco-friendly initiatives, such as adopting clean energy technologies, implementing efficient waste management systems, and reducing greenhouse gas emissions. Green financing mechanisms, including green bonds and sustainable loans, incentivise these companies to transition towards more sustainable and environmentally responsible practices. On the contrary, technological innovation is pivotal in the manufacturing sector's journey towards enhanced environmental performance (Markandya et al., 2018). India has witnessed substantial progress in developing and adopting innovative technologies across various industries, including manufacturing. Breakthroughs in energy-efficient manufacturing processes, eco-friendly materials, and pollution control technologies have empowered Indian manufacturing companies to reduce their ecological footprint. Moreover, digital innovations, such as Industry 4.0 technologies, enable companies to monitor, optimise, and streamline their operations, reducing resource consumption and emissions.

Environmental sustainability is of paramount importance for businesses in the 21st century. This imperative arises from various compelling factors. Firstly, stringent regulatory frameworks and legal requirements governing environmental practices have become more pervasive and rigorous (Porter & Linde, 1995). Non-compliance can result in substantial fines and legal repercussions, tarnishing a company's reputation. Therefore, businesses increasingly recognize the need to align their operations with environmental regulations to ensure long-term viability. Environmental sustainability opens new market opportunities (Hoffman & Woody, 2008). With growing consumer awareness and demand for eco-friendly products and services, businesses that embrace sustainability can tap into emerging markets and gain a competitive edge. Additionally, environmental sustainability is not merely a moral obligation but a strategic necessity for businesses today. It ensures regulatory compliance, mitigates risks, enhances reputation, delivers cost savings, unlocks market opportunities, and attracts responsible investment. By embedding sustainability into their core strategies and operations, businesses can thrive in a dynamic business landscape and contribute to a more sustainable and equitable future.

Over the years, India's manufacturing sector has experienced substantial expansion and transformation, contributing substantially to the nation's economic development. However, this growth has been accompanied by environmental challenges, including pollution, resource depletion, and ecological degradation. In response to these challenges, green financing and technological innovation have become critical factors in enhancing corporate environmental performance among manufacturing companies in India. Across the globe, policymakers are diligently crafting enduring strategies to foster technological progress and effective environmental management (Chien et al., 2021). Green financing is perceived as a substantial catalyst for industries characterized by limited innovation and environmental pollution, as well as for those exhibiting higher levels of creativity. This perspective garners broad support among business and economic analysts, underlining its significance as a driver for ingenuity.

Consequently, it is imperative to thoroughly examine the determinants influencing the success of environmentally conscious business practices before their implementation. Within the realm of green sustainability, green financing stands out as one of the most influential metrics (Yoshino et al., 2019). The structure of green finance, as evidenced in existing literature, exerts a direct and discernible impact on both technological advancement and the environmental performance of corporations.

This study explores the correlation between technological advancement and green financing and their collective impact on enhancing corporate environmental performance among manufacturing companies in India. By examining real-world examples and case studies, this study will provide insights into how these companies leverage financial mechanisms to fund sustainable initiatives and harness technological advancements to drive eco-friendly practices. Furthermore, it will analyse the challenges and opportunities specific to the Indian manufacturing landscape in pursuing environmental sustainability. Understanding the synergistic role of green financing and technological innovation within India's manufacturing sector is crucial in a global context where climate change and environmental sustainability are pressing concerns. This paper sheds light on how manufacturing companies can align their financial strategies with cutting-edge technologies to help India achieve a more sustainable and greener future.

While prior studies have examined the individual roles of green financing and technological innovation in improving corporate environmental performance, the current research addresses a significant gap by exploring the combined effects of both factors within India's manufacturing sector. It contributes to the theoretical understanding of how financial mechanisms and technological advancements interact, highlighting their potential to promote sustainability. The study's theoretical implications span environmental economics, sustainable finance, and innovation management, offering valuable insights for both scholars and practitioners. It also appeals to policymakers, business leaders, and environmental strategists seeking to implement sustainable practices in manufacturing. By addressing these critical areas, the study not only sets a foundation for future research but also offers actionable recommendations for improving corporate environmental performance on a global scale.

The present study begins with an introduction that outlines the research gap and the study's theoretical contributions, followed by a literature review on green financing and technological innovation, particularly in the context of environmental performance. The methodology section details the data collection and analysis processes. The findings are subsequently presented and supported by empirical examples. The study concludes by discussing theoretical contributions, practical implications, and recommendations for future research and policy development.

2. Literature Review and Hypothesis Development

Green finance has emerged as a fundamental concept in addressing environmental challenges and promoting sustainability through financial mechanisms. It encompasses a range of financial products and services, such as green bonds, green loans, and equity investments, to fund projects with positive environmental impacts (Zhou et al., 2020). These projects include renewable energy generation, efficient waste management systems, resource-efficient technologies, and other initiatives contributing to environmental conservation and climate resilience (Afzal et al., 2022). As environmental degradation continues to pose significant threats globally, the role of green finance in fostering sustainable development has gained increasing attention among policymakers, researchers, and industry practitioners (Chin et al., 2022). Empirical studies have demonstrated a strong and positive correlation between green finance and environmental sustainability. For instance, Afzal et al. (2022) analysed green finance activities across forty European countries and found that nations with higher investments in green financial instruments exhibited better environmental outcomes, including significant reductions in carbon emissions and improved air quality. Their findings underscore the critical role of economic resources in driving environmental performance at a macro level. Similarly, Chin et al. (2022) explored the impact of green finance within Belt and Road Initiative (BRI) countries and observed a significant negative correlation between green finance and environmental degradation. This study highlighted that increased green investments were vital in mitigating pollution levels while supporting sustainable economic growth. In the case of China, Zhou et al. (2020) emphasised the transformative role of green financial instruments, such as green bonds and green credit policies, in improving environmental quality. Although the regional impacts varied, the overall findings confirmed a positive relationship between green finance and enhanced environmental performance, indicating the potential scalability of such mechanisms.

