

Unveiling the Link Between Green Innovation and Firm Performance: Insights from Indian Companies

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ABSTRACT

Green innovation is increasingly recognized as vital for addressing environmental challenges and driving economic growth. Understanding its link to firm performance is crucial for evaluating how sustainability contributes to corporate success. This study investigates this association using cross-sectional data from 61 Indian companies (BSE-listed, sourced from Ace-Equity) for FY 2022-23. Empirical findings demonstrate that green innovation exert a favorable and measurable impact on firm performance, demonstrating that embracing environmentally sustainable practices enhances financial and operational outcomes. By focusing on the under-researched Indian context, the study contributes meaningfully to innovation literature. The cross-sectional analysis provides a timely snapshot of green innovation's current impact, offering valuable insights for both practitioners and academics. Key implications include: encouraging managers to strategically prioritize context-specific green innovation for competitive advantage and sustainable growth; urging policymakers to develop effective mechanisms fostering eco-conscious practices industry-wide; and providing a foundation for future research to explore deeper causal relationships and long-term effects. Collectively, this research underscores green innovation's pivotal role in enhancing corporate performance and advancing sustainable development goals.

Keywords: Green innovation, ISO 14001, Sustainability, Financial Performance, Return on Capital Employed (ROCE), Emerging Economies, Resource-Based View (RBV), Ecological Modernization Theory, Transaction Cost Theory.

1. Introduction:

The global economy is witnessing a paradigm shift towards sustainable development, prompting firms to reevaluate their strategies to align with ecological and social objectives. This evolution is driven by mounting concerns over climate change, dwindling resources, and social inequities, prompting businesses worldwide to incorporate sustainability into their core practices (Singh & Rahman, 2021). In this context, green innovation has emerged as a pivotal concept, representing the development and application of novel or improved products, processes, and practices aimed at minimizing environmental harm while fostering economic growth (Mele & Spena, 2015). Green innovation, often viewed as a subset of broader sustainability initiatives, offers a dual advantage: reducing the ecological footprint of businesses while simultaneously enhancing their market competitiveness and long-term viability (Carrillo-Hermosilla et al., 2010).

Green innovation is particularly critical for emerging economies such as India, which face the dual challenge of sustaining rapid economic growth while mitigating environmental degradation (Haldar, 2019). As one of the fastest-growing economies globally, India's trajectory of industrialization, urbanization, and resource consumption has had profound implications for its environment. According to a 2021 report by the World Bank, India is the third-largest emitter of greenhouse gases, contributing approximately 7% of global emissions. Additionally, the country's air quality consistently ranks among the worst globally, with the IQAir 2020 World Air Quality Report identifying 22 of the world's 30 most polluted cities as being in India. The degradation of water resources, deforestation, and biodiversity loss further

underscore the urgency of adopting sustainable practices (Mukherjee et al., 2020). Recognizing these challenges, the Indian government has implemented a series of initiatives to promote green innovation and sustainable development. Notable among these are the National Action Plan on Climate Change (NAPCC), which outlines strategies to combat climate change through eight national missions and the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, which incentivizes the adoption of green mobility solutions. Additionally, programs like the Perform, Achieve, and Trade (PAT) scheme under the Bureau of Energy Efficiency aim to improve energy efficiency in energy-intensive industries. These initiatives highlight the growing emphasis on integrating sustainability into India's industrial and corporate frameworks. The non-financial sector, encompassing industries such as manufacturing, energy, and technology, plays a pivotal role in driving green innovation in India (Mahesh et al., 2022). This sector is responsible for a significant proportion of the country's environmental footprint, accounting for substantial greenhouse gas emissions, energy consumption, and resource utilization (Huang, 2021). For instance, the manufacturing sector alone contributes nearly 20% to India's GDP but is also a major source of industrial pollution. Consequently, the adoption of green innovative practices in these industries holds the potential to bring about transformative environmental and economic benefits. Firms that proactively integrate green innovation can achieve greater resource efficiency, reduce waste, and comply with stringent environmental regulations, thereby positioning themselves as leaders in sustainable business practices (Dong et al., 2023).

