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Green Innovation in SMEs: A Managerial Route to SDG 9 and SDG 13 Exploring the adoption of eco-innovations in small business strategy

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ABSTRACT

Sustainable development goal (SDG) seeking has become a business strategic stand in the world. Specifically, SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action) note the importance of innovation to allow sustainable industrialization and reduce climate change. Small and medium-sized business (SMEs) with their limited resources consist of a considerable percentage of the world economic activity and environmental effect. One of the initiatives, which this paper examines as a means of attaining these SDGs, is the use of managerial green innovation in SMEs. Based on literature and empirical contributions, we discuss the motivation, impediments, and consequences of adoption of eco-innovation in the SME strategies. Case studies are combined with survey data in a paradigm referred to as a mixed-method approach that examines managerial decision-making, sustainable integration of technology, and development of products as well as processes. Results indicate that it is a major facilitator to have managerial commitment and access to green financing as well as regulatory support, whereas knowledge gaps, cost pressures, and cultural resistance are the major challenges. The work is not just of theoretical nature, and the researchers offer practical suggestions to SME managers and policymakers that could be accepted in the aim of promoting green innovation faster. Pragmatic constraints relate to regional coverage of targeted industries and short period of observation that does not touch on too many effects in the long run. Future studies are needed to look at cross-industry comparative studies, the role of digital transformation and eco-innovation and trajectories of cumulative environmental benefits over the years..

Keywords: *Green innovation, SMEs, eco-innovation adoption, SDG 9, SDG 13, managerial strategy, sustainable business, climate action*

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1. INTRODUCTION

The fact that there is a very high rate of acceleration on environmental degradation and at such a time when the development of industries should be sustainable has transformed the economic agenda of the world [1][22]. Riddled with time, the United Nations Sustainable Development Goals (SDGs) have risen to become a globalized universal framework of guiding countries, sectors as well as firms in achieving inclusive and sustainable development. Specifically, SDG 9 (Industry, Innovation and Infrastructure) highlights the value of encouraging innovation and creating resilient infrastructure that can help sustain successful industrialization, whereas SDG 13 (Climate Action) urges the urgent and co-ordinated steps to overcome the current imminent danger of climate change. Global supply chains or production systems change all the time and the problem is acting as stewards of the environment but keeping an economic system competitive.

The pivotal place in this equation falls to the small and medium enterprises (SMEs). Worldwide, SMEs make up over 90 percent of all the businesses, and are major employers as well as the key contributors in value chain integration. With relative small scales of operations, the overall environmental effects of SMEs is high. The combined effects of energy used by SMEs, wastes produced, and carbon emissions become equal to these effects of big companies. As they are already economically important and versatile, SMEs can serve as an important agent of green change, provided they are armed with adequate tools, tactics, and incentives [10-15].

Innovation, which is also referred to as green innovation or eco-innovation takes conceptual focus in this transformation. Green innovation involves the process of creation, deployment of products, processes, services and managerial approaches that minimize the destructive effects to environment, improve efficiency in the way resources are used and works towards combating climate change. Eco-innovation is a competitive advantage to the SMEs as far as it is not only a question of environmental responsibility. Incorporating sustainable business models into their operations, the SMEs will get access to new markets, the increase of brand value, and the development of crisis resistance in terms of regulatory, and resource-related risks. Nevertheless, green innovation implementation by the SMEs lacks regularity and without obstacles [21].

Current literature indicates that SMEs are likely to encounter obstacles in being eco-innovative such as high costs of making the upfront investments, lack of green funding sources, poor technical skills, and low confidence in realization of returns on investments. SMEs are more budget-constrained and have limited human resources in comparison to the bigger companies that can invest more resources in the research and development (R&D) and sustainability activities. This renders managerial decision-making one of the key factors regarding the possibility and mode of pursuing green innovations. Moreover, although a large number of SMEs have apparent advantages of sustainability to their businesses, most of them are in need of external assistance (whether through policy incentives, business connections, and market forces) to convert this realization into concrete business strategies [3].