In the context of India, green finance presents significant opportunities to address critical environmental challenges, particularly in the manufacturing sector. India faces substantial ecological issues, including industrial pollution, inefficient resource utilisation, and escalating waste generation, all of which hinder sustainable development (Afzal et al., 2022). Integrating green finance into the Indian manufacturing landscape can enable companies to adopt cleaner and more energy-efficient technologies, transition to resource-efficient processes, and embrace sustainable business practices

(Chin et al., 2022). Such financial interventions can play a transformative role in fostering a low-carbon and sustainable manufacturing ecosystem, contributing to national and global environmental goals. The hypothesis, based on the findings of Afzal et al. (2022) and Chin et al. (2022), suggests that green finance can effectively reduce environmental degradation and promote sustainable development. One important part of corporate social responsibility, which is frequently overlooked in research, is the focus on sustainable environmental, social, and corporate governance practices (Ershadi et al., 2024). By facilitating access to funding for environmentally sustainable initiatives, green finance empowers manufacturing companies to invest in innovative and sustainable technologies. In turn, this enables a shift towards greener operations, reducing industrial pollution and enhancing resource efficiency, which is critical for achieving long-term environmental sustainability in the Indian context.

2-1. Technology Innovation and Sustainable Practices

Many studies rigorously have investigated the conjecture that green technology contributes to mitigating environmental degradation. For instance, in their study, Chen and Lee (2020) provided cross-country evidence by utilising a panel of 96 economies, revealing that CO2 emissions can be significantly reduced by green technological innovation in high-CO2-emission, high-technology, and high-income economies. Chen et al. (2015) asserted that green innovation is a critical factor in enhancing environmental product quality and positively influences environmental performance, with the results obtained from a survey data from 198 Chinese manufacturing firms. Du et al. (2019) examined the extent to which green technology aids in reducing carbon dioxide emissions, identifying an income level threshold for 71 economies. They concluded that green technology does not significantly reduce CO2 emissions in economies below this threshold, but it does so in those above it. Using data from the 2010 Eurostat Community Innovation Survey, Robinson and Stubberud (2015) explored the motivations behind environmental innovation among small, medium, and large enterprises involved in process innovation, finding that the objective of reducing adverse environmental impacts through green innovation is more pronounced in large enterprises than in SMEs. Dou and Choi (2024) suggested that introducing green technology in industries, coupled with effective trade-in programs, can significantly diminish environmental degradation.

Concerning the relationship between environmental performance and green innovation, researchers such as Cai and Zhou (2014), Darnall et al. (2008), and Frondel et al. (2007) argued that various internal and external forces related to environmental policy compel businesses to promote green innovation. Green innovation in production processes should also be introduced while adhering to environmental regulations, as argued by Chen et al. (2015). This perspective is supported by Bashir et al. (2020) and Nesta et al. (2014), who utilized the data from OECD economies, and Sun et al. (2008) and Wei and Yang (2010), who examined the case of China, as well as Kahouli (2018), who focused on Mediterranean countries. Green innovation enables firms to enhance resource consumption and production processes, ultimately allowing them to meet legal environmental protection requirements (Chan, 2005; Oliva et al., 2019).

Additional significant benefits of green technology include improvements in overall firm performance (Mahto et al., 2020), mitigation of adverse environmental impacts from industries (Lin et al., 2013; Weng et al., 2015), reductions in industrial waste and costs (Day & Schoemaker, 2011; Millard, 2011), and improved customer demand for environmental protection (Handfield et al., 2002). Chiou et al. (2011) conducted an investigation across eight industrial sectors in Taiwan, applying structural equation modeling to survey data from 124 companies, and found substantial benefits of green innovation on environmental performance. Ghisetti and Quatraro (2017) performed a sectoral analysis of Italian regions concerning the effect of environmental innovations on performance, positing that sectors with higher levels of green technologies exhibit better environmental outcomes. Green technology is increasingly becoming a mandatory component of firms' environmental management policies, indicating its role in protecting the environment (Adegbile et al., 2017; Kammerer, 2009). Green energy innovations can reduce energy intensity, which subsequently improves environmental quality and mitigates carbon dioxide emissions (Shahbaz et al., 2018; Shahbaz et al., 2020). The notion that green innovation positively affects environmental performance is supported by Seman et al. (2019), who utilized the data from 123 ISO 14001-certified manufacturing firms. Furthermore, Wang et al. (2023), utilising the data from 57 developing economies, confirmed a long-term relationship between green technology and environmental performance.

The relationship between environmental sustainability and technological advancement has become a focal point in contemporary research and policymaking. Studies indicated that technological advancements hold immense promise for fostering environmental sustainability. Technological innovations, such as solar photovoltaics and wind turbines, have improved energy efficiency and made clean energy sources more accessible and affordable (Aghion et al., 2016). These developments are essential to lowering greenhouse gas emissions and mitigating climate change, as they facilitate the transition away from fossil fuels. Additionally, technological innovations in waste management and resource utilization, as noted in studies by Ghisellini et al. (2016), have led to more sustainable practices, including recycling, waste reduction, and developing eco-friendly materials. Integrating intelligent technologies, the Internet of Things (IoT), and artificial intelligence into environmental monitoring and management systems further enhances resource efficiency and environmental conservation (Zhang et al., 2018). As technological innovation continues to drive progress, it plays a pivotal role in shaping a more sustainable future by addressing environmental challenges through innovative solutions. In light of the arguments presented above, the following hypothesis can be proposed:

> **H1:** Technology innovation significantly affects the adoption of sustainable practices in India's manufacturing sectors.

2-2. Economic Factors and Sustainable Practices

Economic factors play a crucial role in determining the extent to which manufacturing companies adopt sustainable practices. Economic incentives, such as subsidies, tax breaks, and favourable financial conditions, are essential to making green investments financially viable for businesses. These incentives assist in alleviating the substantial upfront costs associated with the transition to cleaner technologies. Ravichandran, R., and Arif, M. (2016) found that financial incentives were significant drivers in promoting green practices among firms in India. By facilitating access to green funding, businesses can reduce the financial burden of adopting sustainable practices, allowing for long-term environmental benefits without facing prohibitive initial costs. Key studies further underline the importance of economic factors in the adoption of sustainable practices. Volz (2018) argued that economic policies, particularly subsidies and financial incentives for green investments, are necessary to drive the transition to green business models in Asia, a transition critical for mitigating environmental risks and supporting sustainable economic growth. Similarly, Dkhili (2019) emphasised the role of economic incentives, noting that access to capital and favourable green finance policies reduce the financial barriers to adopting resource-efficient technologies. Additionally, Chen et al. (2020) highlighted that countries with proactive economic policies in green financing showed greater progress in renewable energy adoption and industrial efficiency improvements. These findings are especially relevant in India, where manufacturing sectors are often capital-intensive and encounter significant challenges due to the high costs associated with green technologies.