Despite the increasing adoption of green innovation, its impact on financial performance remains a subject of debate in both academic and business circles. Existing literature presents a dichotomy in perspectives (Zhan, 2023; Przychodzeń & Przychodzeń, 2014; Marín-Vinuesa et al., 2018). On one hand, proponents argue that green innovation enhances financial performance by driving cost efficiencies, opening new market opportunities, and strengthening brand reputation. It has been clearly demonstrated that green innovation fosters long-term financial gains through resource efficiency and product differentiation (Ch'ng et al., 2020). As per the Boston Consulting Group (2020) companies with strong sustainability practices tend to outperform their peers financially, with higher shareholder returns and reduced risk exposure. On the other hand, critics contend that the high costs related to research and development, regulatory compliance, and technological adoption pose significant challenges (Marchetti, 2012). The debate underscores the need for a nuanced understanding of the factors influencing the association between green innovation and financial performance. Contextual variables such as firm size, industry type, regulatory environment, and consumer preferences play a critical role in shaping this relationship (Marín-Vinuesa et al., 2018). While extensive research has been conducted in developed economies, where institutional frameworks and market dynamics are well-established, studies focusing on emerging economies like India remain sparse (Dahiya & Singh, 2020; Ghosh et al., 2018; George & Reddy, 2015). This gap is particularly pronounced in the non-financial sector, which, despite its substantial contribution to economic output and environmental challenges, has received limited scholarly attention (Ghosh & Kanjilal, 2020).

The present study seeks to address this gap by examining the interplay between green innovation and financial performance in the Indian non-financial sector. This study integrates theoretical frameworks with empirical investigation to elucidate the dual impact of green innovation—enhancing financial performance while advancing environmental sustainability objectives. Through this synergistic approach, the research seeks to establish a robust, multidimensional understanding of eco-innovation's role in driving both economic and ecological value creation. Specifically, the study will explore key drivers and barriers to green innovation adoption, assess its impact on operational and financial metrics, and identify best practices for fostering sustainable growth. The findings are expected to offer actionable insights for policymakers, business leaders, and stakeholders seeking to promote green innovation as a strategic lever for sustainable development in developing economies. In conclusion, as India navigates the complexities of balancing economic growth with ecological preservation, green innovation emerges as a vital enabler of sustainable progress. By aligning environmental objectives with business strategies, firms can not only mitigate their environmental impact but also unlock new avenues for value creation and competitive advantage (Edwards, 2021). This study aspires to contribute to the growing body of knowledge on green innovation, offering valuable implications for advancing sustainability in India and other emerging economies.

The results provide robust evidence that green innovation implementation exerts a significant positive effect on corporate performance measures, highlighting that firms embracing environmentally sustainable practices can achieve improved financial and operational results. The current study contributes to the mounting body of innovation literature by examining this association, offering fresh perspectives on an under-researched area. The study's reliance on cross-sectional data provides a snapshot of the present state of green innovation in India and its connotations for firm performance, yielding valuable insights for academics, practitioners, and policymakers alike. Managers can leverage

these findings to understand the strategic importance of context-specific green innovation as a driver of competitive advantage and sustainable growth. Policymakers, on the other hand, can use the insights to design impactful mechanisms, policies, and guidelines that encourage green innovation and foster ecologically conscious attitudes across industries. Moreover, the findings of this research have implications that go beyond academia, laying the groundwork for future studies to investigate the causal relationships and long-term impacts of green innovation on corporate performance. This study elucidates the transformative potential of green innovation, demonstrating its critical role in aligning corporate strategic frameworks with Sustainable Development Goals (SDGs). By doing so, it contributes to the broader discourse on how eco-innovation serves as a catalyst for transitioning toward a sustainable and resilient global economy.

Hypothesis and related literature

2.1. *Green innovation*

Green innovation has been a subject of growing interest in the academic literature. The various aspects of green innovation have been explored by various researchers, including its drivers, barriers, and impacts. Eco-Innovation Observatory defines green innovation as "the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle." This definition highlights the environmental consequences of innovation, rather than the underlying motivations. Green innovations may emerge from several economic motivations, including the expansion of market share or cost reduction, rather than only from an objective of environmental enhancement. The literature has also explored the differentiation between end-of-pipe technologies and integrated environmental technologies, the latter being inherently more complicated and aiming for various purposes beyond only environmental aims.

The Organization for Economic Co-operation and Development (OECD) defines eco-innovation as the development or application of novel or substantially enhanced products (goods and services), processes, marketing strategies, organizational frameworks, and institutional arrangements that, intentionally or unintentionally, result in environmental advancements relative to pertinent alternatives (Ganapathy et al., 2014).