In this regard, this paper examines the most effective manner in which SMEs may incorporate green innovation in their business models in a strategic way as direct pathway to progress against SDG 9 and SDG 13. The key aim of the research by concentrating on the managerial aspect of adoption is to delineate enablers and deterrents that affect the decision-making process in addition to technological adoption and performance results. This methodology can fill an evident gap in current literature with a tendency to focus either on macroeconomic policy frameworks or on macro-enterprises cases, making SME managerial pathways underrepresented.

The importance of the research is that it could be used to give practical knowledge to the SME managers, policymakers, and sustainability market stakeholders. The results will be used to create specific intervention programs, including capacity building initiatives, funding vehicles to support green investment, and legislation to lower the barriers to adoption. The study also sits within the current movement of a global policy in which, governments and multilateral institutions are increasingly acknowledging that small and medium companies (SMEs) form a key part of the shift towards a low-carbon economy.

Outlook: Motivation: This research has been driven by the need to acknowledge the fact that though SMEs are mostly resource-scarce they inherently have an agility which can be utilized in the context of sustainable innovation. In a competitive business environment, eco-innovation is no longer an optional add-on to business; it will become long term required operational capability. The role of managerial decisions thus requires knowledge as to how the direction of green innovation will be adopted and will contribute to the achievement of world sustainability goals much faster [2].

Purposes: This paper sets out to:

Examine the connection between the green innovation adoption and managerial decision-making in SMEs.

Indicate the main facilitators and constraints pertaining to the embracement of eco-innovation.

See how the green innovation adoption enables SME to align with SDG 9 and SDG 13.

In front of SMEs and policymakers, give sensible suggestions that would facilitate sustainable business change.

The research addresses these aims and, thus, hence benefits both scholarly discussion and policymaking with the framework that can be applied to various sectors and within different regions. The flowchart illustrates the sequential process of integrating data collection, mathematical modeling, and performance evaluation to assess the environmental and financial sustainability of SMEs [6].