Economic factors, such as government subsidies for renewable energy projects, low-interest green loans, and tax rebates, are pivotal in incentivising Indian manufacturing companies to adopt sustainable practices. By alleviating the financial burden on manufacturers, these economic mechanisms foster the integration of green technologies and the pursuit of environmentally responsible business models. The hypothesis aligns with the work of Ravichandran, K., & Arif, I. (2016), Volz (2018), and Dkhili (2019), who identified economic incentives as significant factors in promoting green investments. By facilitating access to financial resources and reducing the risks associated with investment, economic factors play a key role in encouraging manufacturing companies to adopt cleaner and more efficient technologies, thereby contributing to a more sustainable manufacturing sector in India. In light of the arguments presented above, the following hypothesis can be proposed:

> **H2:** Economic factors *significantly* affect the incorporation of sustainable practices in India's manufacturing sectors.

2-3. Social Factors and Sustainable Practices

Social factors play a significant role in driving the adoption of sustainable practices within manufacturing sectors, particularly through societal awareness, public expectations, and consumer pressure. As environmental issues gain prominence, the demand for sustainability in business practices is intensifying. Shrivastava, A., Jain, A., & Rao, V. V. (2019) highlighted that societal pressure, coupled with consumer demand for sustainable products, significantly encourages companies to adopt greener practices. Public awareness campaigns and consumer preferences have increasingly influenced corporate agendas, pushing businesses to invest in green technologies. Iqbal et al. (2021) also noted that aligning corporate practices with societal expectations, such as reducing carbon emissions and embracing energy-efficient solutions, not only improves a firm's environmental performance but also strengthens its reputation, ultimately boosting customer loyalty and market share.

In India, social factors have become particularly influential due to the growing visibility of environmental issues, such as air pollution, water contamination, and waste management challenges. As consumers become more conscious of the environmental impacts of the products they purchase, they are more likely to support companies that demonstrate a commitment to sustainability. This societal shift is driving manufacturing companies to explore green finance options and invest in environmentally friendly technologies to meet the increasing consumer demand for sustainable products. Moreover, pressures from NGOs, investors, and other stakeholders have amplified the need for businesses to embrace corporate social responsibility (CSR), ensuring that they align with broader environmental goals and expectations (Bansal, R. D., Wu, & Yaron, A., 2018).

The hypothesis is grounded in the findings of Shrivastava, A., Patel, R., & Kumar, S. (2019), Iqbal et al. (2021), and Bansal, P., Jain, A., & Kumar, S. (2018), who emphasised the growing influence of societal and consumer pressure in driving companies toward greener practices. As societal expectations evolve and environmental concerns gain more attention, firms in India are likely to adopt green finance initiatives to stay competitive and align with the increasing demand for sustainability. These social factors play a critical role in shaping the corporate strategies of manufacturing companies, thereby urging them to invest in sustainable and eco-friendly practices. In light of the above arguments, the following hypothesis can be proposed:

> **H3:** Social factors significantly affect the incorporation of sustainable practices in India's manufacturing sectors.

2-4. Environmental Factors and Sustainable Practices

Environmental factors, such as the need to reduce carbon emissions, manage waste, and protect natural resources, are central to the adoption of green finance within the manufacturing sector. The increasing focus on mitigating environmental impact has prompted businesses to invest in sustainable practices, driven by both regulatory requirements and the desire to reduce long-term environmental risks. Sahoo, Dhar, & Dash (2018) argued that environmental challenges, such as pollution and resource depletion, are powerful motivators for manufacturing companies to explore green finance. Companies are adopting greener technologies and sustainable practices as a means of mitigating the environmental damage caused by industrial processes, improving their environmental performance, and complying with stringent regulatory frameworks. Gao et al. (2023) supported this view, noting that firms in regions with stricter environmental regulations are more likely to invest in green technologies and sustainable practices. Additionally, Ahmed et al. (2022) found that organisations in pollution-intensive industries tend to adopt green finance as a strategic approach to address both compliance and reputation concerns. Regulatory pressures, combined with the potential for cost savings through energy efficiency and waste reduction, make green finance an attractive option for businesses looking to reduce their environmental footprint.

This trend is particularly evident in countries such as India, where environmental pollution is a major concern. In India, manufacturing companies are increasingly adopting green finance to meet environmental regulations and reduce their environmental impact (Ahmed et al., 2022; Sahoo, Das, & Yadav, 2018). The funding provided by green finance enables businesses to implement eco-friendly technologies that reduce waste, energy consumption, and pollution. The hypothesis builds on the work of Sahoo, Dhar, & Dash (2018) and Gao et al. (2023), who emphasised that environmental pressures are significant drivers of green finance adoption. Manufacturing companies in India, under pressure from both regulatory authorities and public opinion, are likely to adopt sustainable practices to reduce their environmental footprint and comply with environmental regulations. In light of the above arguments, the following hypothesis can be proposed:

H4: Environmental factors *significantly* affect the incorporation of sustainable practices in India's manufacturing sectors.

2-5. Financial Factors and Sustainable Practices

Financial factors, such as access to capital, availability of green loans, and the cost-effectiveness of green technologies, are crucial for the widespread adoption of green finance in manufacturing sectors. The availability of green financial products, particularly at competitive rates, can significantly reduce the initial investment required for firms to transition to sustainable practices. For businesses seeking to implement environmentally friendly technologies, financial support from green finance instruments helps alleviate the high upfront costs associated with such investments. Bansal, R., Sharma, T., & Verma, P. (2018) highlighted that financial factors, such as access to green finance and low-interest loans, are essential drivers for the adoption of green technologies. They found that the financial benefits tied to green investments—such as lower operational costs and improved energy efficiency—make it financially attractive for businesses to adopt sustainable practices. Similarly, Gianfrate and Peri (2019) explored the role of green bonds, indicating that they are financially favourable compared to traditional non-green bonds. Mishra et al. (2021) argued that government-backed financial instruments, such as green credit schemes, could significantly reduce the perceived risks of green investments. Green bonds provide issuers with an opportunity to finance environmentally sustainable projects at more favourable terms, thereby making green investments more accessible and financially viable.