While other researchers have explained green innovation as the design, implementation, or utilization of new or considerably enhanced products, services, production processes, organizational structures, or management and business practices (Ganapathy et al., 2014). These technologies are new to the firm or user and reduce environmental impacts throughout their life cycle. Green innovation reduces environmental dangers, pollution, and resource usage, particularly energy utilization. Developing environmentally friendly alternatives and adopting strategies that use natural resources more efficiently contributes to the firm's and society's sustainability (Loučanová et al., 2021). By integrating green innovation into various business processes, firms can gain long-term environmental benefits, such as cutting carbon emissions, reducing waste, conserving water, and improving energy efficiency. Additionally, green innovation plays a significant role in supporting a circular economy, where resources are exploited in a way that optimizes their value and reduces their environmental effect (Sumrin et al., 2020).

The subjective view on innovation corresponds closely with the Oslo Manual but somewhat deviates from Schumpeter's typical economic definition. Schumpeter described innovation as the initial market release of a new product, method, service, or organizational structure, focusing largely on the development of something wholly new (Ács & Sanders, 2013). However, Kemp and Pearson enhance this definition by stressing the acceptance and implementation of ideas that have been offered by others, underscoring the importance of technological diffusion. They say that innovation is not just about finding new solutions, but also about how these breakthroughs spread and are employed across diverse industries and organizations. (Stoneman & Battisti, 2010)

In this larger view, green innovation plays a key role in defining sustainable development. It goes beyond the simple creation of environmentally friendly technology; it also covers the adoption and adaption of these technologies to decrease environmental effects and boost the efficiency of natural resource utilization (Ermilova et al., 2019). Green innovation offers enterprises with vital tools to explore alternate routes towards sustainability, helping them to decrease ecological footprints, preserve resources, and optimize energy use. By supporting the proliferation of eco-friendly solutions, green innovation may greatly contribute toward an ecologically balanced, low-carbon economic paradigm (Gandenberger et al., 2020).

The MEI definition stresses outcomes over motivations. According to this viewpoint, it is of little significance whether environmental improvements were the main purpose of a new product or process, or developed as a by-product or by

chance (Kurk & Eagan, 2007). Green innovations could originate from other economic drivers, like gaining market share or cutting costs. It can be deduced that numerous developments in minimizing adverse environmental effects have not been largely driven by environmental considerations. While previous end-of-pipe technologies had a sole conservational target and entailed additional expenses, invention of cohesive environmental technologies - known as cleaner production - constituted a complicated innovation activity with numerous aims.

Lastly, the definition necessitates that green innovations have clear environmental benefits when compared to applicable alternatives, such as energy-efficient light bulbs relative to traditional bulbs. The last section of the definition ascertains that green innovations have concrete impacts on an organization's environmental footprint (Papetti et al., 2013).7