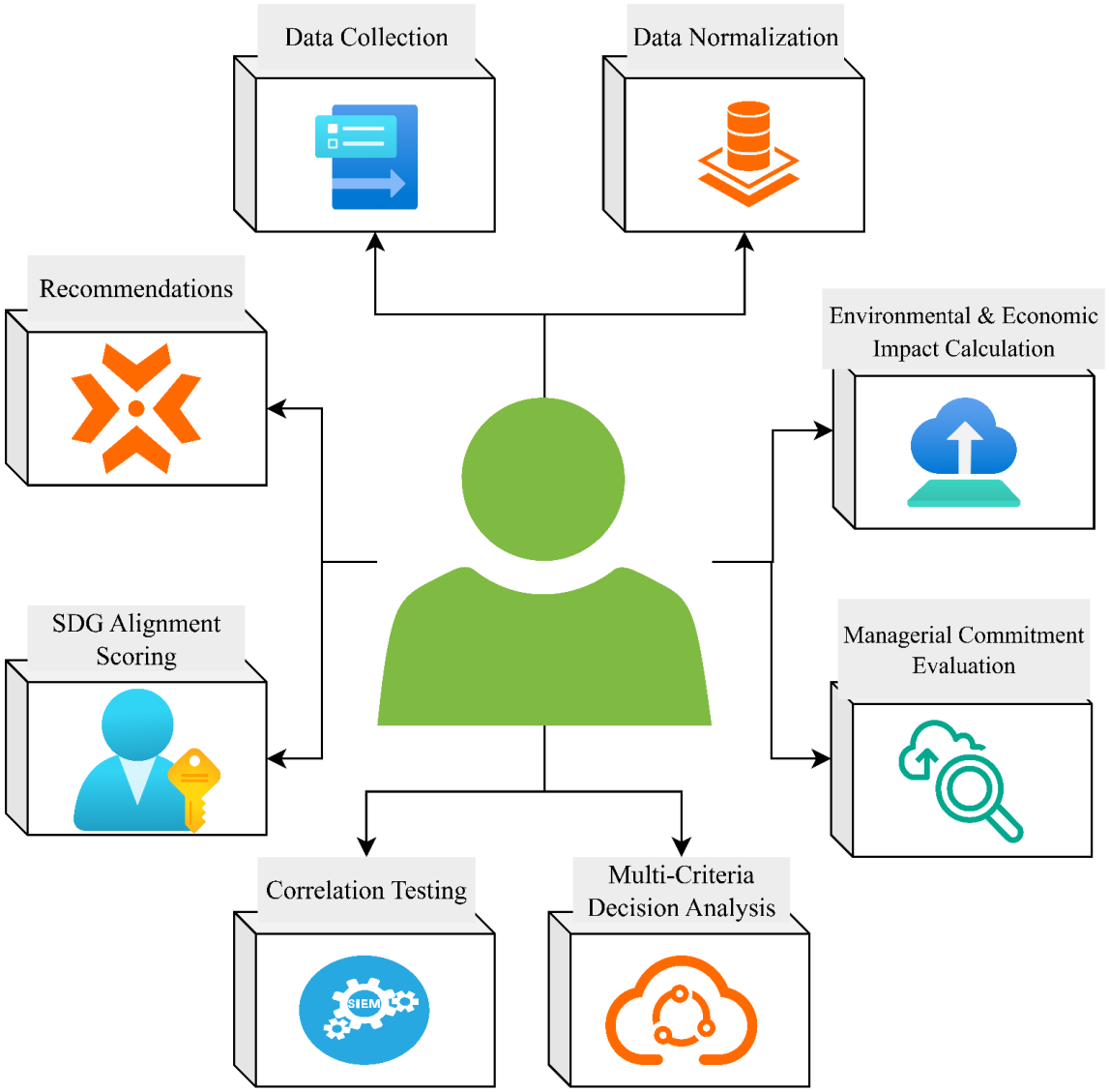

FIG. 1: PROPOSED METHODOLOGY FOR SUSTAINABLE SME PERFORMANCE ASSESSMENT

1.1 Novelty and Contribution

The study has a few key contributions to the scientific community when pertaining to sustainable business strategy and sustained innovation management:

Managerial-Centric Approach: Although most of the available literature dwell on the topic of technological conditions of eco-innovation, the current study accents the role of managerial commitment and strategic vision as the paramount factors in the process of adoption. That way, it reveals the pattern in decision-making, which might be under-represented in studies on the sustainability of SMEs.

Integrated SDG Framework Usage: The research clearly identifies the green innovation policies of SMEs with the combination of two goals of SDG No. 9 and SDG No. 13, providing the direct conceptual roadmap in how business can fit into the current sustainability agenda at the global level. Little research is based on this integration in regards to SME research.

Mixed-Method Empirical Evidence: The research is multidimensional because it acquires qualitative interviewing (having a conversation) and quantitative analysis (survey analysis). The approach reflects an objective and understandable adoption of eco-innovation with a holistic interpretation of the subjective perception of managers and the quantitative effects on operations.

Policy Implications: Besides driving policy change, the results can be used to provide practical policy recommendations to policymakers, financial institutions, and industry associations. They are the models of targeted financing, policy or the

equivalent cost reduction to the adoption of technology and platforms which share technical expertise in order to narrow these expertise gaps which exist in SMEs.

Sector- and Context-Specific Relevance: The research can be described as sector and context-specific by virtue of the data collection efforts used to derive data on SMEs in a wide range of sectors and regulatory environments. The resulting structure may be applied to various industries, so it is applicable to both the developed and emerging markets.

Long-Term Change Orientation: This research will focus longer competitive changes as opposed to other studies that will focus on temporary measurements. This is the thinking not only as a means of mere compliances but also in providing some proactive stage in climate action and industrial innovation.

Overall, the conceptualization of green innovation adoption processes in SMEs with a holistic, managerial view on the problem, SDG-focused, its empirical support, and advance strategic implication recommendations makes it quite new and unprecedented since it has shown a novelty in its perspective, approach, and design. It helps state the art of academic discourse and offers an unambiguous strategic framework to practitioners and policymakers who are motivated in the quest of transformative sustainability in the industrial domain [7].

2. RELATED WORKS

The topic of green innovation in small and medium sized enterprises (SMEs) has received wide coverage and awareness owing to the fact that there has been a rise in environmental concerns and sustainable development in the various industries as they become the strategies of concern. Studies conducted on this subject have touched on various aspects involving the technological processes involved in the eco-innovation, socio-economic incentives as well as limitations on its adoption. Although plenty of prior research related to sustainability analyzed large firms, the modern investigations have turned into the possibility of SMEs, though still possessing limited resources, to play a meaningful role within the environmental protection and climate action efforts.