The hypothesis draws on the findings of Bansal, Wu, & Yardon (2018), Gianfrate and Peri (2019), and Mishra et al. (2021), emphasising that financial incentives and green finance mechanisms can reduce the financial barriers faced by companies, thereby enabling the adoption of sustainable practices. These factors encourage the manufacturing sector in India to embrace cleaner technologies and more sustainable business models. In light of the above arguments, the following hypothesis can be proposed:

H5: Financial *factors* significantly *affect the incorporation of sustainable practices in India's manufacturing sectors.*

3. Methods and Design

3-1. Participants and Procedures

Data were collected from managers of selected manufacturing industries in India. These areas were chosen because they typically contribute significantly to a country's GDP and offer a rich and diverse landscape for research, with the potential to influence economic, environmental, financial, and social outcomes on a substantial scale. Participants in this study were recruited from managerial positions across various manufacturing sectors, including companies such as Apollo Tyres Ltd., Bharat Heavy Electricals Ltd. (BHEL), Dabur India Ltd., Eicher Motors Ltd., Indian Oil Corporation Ltd., Hero MotoCorp Ltd., Havells India Ltd., JK Tyre & Industries Ltd., Maruti Suzuki India Ltd., and NTPC Ltd. A total of 350 questionnaires were distributed, of which 217 were returned. After excluding five incomplete responses and two containing multiple outliers, 210 questionnaires were deemed suitable for subsequent statistical analysis, resulting in a response rate of 60%.

Among the respondents, 145 individuals were male, constituting 69.05% of the total sample, while 65 were female, representing 30.95%. The largest age group was 31–35 years, comprising 33.33% of the respondents, followed by 23.81% in the 36–40 years category, 21.90% in the above-41 years category, and 20.95% in the 25–30 years category. Regarding work experience, 33.33% of the respondents had over six years of experience, 30.95% had 4–6 years, 23.81% had 0–1 years, and 11.90% had 1–3 years of experience. In terms of education, 41.90% held a bachelor's degree, 40.48% had a master's degree, and 17.62% possessed diplomas in various fields. Organizationally, 35.71% of respondents worked in group-registered firms, 28.10% in partnership-based firms, 18.57% in sole proprietorships, and 17.62% in limited companies. Firm sizes varied, with 37.14% of respondents employed in firms with 11–15 employees, 29.52% in firms with 1–10 employees, and 16.67% in firms with either 16–20 employees or more than 20 employees. Finally, the majority of respondents (80.95%) were affiliated with local industries, while 19.05% were associated with foreign enterprises.

Table 1. The Sample Information

Classification	Frequency	Percentage
Gender		
Male	145	69.05
Female	65	30.95
Total	210	100.00
Age (years)		
25–30	44	20.95
31–35	70	33.33
36–40	50	23.81
41 Above	46	21.90
Total	210	100.00
Work Experience (Years)		
0–1	50	23.81
1–3	25	11.90
4–6	65	30.95
6 Above	70	33.33
Total	210	100.00
Education Level		
Masters	85	40.48
Bachelors	88	41.90
Diploma	37	17.62
Total	210	100.00
Registration		
Groups	75	35.71
Limited company	37	17.62
Partnership	59	28.10
Sole proprietorship	39	18.57
Total	210	100.00
Number of Employees (Firm size)		
1–10	62	29.52
11–15	78	37.14
16–20	35	16.67
21 Above	35	16.67
Total	210	100.00
Firm types		
Local	170	80.95
Foreign	40	19.05
Total	210	100.00

3-2. Measures

Technology Innovation: The measurement of technological innovation factors was conducted using a six-item scale, which had been validated in prior research and adopted from the work of Chen and Wang (2020). This scale was designed to gauge the effects of technological innovation on enhancing corporate environmental performance among manufacturing companies in India. All the scale items related to technological innovation met the minimum acceptable Cronbach's alpha value of 0.7, which was used to assess the reliability of the measurement scale.

Economic Dimension: The economic dimension in green financing is a crucial aspect underpinning the viability and success of environmentally sustainable projects and initiatives. This dimension encompasses various economic factors and considerations that influence the allocation and utilization of financial resources for green projects. It was measured using four items from Jha and Bakhshi (2019). The Cronbach's alpha for all items met the minimum acceptable value of 0.7, which was employed to evaluate the reliability of the measurement scale.

Social Dimension: Social factors play a pivotal role in green financing, encompassing various social dimensions that influence the adoption and effectiveness of green financing initiatives. These factors were measured using six items from Shrivastava, Patel, & Kumar (2019). The Cronbach's alpha for all items met the minimum acceptable value of 0.7, ensuring the reliability of the measurement scale.

Environmental Dimension: The environmental dimension in green financing is fundamental and revolves around the core objective of financing projects and initiatives that promote environmental sustainability, while minimizing adverse ecological impacts. This dimension covers various aspects of environmental conservation and protection within the context of financing. Its measurement utilized six items sourced from Sahoo, P. R., Dhar, R. L., & Dash, S. R. (2018). The Cronbach's alpha for all items met the minimum acceptable value of 0.7, confirming the reliability of the measurement scale.

Financial Dimension: The financial dimension in green financing addresses the allocation and management of financial resources for environmentally sustainable projects and initiatives. It encompasses various economic factors and considerations essential for successfully implementing green financing mechanisms. The measurement for this dimension involved four items sourced from Bansal, Sharma, & Verma (2018). The Cronbach's alpha for all items met the minimum acceptable value of 0.7, verifying the reliability of the measurement scale.

Sustainable Performance: The sustainable performance dimension in green financing evaluates the long-term impact and effectiveness of environmentally sustainable projects and investments. It ensures that financial initiatives contribute significantly to environmental and broader sustainability goals. This was assessed using six items from Bansal, Wu, & Yardon (2018). The Cronbach’s alpha for all items met the minimum acceptable value of 0.7, affirming the reliability of the measurement scale.

3-3. Data Analysis Technique

The researcher utilised SPSS version 24 for descriptive analytics to summarise and interpret key dataset characteristics, providing a foundational understanding of the data. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to test the hypothesised relationships, a method known for its ability to handle complex models, smaller sample sizes, and both reflective and formative constructs. This strategy would use two different methods: a measurement model (outer model) and a structural model (inner model) (Iqbal et al., 2024). The SEM process followed the two-step approach proposed by Hair et al. (2011) and was based on Anderson and Gerbing’s (1988) framework. The first step involved evaluating the measurement model using Confirmatory Factor Analysis (CFA) to assess validity and reliability. This included testing convergent validity through Average Variance Extracted (AVE) and factor loadings, discriminant validity via the Fornell-Larcker criterion and HTMT ratio, and internal consistency reliability using Cronbach’s alpha and composite reliability—the second step involved path analysis of the structural model to evaluate hypothesised relationships. Before finalising the model, the initial measurement model underwent rigorous evaluation and refinement using Smart PLS-SEM version 4.0, addressing model fit and ensuring construct robustness. This methodological rigour ensured statistically valid and reliable findings, enhancing the study’s credibility and providing a robust basis for theoretical and practical implications.