2.2. *Green innovation and firm performance*

The open innovation paradigm constitutes a collaborative framework wherein organizations strategically engage with external entities—including suppliers, research institutions, and industry partners—to co-develop novel solutions or enhance existing technologies. This approach enables firms to achieve three key competitive advantages: (1) cost optimization in research and development, (2) risk mitigation through shared knowledge pools, and (3) accelerated innovation cycles from ideation to commercialization. The rise of green innovation and sustainable development has received substantial policy support, promising a bright future for these endeavors. However, there remains confusion surrounding whether a comprehensive development approach matches with the individual motivations at the firm level (Beltramello et al., 2013). The integration of open innovation principles with environmentally sustainable practices results in an emergent paradigm of open green innovation, which plays a significant role in developing a new economic paradigm. In this paradigm, corporations are heavily encouraged to assume leadership roles in driving innovation, particularly in terms of environmental stewardship. This impetus leads in the quick proliferation of sustainable solutions, driving the transition towards more sustainable economic framework (Sherafati et al., 2019). A major question is whether individual enterprises may receive economic or financial benefits from green innovation. Recent research has inspired innovation and inventiveness in solving this challenge. From an economic aspect, adopting green innovation exerts a significant influence on firm performance (Zhang et al., 2019). Knowledge, typically seen as a valued asset, frequently provides firms with a competitive edge. According to the Resource-Based View (RBV) theory, by strategically exploiting both tangible and intangible resources enterprises can obtain a competitive edge (Fahy, 2000). The integration of RBV theory with the capability-based perspective offers valuable insights into the mechanisms through which open innovation fosters dynamic capability development in manufacturing systems. While the benefits may not be immediately evident, especially in the first year of implementation (Lin & Wu, 2013), the relationship grows increasingly important over time (Giniuniene & Pundzienė, 2020). By the second year, the beneficial benefits of green innovation on financial performance are evident (Zhan, 2023), since green innovations directly contribute to an increase in financial results (Huong et al., 2021). The ecological modernization theory described that green management acts as a mechanism through which companies can integrate environmental concerns into their operations by escalating innovation (Ch'ng et al., 2020). This mechanism involves examining how sustainable practices might increase a firm's competitiveness and profitability (Süder, 2006). Therefore, corporations predict that green innovations will offer future benefits, such as reduced costs through better raw material utilization and stronger consumer demand, aligning with transaction cost theory (El-Kassar & Singh, 2018). As such, transaction cost economics plays a vital role in influencing the impact of open innovation. Innovation inside enterprises primarily aimed at decreasing costs, saving time, and boosting performance. This focus on efficiency supports the role of green innovation in the present study. Green innovation can increase both the economic and environmental performance of a corporation. Numerous research studies support this idea suggesting that proactive green innovation helps firms gain an upper hand by uncovering novel market opportunities, strengthened corporate reputation, enhanced institutional legitimacy, and superior competitive positioning (Colombelli et al., 2020; Wei et al., 2012; Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Küçükoğlu & PINAR, 2015). It was also discovered that green patenting had a beneficial impact on the performance of Chinese firms (Zhang et al., 2019). Similarly, it was found that green innovation positively increased business performance in Japan from 2001 to 2010. This was further corroborated with a survey of 374 manufacturing enterprises, revealing a strong association among green innovation and corporate performance (Asni & Agustia, 2021). However, much existing research focuses on organizations or industries within a limited number of (often developed) nations, potentially limiting the generalizability of findings to diverse contexts like India. The present study addresses this gap by specifically examining the influence of green innovation on shareholder wealth within the under-explored Indian context. Utilizing cross-sectional data from the Ace Equity platform for Indian companies during FY 2022-23, the research provides crucial

insights into this relationship in a major emerging economy. On the other hand, it was suggested that enterprises implementing green innovation practices may fail to enjoy increases in their financial performance (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013), and it was shown that a negative link between green innovation and corporate value exists (Yao et al., 2019). A study related to developed nations Austria, Germany, and Switzerland conveyed that only 19% of enterprises claim improved performance from sustainable investments, while 81% saw negligible or even negative returns (Stucki, 2018). Therefore, the relationship between green innovation and business performance remains ambiguous. There is a dearth of thorough study on the impact of green innovation methods on firm performance (Soltmann et al., 2014; Ghisetti & Rennings, 2013; Ma et al., 2018). The results related to this relationship are equivocal and may be impacted by variations in sampling frameworks, analytical approaches, and research design parameters (Zhang et al., 2019). Based on this discussion, this study suggests the following hypothesis.

H1.: The adoption of green innovation positively influences the corporate performance of Indian firms.

2. Research Methodology

3.1. Sample and Data

This research examined a cross-sectional dataset to evaluate the proposed hypotheses. The research examines the relationship between green innovation and firms' financial performance. Data was gathered from BSE 100 companies for the financial year 2022-23. Financial companies were excluded from the analysis due to variations in accounting practices and their distinct environmental and social regulatory requirements (Atif et al., 2022). Additionally, firms with incomplete data for relevant variables were omitted. The final sample comprised 61 companies.

3.2. Description of variables

3.2.1. Dependent variable

This paper relies on accounting-based performance as the response variable in its analytical framework. Consistent with the findings of Tariq et al., (2019) and Lin et al., (2019), accounting-based measures are considered more effective indicators for examining the relationship between green innovation and firm performance. Therefore, the current study utilizes the ROCE (Return on Capital Employed) accounting measure to assess company performance, which reflects the return generated from the capital invested in the business. This measure emphasizes the corporate's internal competences and management efficacy (Lin et al., 2019). A firm's social responsibility outcomes can substantially affect its internal competency measurements. Study by Tariq et al. (2019) confirms that successful adoption of sustainable innovation approaches represents an indispensable requirement for industrial competitiveness. This study aims to introduce novel green innovation notions to address existing gaps.