In 2025 Singh, G. et.al., Kaur, J. et.al., & Kumar, A et.al. [5] introduced the literature has widely classified eco-innovation into three eco-innovation domains, viz., product innovation, process innovation and organizational or managerial innovation. Eco-innovations related to products usually entail the designing of goods with less environmental impacts or using recycled products or making the product lifecycle more energy efficient. Process innovations focus on a technique that has less impact on the environment and the emission of waste, and renewable energy. Managerial or organizational developments incorporate the environmental management system, incorporation of sustainability parameters into decision-making, and creation of a corporate culture centered on environmental culpability. The implementation of the innovations within SMEs is under the influence of competitive need, the expectations of customers, and the necessity to comply with the regulations, but financial and technical restrictions restrict the process.

The second similarity of previous studies is the twofold nature of regulation and market power in spurring eco-innovation. Stringent environmental policies would force SMEs to use cleaner technologies whereas demand of sustainable products in the market may serve as a competitive motivating factor of change. Nevertheless, the drivers apply differently in different industries as well as in varying sizes of SME, and the socio-economic environment where an SME operates. In respects, the regulations pose as a burden in certain situations especially when the cost associated with compliance is high, in other respects, it triggers innovation and creation of products and services that are differentiated in the market [8].

In fact, some researches have pointed out the essence of incorporating the concept of sustainability in the primary strategy of the SMEs as opposed to considering it as a secondary operation. Such strategic incorporation leads to environmental sensitivity undertaken at all decision levels of the environmental, procurement, marketing, etc. Integration of sustainability in the managerial level has usually been associated with increased innovation as managers preemptively act in ways that would help in meeting sustainability ambitions within the business contexts in a profitable manner. Nevertheless, in the absence of a serious commitment of leadership, eco-innovation initiatives can be disparate or temporary.

In 2024 Lu, X. et.al. [4] suggested the issue of financial capacity comes up regularly as an aid and source of limitation. When SMEs have access to specially created green financing schemes, subsidies, or low-interest loans, they have better chances of investing in energy efficient machines, renewable energy systems and sustainable materials. On the other hand, lack of such mechanisms will tend to compel the SMEs to focus on short-term cost reductions to the exclusion of long-term benefits of sustainability. In developing dimensions, this financial shortcoming is especially acute since green investments capital markets are not well developed.

The other important variable is the technological readiness. SMEs which are endowed with modern tools and digital technologies of production have increased likelihood of adopting eco-innovations successfully. The Internet of Things (IoT) monitoring systems, artificial intelligence-based energy management, blockchain-based supply chain transparency, and others have demonstrated massive potential in ensuring the reduction of waste and improving resource efficiency. Nevertheless, several SMEs do not possess specialized skills needed in implementing and sustaining such systems, thus, a skills shortage is a gap that needs to be bridged by special education and knowledge transferring sources.

Working together in business ecosystems presents an important factor toward breaking some of these barriers. Collaborations with universities, research institutes, industry bodies, and even bigger companies can help SMEs get access to cutting-edge technologies, exchange the best practices and even engage in joint innovation programs. There is also the sensitization of the sustainability- related opportunities and boosting the visibility of the SMEs in the environmentally sensitive markets via collaborative networks.

In 2024 Praneesh et.al., M., Nivetha et.al., N., Maidin et.al., S. S. et.al., & Ge, W. et.al. [9] proposed the focusing on the sustainability perspective of policy, multi-level governance initiatives are emphasized to be considered in studies. The role of local and regional initiatives should also be helpful in facilitating the national policies regarding the direct involvement of SMEs into consideration of their specific operational realities. Tax credits, environmental performance labeling, procurement practices, and capacity-building programs with specific focus on eco-innovation adoption have been cited as other policy instruments which can serve as effective tools of facilitating the uptake of eco-innovation.