3-4. Statistical Strategy

SPSS version 24 was used to analyse correlations, reliability metrics, and descriptive statistics. The researcher employed partial least squares structural equation modeling (PLS-SEM), following the recommendations of Hair et al. (2018), to test the hypotheses of the study. PLS-SEM was selected due to its extensive applicability in various scientific fields, such as marketing, strategic management, human resource management, and hospitality (Hair et al., 2012; Ringle et al., 2018). Its versatility in handling diverse data types and its recognized effectiveness in estimating path coefficients within structural models further justified its use in this research (Hair et al., 2017). Although PLS-SEM has some acknowledged limitations, it remains a valuable tool for estimating path coefficients, particularly in models involving latent constructs. It is especially effective in managing limited sample sizes and non-normal data distributions (Hair et al., 2017). The decision to use PLS-SEM for this analysis is also supported by its ability to accurately estimate dependent variables, making it well-suited for the study's objectives (Hair et al., 2010). Moreover, the gradual relationships explored in this study, such as the mediating role of career resilience between career competency and career success, align with PLS-SEM's strengths in this research context (Hair et al., 2017).

To ensure an adequate sample size for PLS-SEM, the researcher adhered to the "10 times rule," which requires the sample size to be at least ten times the number of indicators in the most complex construct in the model. The initial measurement model was thoroughly examined for internal consistency, validity, and reliability. The final model testing was conducted using Smart PLS 4, the structural PLS software.

4. Results and Discussion

4-1. Measurement Model Assessment

The reliability of the components was evaluated by examining the loadings of each item on its corresponding construct. Chin (1998) suggested that standardised loadings should exceed 0.7 to ensure adequate reliability. As presented in Table 2, most items meet this criterion, indicating strong validity. However, items TI6 and ED2 fell below this threshold. Despite this, Byrne (2016) stated that loadings above 0.6 are still acceptable, allowing these items to remain part of the analysis.

Table 2. Outer Loadings of the Measurement Model

Code	Items of the constructs	Outer loadings
	Technology Innovation	
TI1	Our organization has successfully launched innovative product lines.	0.775
TI2	Significant investments have been made in Research and Development (R&D) to ensure the production of high-quality products.	0.874
TI3	State-of-the-art technology has been integrated into our production processes, reflecting our commitment to advanced manufacturing practices.	0.753
TI4	Innovative methods and procedures have been implemented in production and service delivery, enhancing efficiency and quality.	0.871
TI5	New products introduced by our company have been actively marketed to reach a wider audience.	0.702
TI6	The rebranding of our products has contributed to a noticeable increase in our company's market share.	0.676
	Economic Dimensions	
ED1	Our company prioritizes hiring local employees to strengthen community ties.	0.840
ED2	We encourage and promote sustainable practices among our employees.	0.630
ED3	Dedicated funds are allocated to support and implement sustainable initiatives.	0.885
ED4	Our company actively contributes to the community through donations and support.	0.732
	Social Dimension	
SD1	We prioritize workplace safety to minimize accident risks.	0.742
SD2	Ongoing employee training is a key investment for our company.	0.872
SD3	Equal treatment is ensured for all employees.	0.799
SD4	We uphold human rights standards in business partnerships.	0.883
SD5	Our employees respect the right of association.	0.775
SD6	We conscientiously evaluate the local impacts of our activities.	0.861
	Environmental Dimension	
END1	Our company uses as little energy, water, and raw materials as possible.	0.790
END2	Our company aggressively protects protected areas and biodiversity.	0.850
END3	Air emissions are reduced, including those of greenhouse gases and other pollutants.	0.888
END4	Our company strictly limits discharges into aquatic environments.	0.730
END5	Efforts are made to minimize residual materials, contributing to waste reduction.	0.847
END6	Throughout its existence, our company has been dedicated to reducing the environmental impact of its goods.	0.736
	Financial Dimension	
FD1	Profitability	0.880
FD2	Corporate image	0.717
FD3	Environmental sustainability	0.792
FD4	Shareholder’s satisfaction	0.808
	Sustainable Performance	
SP1	Minimizing the number of toxic compounds released into the air and water	0.731
SP2	Emphasizing waste reduction and material reuse in the production process.	0.790
SP3	Expanding the usage of biofuels and renewable energy sources.	0.885
SP4	Actively working towards improving environmental conditions.	0.700
SP5	Implementing measures to reduce inconsistencies in environmental impact	0.881
SP6	Harmonizing economic growth with environmental preservation for long-term sustainability.	0.872

Convergent validity is a critical concept in research that evaluates how well an indicator, such as a questionnaire item, aligns with the construct required to measure, while also considering related constructs. It ensures that different indicators for the same underlying concept converge in their measurements. Statistical techniques such as Average Variance Extracted (AVE) and Composite Reliability (CR) are commonly used to assess convergent validity as part of the measurement model. Following the guidelines of Hair et al. (2010), this study applied both AVE and CR to evaluate the constructs. AVE quantifies the proportion of variance a construct explains relative to measurement error, with a recommended threshold of 0.50. In this study, AVE values exceeded this threshold, indicating that the indicators effectively measure the intended construct. Similarly, CR assesses internal consistency, with a recommended threshold of 0.70. The CR values in this study also surpassed this benchmark, confirming the reliability of the indicators.

The fact that both AVE and CR values met or exceeded their respective thresholds provides robust evidence for the reliability and convergent validity of the constructs. This demonstrates that the research instruments consistently and effectively measure the intended constructs, enhancing the credibility of the study's findings.