3.2.2. Independent variables

The primary explanatory variable in this study is green innovation. To evaluate green innovation activities, this paper utilized ISO 14001 standards, similar to those applied by Radonjić & Tominc, (2006), Toha et al., (2020), McGuire, (2014), Vries et al., (2012), Nga, (2009), and Psomas et al., (2011). Scholarly investigations (Lin et al., 2019) establish that ISO 14001 certification criteria form the structural basis for robust environmental management systems in organizational contexts. These standards are considered essential for organizations aiming to make a positive environmental impact (Sartor et al., 2019) and achieve business success (Psomas et al., 2011). ISO 14001 facilitates companies in managing their environmental responsibilities and promoting sustainability (Puvanasvaran et al., 2014). It enables organizations to work towards their environmental objectives, providing benefits to the environment, companies, and associated stakeholders (Khan et al., 2019).

The integration of an environmental management system (EMS) into corporate sustainability frameworks enables comprehensive lifecycle control, thereby enhancing overall environmental performance metrics (Phan & Baird, 2015). This research employs ISO 14001 certification as a proxy for green innovation evaluation based on two key rationales. First, as Vries et al. (2012) establish, ISO 14001 serves as an internationally validated environmental management framework that embodies institutional transformation through voluntary EMS implementation. Second, while organizational self-declaration of ISO 14001 compliance is permissible, formal certification requires external verification of ecological practices under public oversight (Deb, 2021). As Kaman (2020) corroborates, product certifications conforming to global standards such as ISO 14001 constitute the most credible mechanism for corporations to validate regulatory compliance with environmental protocols. Arocena et al., (2020) emphasized the importance of corporations actively pursuing sustainable practices. This objective can be attained through adherence to internationally recognized environmental and social governance frameworks, including ISO 14001 certification. The significance of

ISO 14001 stems from its comprehensive applicability across diverse organizational contexts, irrespective of type, size, or operational characteristics, while systematically addressing environmental dimensions of business operations, outputs, and services (Puvanasvaran et al., 2014). This standard allows businesses to meet obligations, achieve environmental objectives, and foster sustainability (Nunhes et al., 2020).

3.2.3. Control variables:

This study incorporates the following control variables to address potential estimation bias from omitted variables (Gibassier & Alcouffe, 2018), thereby reducing their confounding effects on the dependent variables (Rahman & Alam, 2022). This methodological approach aligns with established practices in prior research (Zhang et al., 2020). Firm Size (SIZE), Firm Risk (RISK), Board Gender Diversity (BGD), Firm Age (AGE) and Sales Growth (GROWTH) are incorporated as a control variable. This ensures that variations in performance are not exclusively attributed to green innovation.

Table 1 Conceptualization and Quantification of Research Variables

Variable	Label	Variable Conceptualization and Quantification
Dependent Variables:		
Return on Capital Employed	ROCE	EBIT divided by capital employed
Independent Variable:		
Green innovation	GI	Assigned a value of 1 if the company declares ISO 140001 certification; otherwise, assigned a value of 0
Control Variables:		
Firm Size	SIZE	Derived from the natural log of consolidated balance sheet assets.
Firm Risk	RISK	Computed as the ratio of total liabilities to aggregate assets.
Board Gender Diversity	BGD	It is calculated as the proportion of female directors relative to the total number of board members.
Firm Age	AGE	Computed as the cumulative years of operation from incorporation to the analysis timeframe.
Sales growth	GROWTH	Calculated as the percentage change in sales

3. Research Model:

To investigate the relationships among the variables of interest, an Ordinary Least Squares (OLS) regression model was employed. The choice of OLS regression is appropriate given the nature of the dependent and independent variables and the cross-sectional nature of the data. The model allows for estimating the linear relationships between the dependent variable and the set of independent variables while controlling for other covariates. Furthermore, the study employed robust standard errors to ensure heteroskedasticity-adjusted results.