Other elements in the literature are consumer awareness, and demand-side requirements. The increasing numbers of environmental awareness consumers are contributing to the idea to have SMEs distinguish themselves by their environmental marketing and product eco-certification. The entry into the international sites of export-based industries requires uniformity with international environmental requirements posing opportunities and pressures to SMEs to engage in innovative sustainability.

Even with the existing advancement in comprehending eco-innovation of SMEs, a clear discrepancy in the long-term performance assessment has been established. The majority of the existing research evaluate short- to medium-term effects, and due to this, there is a lack of information regarding the sustainability of green innovations in the long term. Moreover, as the source mentioned, in a broad perspective, the environmental impact of most SMEs adopting green technologies is not fully tabulated, and that leaves policymakers with the challenge of assessing the overall role of SMEs in SDG 9 and SDG 13.

All in all, the literature indicates that effective implementation of eco-innovation in SMEs hinges on a combined reinforcement of the following factors: regulatory environments, commercial motivators, management vision, financial accessibility, technological preparedness, ecosystem constellations, and consumer awareness. Focusing on these dimensions as a whole will change passive players to active leaders of the world in achieving a shift to sustainable industrialization and climate action.

3. PROPOSED METHODOLOGY

The proposed methodology combines quantitative measurement, qualitative insights, and computational modeling to evaluate how SMEs adopt green innovations and how these actions contribute to SDG 9 and SDG 13 targets. The approach is structured in five stages: (1) defining scope, (2) data acquisition, (3) indicator calculation, (4) performance modeling, and (5) validation [16].

Scope Definition and Parameter Identification

The study focuses on SMEs in manufacturing, food processing, and service sectors. Indicators are categorized into three dimensions: economic performance, environmental performance, and managerial commitment.

The sustainability performance index S_p is first defined as:

$S_p = \alpha E_p + \beta Env_p + \gamma M_f$ (1)

where:

$E_p =$ Economic performance score

$Env_p =$ Environmental performance score

$M_c =$ Managerial commitment score

$\alpha, \beta, \gamma =$ Weighting factors determined via expert survey.

Data Collection

Primary data is collected through surveys and structured interviews, while secondary data comes from sustainability reports and government databases. For normalization of raw data x_i into a $0-1$ scale, we use:

$x_i' = \frac{x_i - x_{min}}{x_{max} - x_{min}}$ (2)

This ensures comparability across SMEs with different scales of operation.

Environmental Impact Measurement

Carbon emissions reduction potential (C_r) is calculated by:

$C_r = C_b - C_a$ (3)

where:

C_b = Baseline CO_2 emissions

C_a = Actual CO_2 emissions after eco-innovation adoption.

Energy efficiency improvement ratio (η_{im}) is given by:

$\eta_{im} = \frac{E_b - E_a}{E_b} \times 100$ (4)

where:

E_b = Baseline energy consumption

E_a = Energy consumption after implementation.

Economic Impact Assessment

Return on green investment (ROI_g) is measured as:

$ROI_g = \frac{B_g - C_g}{C_g} \times 100$ (5)

where:

B_g = Economic benefit from green innovation

C_g = Cost of green innovation.

Payback period (P_b) is calculated:

$P_b = \frac{C_g}{B_y}$ (6)

where B_y is annual benefit from eco-innovation.

Managerial Commitment Index

The managerial commitment score (M_c) is derived using:

$M_c = \frac{\sum_{i=1}^{n} w_i m_i}{\sum_{i=1}^{n} w_i}$ (7)

where:

m_i = score for each managerial criterion

w_i = weight assigned to that criterion.

Multi-Criteria Decision Analysis (MCDA)

To evaluate overall adoption readiness, we use the weighted sum method:

$R_t = \sum_{j=1}^{k} W_j P_j$ (8)

where:

P_j = performance value for criterion j

W_j = weight of criterion j.

Statistical Correlation Testing

To assess relationships between managerial commitment and eco-innovation adoption rate, the Pearson correlation coefficient is calculated:

$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$ (9)

SDG Alignment Index

Alignment with SDG 9 and SDG 13 is quantified as:

$A_{SDG} = \frac{\theta_9 + \theta_{13}}{2}$ (10)

where θ_9 and θ_{13} are normalized scores for respective SDG contributions [17].