Table 3. Construct Reliability and Validity

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Economic _Factors	0.739	0.738	0.822	0.538
Environmental _Factors	0.782	0.794	0.847	0.583
Financial _Factors	0.780	0.789	0.857	0.601
Social_ Factors	0.774	0.814	0.838	0.675
Sustainable _Performance	0.749	0.767	0.824	0.643
Technological _Innovation	0.803	0.806	0.859	0.505

Discriminant validity is essential in research to ensure that distinct constructs are truly different and do not overlap, particularly in structural equation modelling and measurement theory. Establishing discriminant validity is critical as its absence can lead to misinterpretation of results and unreliable findings. This study assessed discriminant validity using the Fornell and Larcker (1981) method. According to this method, a construct’s average variance extracted (AVE) should exceed the shared variance it has with any other construct. Table 3 illustrates that the square root of each construct’s AVE, which is shown along the diagonal of the correlation matrix, surpasses the correlations between constructs that are shown off-diagonal. This confirms that each construct accounts for more of its variance than it shares with other constructs, thereby establishing discriminant validity.

In practical terms, the measurement model in this study effectively distinguishes between constructs, ensuring that they are unique and do not overlap. This validation confirms the accuracy and robustness of the research, providing confidence in the study’s findings. Researchers and readers can trust that the constructs investigated are distinct and that they enhance the overall validity and reliability of the conclusions drawn.

Table 4. Discriminant Validity Employing the Fornell-Larcker Criterion

	Economic _Factors	Environmental _Factors	Financial _Factors	Social_ Factors	Sustainable _Performance	Technological _Innovation
Economic _Factors	0.662					
Environmental _Factors	0.292	0.695				
Financial _Factors	0.320	0.686	0.775			
Social_ Factors	0.416	0.654	0.630	0.689		
Sustainable _Performance	0.368	0.591	0.675	0.651	0.772	
Technological _Innovation	0.700	0.254	0.315	0.438	0.398	0.711

The study also employed the Heterotrait-Monotrait Ratio (HTMT) technique, introduced by Henseler et al. (2015), to further assess discriminant validity. According to the criteria set by Gold et al. (2001) and Henseler et al. (2015), HTMT values should remain below 0.90 to confirm the distinctiveness of constructs in the measurement model.

As presented in Table 5, all HTMT values in this study were below the 0.90 threshold, confirming compliance with the criterion. Furthermore, confidence interval analysis, following Kline's (2015) guidelines, revealed that no construct had a confidence interval containing the value "1." This finding strengthens the evidence of discriminant validity, affirming that the constructs are distinct and do not share substantial variance.

Table 5. Heterotrait-Monotrait Ratio (HTMT) Ratio

	Economic _Factors	Environmental _Factors	Financial _Factors	Social_ Factors	Sustainable _Performance	Technological _Innovation
Economic _Factors	-					
Environmental _Factors	0.392					
Financial _Factors	0.421	0.882				
Social_ Factors	0.555	0.782	0.793			
Sustainable _Performance	0.494	0.728	0.819	0.798		
Technological _Innovation	0.642	0.329	0.399	0.573	0.533	-

4-2. Assessment of the Results of Structural Model

In the present study, the researcher employed statistical techniques, including Partial Least Squares Structural Equation Modeling (PLS-SEM), to ensure the robustness and reliability of the findings while examining the relationships among the variables. The outcomes from these analyses are presented in Tables 6 and 7. A critical part of the PLS-SEM analysis involved evaluating the Variance Inflation Factor (VIF) for the independent variables, specifically Economic Value and Sustainable Performance. The computed VIF value of 2.031 was well below the established thresholds of 5 (Hair et al. 2011) and 3.3 (Diamantopoulos & Siguaw, 2006), suggesting that no multicollinearity issues were present among the independent variables.

After assessing the measurement model, the researcher constructed the structural model and evaluated the path loadings between the constructs. The statistical significance of these paths was determined using T-statistics derived from 500 bootstrapped samples, each containing 500 cases. Since PLS analysis is non-parametric, bootstrapping was employed to mitigate potential Type I errors arising from distributional assumptions, as recommended by Ramayah et al. (2018). The bootstrapping technique also provided standard errors for assessing the significance of the relationships, as detailed in Table 6 and Figure 2. All the relationships, except for the one between economic factors and sustainable performance, were found to be statistically significant.

The results indicated a considerable positive impact of green financial factors—encompassing environmental, financial, and social aspects—as well as technological innovation on sustainable performance. However, a negative effect was observed with economic factors and their impact on sustainable performance. In summary, the present study utilised a comprehensive range of analytical techniques to ensure the reliability and validity of the results, contributing to a robust understanding of the relationships under investigation. The coefficient of determination (R^2) suggested that green financial factors and technological innovation play a substantial role in influencing sustainability performance, explaining a moderate to substantial portion of the variance in sustainability outcomes (Cohen, 1988). These findings provide a meaningful contribution to the understanding of the variables' dynamics and offer strong evidence supporting the relationships explored in the study.

The coefficient of determination, denoted as R^2, is a key statistical metric used to assess the predictive power of a model. It indicates the proportion of variance in the dependent variable that is explained by the independent variables, thereby providing insight into how well the model predicts outcomes.

In the present study, the R^2 value of 0.557 indicates that, approximately, 55.7% of the total variance in overall sustainable performance is explained by the combined effects of green financial factors and technological innovation. This finding is significant as it reveals that over half of the variability in sustainable performance can be attributed to the influences of these two factors, underscoring their substantial effects.