The general specification of the regression model is as follows:

$$FP = \beta_0 + \beta_1 GI + \beta_2 SIZE + \beta_3 RISK + \beta_4 BGD + \beta_5 AGE + \beta_6 GROWTH + \varepsilon$$

Where: FP= Financial Performance,

GI= Green Innovation,

SIZE= Firm Size,

RISK= Firm Risk which is measured through Debt-To-Equity Ratio,

BGD= Board Gender Diversity,

AGE= Company Age,

GROWTH = Sales Growth,

ε = error term

4. Results:

5.1. Descriptive statistics:

The empirical results are systematically presented in Tables 2 and 3. Table 2 displays descriptive statistics for all study variables across the sample of 61 Indian firms during FY 2022-23. Regarding financial performance metrics, the dataset reveals a mean Return on Capital Employed (ROCE) of 19.60%, with observed values distributed between -5.36% and

71.76%. The independent variable, measured by the Green Innovation Score, demonstrates a mean value of 83.61% across the sample of Indian firms, indicating robust green innovation adoption. This performance level slightly exceeds the 2011-2017 automotive sector findings reported in Lin et al. (2019), suggesting progressive advancement in sustainable innovation practices.

Table 2

Descriptive statistics.

Variable	Mean	Median	Minimum	Maximum	Std. Dev.	Skewness	Ex. kurtosis
ROCE	19.603	16.585	-5.3653	71.764	14.269	1.5491	3.0774
GI	0.83607	1.0000	0.0000	1.0000	0.37329	-1.8155	1.2961
SIZE	10.696	10.723	7.8676	13.956	1.2401	0.081127	-0.38309
RISK	0.71480	0.12595	-0.35782	9.2298	1.3857	4.1963	21.908
BGD	20.284	17.000	6.0000	57.140	11.664	1.2613	1.5025
AGE	49.377	42.000	8.0000	116.00	26.338	0.70825	-0.24806
GROWTH	27.256	20.231	-13.307	109.97	23.598	1.7416	3.2720

The descriptive characteristics of key control variables measures are additionally presented in Table 2. Company size ranges from 7.87 to 13.96, with an average size of 10.696. The RISK variable spans from -0.358 to 9.2298, with a mean of 0.71480 and a standard deviation of 1.2401. Board Gender Diversity (BGD) averages 20.284%, fluctuating between 6% and 57.140%, with a standard deviation of 11.664. Company age varies significantly, ranging from 8 to 116 years, with a mean age of 49.377 years and a standard deviation of 26.338. Sales Growth shows a range from -13.307% to 109.97%, with an average of 27.256% and a standard deviation of 23.598.

As preliminary analysis preceding formal econometric testing, Pearson correlation analysis was employed to examine bivariate associations between study variables. Table 3 reports inter-variable correlation coefficients for all regression covariates (Chouaibi et al., 2022), with the strongest observed relationship being a modest 0.2205 correlation between RISK and SIZE - well below conventional multicollinearity thresholds. To rigorously evaluate potential multicollinearity, variance inflation factor (VIF) diagnostics were subsequently performed (Lin et al., 2019), complementing the correlation analysis with more sophisticated collinearity assessment. The VIF results reveal that the highest VIF value is 1.159, which is well below the commonly accepted threshold of 10, confirming no multicollinearity concerns (Mansour et al., 2023b).

Table 3

Correlation matrix.

	ROCE	GI	SIZE	RISK	BGD	AGE	GROWTH
ROCE	1						
GI	0.173	1					
SIZE	-0.1846	-0.0008	1				
RISK	-0.2505	0.1226	0.2205	1			
BGD	-0.2413	-0.0197	-0.3106	-0.1427	1		
AGE	0.1871	0.1556	0.0809	-0.0523	-0.1298	1	
GROWTH	-0.2536	-0.1269	0.0813	0.1296	-0.0838	-0.3044	1
VIF		1.055	1.156	1.098	1.139	1.159	1.148

5.2. Regression results:

This study utilized OLS regression analysis on cross-sectional data to examine the relationship between the independent and dependent variables, focusing on both the strength and direction of the association (Mansour et al., 2023a). The analysis incorporated heteroskedasticity-robust standard errors (HC1 variant) to enhance reliability.

The findings, summarized in Table 4, reveal an F-statistic of 5.33 (p-value = 0.000223), indicating that the regression model is statistically significant and effectively rejects the null hypothesis of no explanatory power. The R-squared value of 0.2766 suggests that the model accounts for approximately 27.66% of the variance in ROCE, while the adjusted R-squared value of 0.1962, adjusted for the number of predictors, indicates that the independent variables explain a relatively small portion of the variation in the dependent variable. Furthermore, the RESET test for model specification

yields a p-value of 0.6937, providing no evidence of misspecification and confirming the model is appropriately specified. Additionally, White's test for heteroskedasticity returns a p-value of 0.7429, suggesting no evidence of heteroskedasticity in the residuals, which supports the robustness of the model's standard errors.

Table 4

OLS regression, using observations 1-61

Dependent variable: ROCE

	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	VIF
const	54.7592	14.1707	3.864	0.0003***	
GI	6.15557	3.27992	1.877	0.0660*	1.055
SIZE	-2.64623	1.42333	-1.859	0.0685*	1.156
RISK	-2.48592	1.09014	-2.280	0.0266**	1.098
BGD	-0.430560	0.138327	-3.113	0.0030***	1.139
AGE	0.0343917	0.0654603	0.5254	0.6015	1.159
GROWTH	-0.116892	0.0531761	-2.198	0.0322**	1.148

Note: Asterisks ***, **, and * denote the significance of the variable at the 1%, 5%, and 10% levels, respectively.

R-squared	0.276619	Adjusted R-squared	0.196243
F(6, 54)	5.330209	P-value(F)	0.000223

H1 posits a positive relationship between green innovation and financial performance. Among the independent variables, green innovation has a positive coefficient (6.15557), suggesting that rise in green innovation is correlated with rise in ROCE. However, its p-value of 0.0660 indicates significance at the 10% level, which, while modest, is still noteworthy. This points to a marginally significant positive relationship between green innovation and ROCE. Recent empirical work by Kruglov and Shaw (2024) corroborates the positive innovation-performance relationship, demonstrating significant associations between sustainability-oriented innovation metrics and financial outcomes in U.S. firms. This alignment with preceding findings (Ahsan et al., 2024; Michalski et al., 2023; Mondal & Sahu, 2023) strengthens the evidence base for innovation-driven performance enhancement. However, a substantive counter-literature (Stucki, 2018; Palmer & Truong, 2017; Ghisetti & Rennings, 2013; Zhang et al., 2019) contests the presumed 'win-win' paradigm of green innovation, presenting empirical cases where ecological investments fail to translate into concurrent financial gains. Adopting Green innovation initiatives allows companies to boost ROCE, improve corporate reputation, reduce production costs (Ren, 2021), and demonstrate social responsibility (Przychodzeń & Przychodzeń, 2014), aligning with the resource-based view. The study by Lin et al. (2019) highlight that environmentally innovative firms experience greater customer acquisition, leading to expanded market presence. Thus, the empirical findings confirm that prioritizing green innovation enables companies to enhance productivity, avoid regulatory penalties, market diversification opportunities, sustainability branding enhancement, and sustainable competitive positioning. These conclusions are consistent with the work Dong et al., (2023), Fernando & Wah, (2017), Doran & Ryan, (2014) and Ghisetti & Rennings, (2013).

Concerning control variables, Firm size shows a negative relationship with ROCE (-2.65) and is weakly significant at the 10% level (p-value = 0.0685), suggesting larger firms may experience diminishing returns on capital. Risk has a statistically substantial negative effect on ROCE (-2.49, p-value = 0.0266), highlighting that higher risk is associated with lower capital efficiency. Board gender diversity is also negatively related to ROCE (-0.43, p-value = 0.0030), suggesting that companies with more gender diversity on their boards tend to have lower returns on capital. Company age has an insignificant positive effect on ROCE, and sales growth exhibits a negative relationship with ROCE (-0.12, p-value = 0.0322), indicating that rapid growth may come at the cost of capital efficiency.

5. Conclusion

This study introduces an original conceptual model that establishes a systematic relationship between green innovation initiatives and organizational performance outcomes, thereby advancing current scholarly discourse on sustainable development through strategic innovation lenses. Contemporary business practices reveal growing corporate adoption of ecological modernization principles, reflecting a strategic shift toward environmentally conscious operational paradigms and innovative sustainability solutions. The results of this study demonstrate a significant positive correlation between green innovation initiatives and corporate performance, providing empirical support for the theoretical underpinnings of green innovation and shedding light on the challenges firms face in adapting to environmental

concerns. This research is theoretically grounded in transaction cost economics and ecological modernization theory, both of which are pivotal in understanding environmental innovation. These theoretical perspectives provide critical lenses for resolving conflicts between economic development objectives and ecological conservation imperatives. Specifically, Ecological modernization theory, in particular, underscores how green enterprises view green innovation as a mechanism for fulfilling social responsibilities. By showcasing environmental commitment, firms can foster green initiatives and adopt eco-friendly innovation strategies. The study further highlights the multifaceted benefits of engaging in green innovation activities. Firms that integrate green concepts into their operations often experience enhanced financial performance, improved corporate reputation, and increased operational efficiency. By reducing waste, optimizing resource utilization, and promoting sustainability, green innovation enables companies to achieve long-term growth while aligning with global sustainability goals. This research underscores the strategic importance of green innovation as a pathway to achieving both economic success and environmental stewardship, providing actionable insights for policymakers, managers, and stakeholders.