Table 6. Cross-Loadings

Items	Economic Factors	Environmental Factors	Financial Factors	Social Factors	Sustainable Performance	Technological Innovation
ED1	**0.743**	0.285	0.25	0.27	0.262	0.537
ED2	**0.732**	0.197	0.235	0.258	0.204	0.477
ED3	**0.785**	0.14	0.171	0.278	0.238	0.327
ED4	**0.732**	0.184	0.212	0.293	0.265	0.379
ED5	**0.729**	0.167	0.175	0.259	0.213	0.341
END1	0.179	**0.89**	0.465	0.489	0.433	0.147
END3	0.193	**0.755**	0.528	0.511	0.425	0.187
END4	0.167	**0.788**	0.527	0.474	0.419	0.147
END5	0.293	**0.83**	0.346	0.297	0.289	0.252
END6	0.194	**0.847**	0.486	0.393	0.401	0.151
END2	0.228	**0.736**	0.486	0.522	0.469	0.203
FD1	0.225	0.586	**0.885**	0.431	0.497	0.207
FD2	0.266	0.523	**0.717**	0.475	0.422	0.26
FD3	0.223	0.526	**0.892**	0.52	0.572	0.247
FD4	0.283	0.505	**0.808**	0.522	0.578	0.267
SD1	0.273	0.157	0.293	**0.842**	0.242	0.305
SD2	0.223	0.216	0.293	**0.872**	0.274	0.301
SD3	0.344	0.486	0.474	**0.799**	0.5	0.323
SD4	0.363	0.531	0.476	**0.783**	0.542	0.357
SD5	0.243	0.52	0.54	**0.775**	0.52	0.261
SD6	0.291	0.615	0.468	**0.761**	0.506	0.32
SP1	0.282	0.519	0.651	0.557	**0.731**	0.264
SP2	0.228	0.563	0.589	0.473	**0.891**	0.186
SP3	0.237	0.313	0.368	0.437	**0.785**	0.285
SP4	0.205	0.339	0.358	0.359	**0.784**	0.259
SP5	0.252	0.268	0.356	0.451	**0.781**	0.32
SP6	0.282	0.237	0.206	0.231	**0.872**	0.339
TI2	0.534	0.169	0.217	0.279	0.256	**0.875**
TI2	0.534	0.169	0.217	0.279	0.256	**0.875**
TI3	0.484	0.152	0.22	0.332	0.283	**0.753**
TI4	0.504	0.22	0.254	0.368	0.308	**0.771**
TI5	0.506	0.193	0.238	0.307	0.296	**0.702**
TI6	0.535	0.169	0.22	0.295	0.265	**0.776**
TI1	0.429	0.176	0.195	0.278	0.283	**0.882**

Table 7. The Results of the Structural Model

Hypothesis	Relationship	Path Coefficient (β)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
H1	Economic _Factors -> Sustainable _Performance	0.017	0.017	0.047	0.354	0.723
H2	Environmental _Factors -> Sustainable _Performance	0.114	0.117	0.054	2.116	0.034
H3	Financial _Factors -> Sustainable _Performance	0.378	0.375	0.055	6.877	0.000
H4	Social_ Factors -> Sustainable _Performance	0.282	0.283	0.050	5.613	0.000
H5	Technological_ Innovation-> Sustainable _Performance	0.114	0.116	0.048	2.370	0.018

Following the measurement model outlined in the previous section, the study proceeded with hierarchical regression analysis, as shown in Table 7. In this analysis, interaction variables were sequentially introduced into the model, and hypotheses were evaluated based on t-values and p-values. If the t-value exceeded 1.96 or the p-value was less than 0.05, the hypotheses were considered supported. The findings emphasize the critical role of environmental, financial, social, and technological innovation in driving sustainable performance within selected manufacturing industries in India. This highlights the explanatory power of the cumulative impact of interactions between green finance practices and technological innovation. Upon assessing the structural model, technological innovation (TI) was found to significantly influence sustainable performance (SP), with a β coefficient of 0.114 and a p-value of 0.018. Likewise, environmental factors ($\beta = 0.11$, $p = 0.034$), financial factors ($\beta = 0.378$, $p = 0.000$), and social factors ($\beta = 0.282$, $p = 0.000$) all demonstrated the substantial impacts on sustainable performance, supporting hypotheses 2 and 3. In contrast, economic factors ($\beta = 0.017$, $p = 0.723$) indicated a negligible effect on overall sustainable performance, contradicting hypothesis 1.

Therefore, the theoretical model employed in this study was found to have strong explanatory power, as suggested by Chin (1998). The results indicated that companies implementing green finance practices are more likely to experience significant improvements in the sustainable performance of manufacturing industries in India. These findings offer valuable insights for both academia and industry, underscoring the importance of green finance practices and technological innovation in fostering sustainability within India's manufacturing sector.