6. Implications of the paper

The study elucidates significant strategic implications of green innovation, emphasizing its profound impact on profitability, competitiveness, and sustainability. Green innovation serves as a strategic tool for managers to enhance business operations while addressing environmental challenges. By incorporating green innovation into strategic planning, firms can reduce waste, reuse resources, and improve operational efficiencies, resulting in cost savings and long-term financial benefits. This approach not only promotes environmental stewardship but also strengthens market positioning and brand reputation. Ecological incentive programs play a vital role in promoting sustainable practices. Managers must leverage these programs, such as subsidies for green R&D and access to cheaper capital, to offset the initial costs of adopting green innovative technologies. Evaluating the effectiveness of such incentives ensures alignment with organizational goals and facilitates compliance with regulatory requirements. For instance, securing grants can enable firms to adopt advanced technologies, thereby gaining a competitive edge. Open innovation is another key aspect of green innovation, allowing managers to collaborate with external stakeholders such as universities, research institutions, and industry partners. Although initial implementation costs may be high, the long-term benefits—including enhanced knowledge sharing, faster innovation cycles, and access to advanced technologies—justify the investment. Managers must foster flexibility and adapt to new information, cultivating a culture of continuous improvement and sustainability within their organizations.

Green innovation also acts as a signal of sustainability commitment, enhancing brand reputation, attracting environmentally conscious consumers, and improving investor confidence. Larger enterprises, often required to disclose CSR reports, can use green innovation to demonstrate tangible sustainability efforts. Proactively addressing environmental concerns helps mitigate risks associated with non-compliance and stakeholder criticism. The role of stakeholder pressure in driving green innovation adoption is significant. Managers should respond to environmental demands by integrating green practices into their operations and strategies. Collaborating with supply chain partners to implement eco-friendly processes and engaging employees through training and incentives fosters a collective commitment to sustainability goals. Policymakers are instrumental in supporting green innovation by providing grants, tax incentives, and subsidies for green R&D. At the same time, imposing penalties for non-compliance encourages firms to adopt sustainable practices. Managers must work closely with policymakers to align corporate objectives with governmental sustainability goals, ensuring mutual benefits for businesses and society.

Context-based green innovation is crucial, requiring managers to tailor initiatives to specific industry needs and market dynamics. A thorough understanding of regulatory environments, consumer preferences, and market trends helps ensure that green innovation aligns with organizational capabilities and strategic objectives. Green innovation delivers significant advantages for stakeholders, businesses, and society. It fosters trust and long-term partnerships, offers differentiation and risk mitigation opportunities for companies, and contributes to environmental preservation and resource efficiency for society. Managers must prioritize green innovation initiatives and actively engage stakeholders to maximize these benefits. Green innovation is a transformative approach to addressing environmental challenges while achieving financial and competitive advantages. Enterprise managers should adopt a strategic, context-driven approach and leverage government support to facilitate sustainable growth. By fostering collaboration among businesses, stakeholders, and policymakers, green innovation can drive shared value and long-term sustainability for all parties involved.

7. Limitations and Future Directions

No study is without its limitations, and this research acknowledges the following limitations. First, the study solely utilized ISO 14001 certification as the exclusive proxy to evaluate green innovation. To strengthen the assessment of green innovation adoption, prospect research could explore the use of alternative methods to improve the generalizability of the results. Second, the sample was restricted to the largest Indian firms. Future research could explore green innovation practices among smaller firms. Third, the study employed ROCE, an accounting measure, as the sole indicator to examine the relationship between green innovation and corporate performance. To gain deeper insights, future studies should incorporate additional performance metrics. Fourth, the analysis focused on the analysis impact of green innovation on firm performance within the same year. Future research could extend this investigation by analyzing the influence of green innovation on performance in subsequent years. Additionally, researchers could explore potential confounding variables that might affect the relationship between green innovation and firm performance. Lastly, future studies should consider examining the impact of green innovation on other firm attributes, such as operational efficiency, environmental performance, and corporate reputation.

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