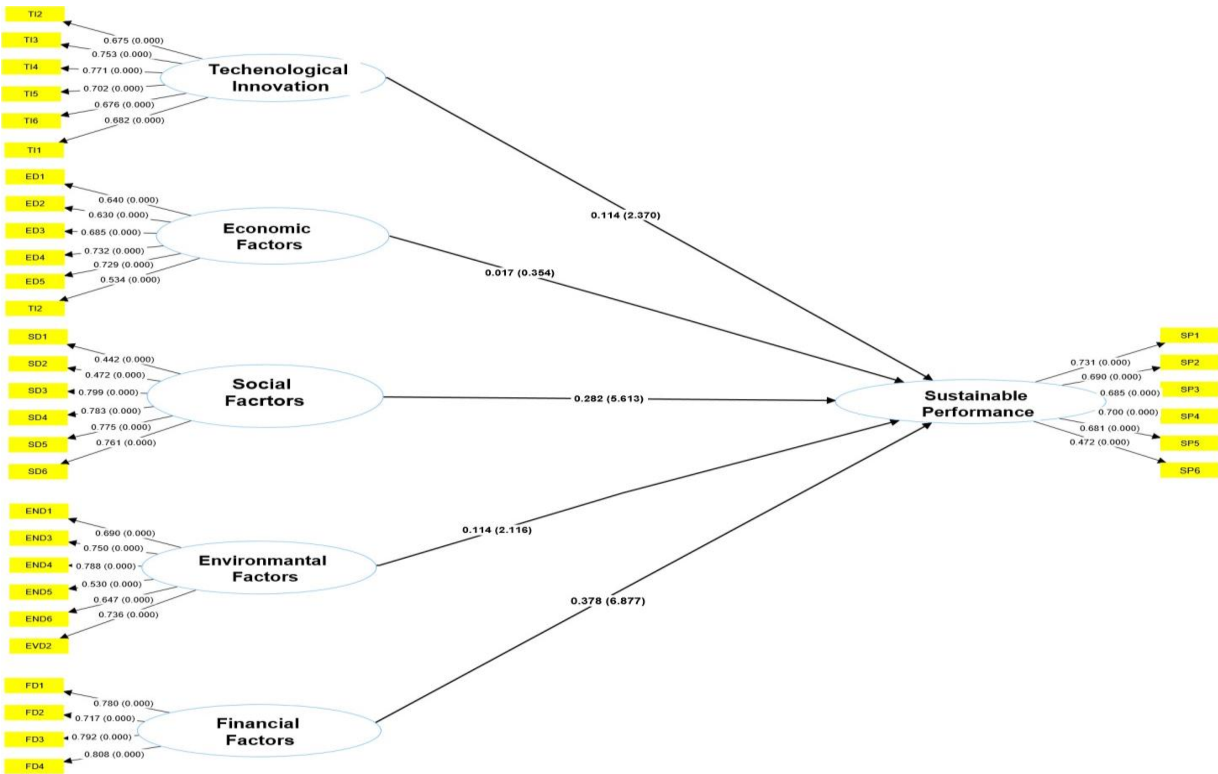

Fig. 1. Structural Model

5. Conclusion

This study utilized structural equation modeling (SEM) to establish the relationship between green financing initiatives and sustainable performance in specific manufacturing industries in India. The companies examined included Tata Steel, Tata Motors, Robert Bosch, Dixon Technologies, Havells India, Hindalco Industries, Hindustan Aeronautics Ltd (HAL), Hindustan Petroleum Corporation Limited (HPCL), and PG Electroplast. These firms were chosen for their prominence, as highlighted in the 2024 Indian Brand Equity Foundation (IBEF) Report. By focusing on these leading companies, the study aimed to provide a detailed analysis of the impact of green financing on various aspects of corporate sustainability. SEM was particularly suitable for this study due to its ability to analyse complex relationships among multiple variables, including economic, social, environmental, financial, and technological factors. This method allowed for the assessment of both direct and indirect effects, making it ideal for capturing the intricate connections between these factors as well as their influence on sustainable performance. Through this model, the research provided a nuanced understanding of how green financing impacts not only financial results but also broader sustainability objectives, such as technological innovation and environmental stewardship. Data were gathered from these companies, with a focus on their financial strategies, environmental practices, and technological advancements. These factors were subsequently analysed to assess their contributions to overall sustainable performance. The results confirmed that green financing plays a critical role in driving economic and financial performance, while also delivering positive social and environmental outcomes, thereby enhancing corporate sustainability.

A key finding of the study is the significant positive impact of environmental, financial, and social factors on sustainable organizational performance. Environmental sustainability emerged as a key driver, with the adoption of green technologies and eco-friendly practices leading to better environmental results. Financial factors, including funding for sustainable projects, also had a strong positive impact. Similarly, social factors, such as corporate social responsibility and community engagement, were linked to improved organizational performance. These findings suggest that sustainable performance is shaped not only by financial concerns but also by commitments to environmental and social responsibilities.

The study, however, found that economic factors alone did not have a significant impact on overall sustainability. While green financing can result in long-term financial benefits, short-term economic gains may not be immediately evident, especially for companies making substantial investments in environmentally friendly technologies. This finding underscores the need for a more nuanced exploration of how economic factors contribute to sustainable performance, and suggests that firms should prioritize long-term sustainability objectives rather than seeking immediate economic returns from green investments. The research also highlights the essential role of technological innovation in driving sustainable performance. Technological advances, particularly in energy efficiency, renewable energy, and waste reduction, were found to significantly enhance sustainability outcomes. Companies that invest in innovation not only improve their operational efficiency but also contribute to broader environmental and social goals. As a result, technological innovation is pivotal for sustainability, and firms should prioritise it as a key component of their sustainability strategies.

The findings of this study are consistent with prior research highlighting the importance of environmental, financial and social factors in driving sustainable business performance. Environmental issues have become a major worldwide concern, as manufacturing activities have a negative impact on the environment (Sajuygbe et al., 2024). Previous studies have also highlighted the role of green technologies and environmentally friendly practices in improving environmental performance (Goyal et al., 2023). Similarly, financial support for sustainability initiatives is a key factor in promoting long-term business success (Singh & Sharma, 2022). The link between social factors, such as CSR and community involvement, and better organisational performance is well documented in the literature on sustainability (Kumar et al., 2021). However, the finding of the study, that economic factors alone do not significantly impact sustainability, is consistent with Brown and Jones’s (2020) argument that short-term financial pressures often prevent sustainable investment, despite its long-term benefits. Additionally, the role of technological innovation in enhancing sustainability is supported by prior research, which highlights the impacts of advances in energy efficiency, renewable energy, and waste management on organizational sustainability (Chen et al., 2022). These findings reinforce the idea that organisations should integrate environmental, financial, and social considerations into their long-term sustainability strategies

The study offers several recommendations for managers and policymakers. For industry leaders, the research stresses the importance of cultivating a culture of sustainability and innovation within their organisations. Managers should embed sustainability into the core of their operations, invest in green technologies, encourage environmentally friendly behaviours among employees, and integrate sustainability into decision-making processes. It is crucial to encourage a leadership-driven commitment to sustainability, as organizational values are often shaped by the actions and priorities of top executives. A strong commitment from leadership can help integrate sustainability as a core organizational value, influencing all levels of the company. For policymakers, the study advocates for the creation of incentives that promote green financing and technological innovation. The Indian government, in particular, can play a significant role by offering financial incentives for eco-friendly technologies, such as tax rebates, subsidies for green investments, and research grants for clean technologies. Additionally, policymakers should encourage collaborations between the private sector, research institutions, and government bodies to facilitate the development and implementation of sustainable technologies. These findings align with previous studies, such as those by Awawdeh et al. (2022), which emphasize the positive relationship between technological innovation and sustainable performance. Similarly, Bag et al. (2021) found that green financing in manufacturing significantly improves efficiency and environmental outcomes. Together with this research, these studies demonstrate the critical role green financing and technological innovation play in advancing sustainability in the manufacturing sector.

Despite its contributions, this study has several limitations that future research should address. The sample size, limited to 210 employees from selected manufacturing companies in northern India, raises questions about the generalizability of the findings to other regions or sectors. Future research should include a larger, more diverse sample to enhance the external validity of the results. A broader sample would allow for a more comprehensive analysis of the factors driving sustainable performance in different contexts, including other developing economies. Additionally, this study focused primarily on the direct effects of green financing and technological innovation on sustainable performance. However, the complexity of sustainability suggests that other mediating factors, such as employee behaviour, organizational culture, and environmental strategy, also play key roles. Future research could explore these factors to provide a more comprehensive understanding of the drivers of sustainable performance. Investigating the influence of technological knowledge, employee engagement in sustainability, and corporate environmental strategies would further enrich the model and offer a more complete view of sustainability dynamics.

Finally, this research offers valuable insights for today’s managers and policymakers while laying the groundwork for future studies. By addressing its limitations and exploring additional mediating factors, future research can provide a more holistic understanding of the enablers of sustainability in diverse organizational contexts. This will not only help businesses develop more effective sustainability strategies but also guide policymakers in creating supportive frameworks for green innovation and financing in the manufacturing industry.

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