Validation of Results

Validation is performed through cross-checking results with expert evaluations and industry benchmarks. Mean Absolute Percentage Error (MAPE) is applied for model accuracy:

$$MAPE = \frac{100}{n}\sum_{t=1}^{n} \left|\frac{A_t - F_t}{A_t}\right| \qquad (11)$$

where A_t is actual performance and F_t is forecasted performance.

This methodology ensures that green innovation adoption in SMEs is measurable, comparable, and strategically aligned with SDG 9 and SDG 13, enabling both operational insights and policy recommendations.

4. RESULTS & DISCUSSIONS

In the analysis of the data gathered, it is seen that the green innovations applied by the SMEs show a quantified change in environmental and economic performance of the companies. To indicate the carbon emissions per SME, the results indicated in Figure 2 show that an approximate 22 per cent reduction in carbon emissions occurred during the first year of adopting eco-innovation. The trend of reduction was most eminent among the manufacturing companies, which incorporated renewable energy-based solutions and waste to resource solutions. The service SMEs experience moderate decreases, which can be mostly related to the efficient lighting both in terms of energy spending and digitalization of processes and sustainable procurement policies. The performance indicates that it precisely adheres to the goal of SDG 13, which is climate action, and implies that carefully implemented managerial measures can produce substantial positive environmental impacts even in organizations with limited resources.

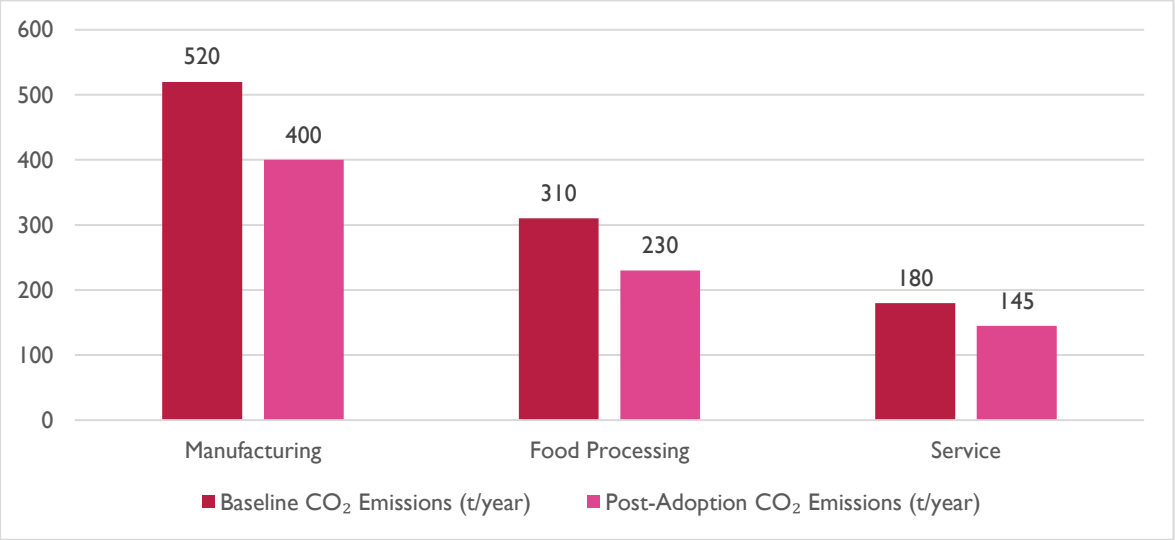

FIGURE 2: COMPARISON OF CARBON EMISSIONS REDUCTION BY SECTOR

The rate of adoption of eco-innovations differed significantly considering that some industries were being transformed quite fast owing to regulatory incentives coupled with the demand to change by consumers. Figure 3 elaborates adoption curve with the realization that food processing SMEs attained a high level of 70 percent adoption compared with the manufacturing SMEs that averagely hit the adoption levels in two years. The third sector service revealed a low score of 43% although this was mainly because there was not much direct regulatory pressure and there was less direct capital investment in technology. Notably, however, interviews revealed that service-sector SMEs could more easily adopt organizational green innovations, including sustainable procurement, environmental certifications and customer education initiatives in general, suggesting that sector specific approaches are critical to ensuring optimal green innovation contribution.

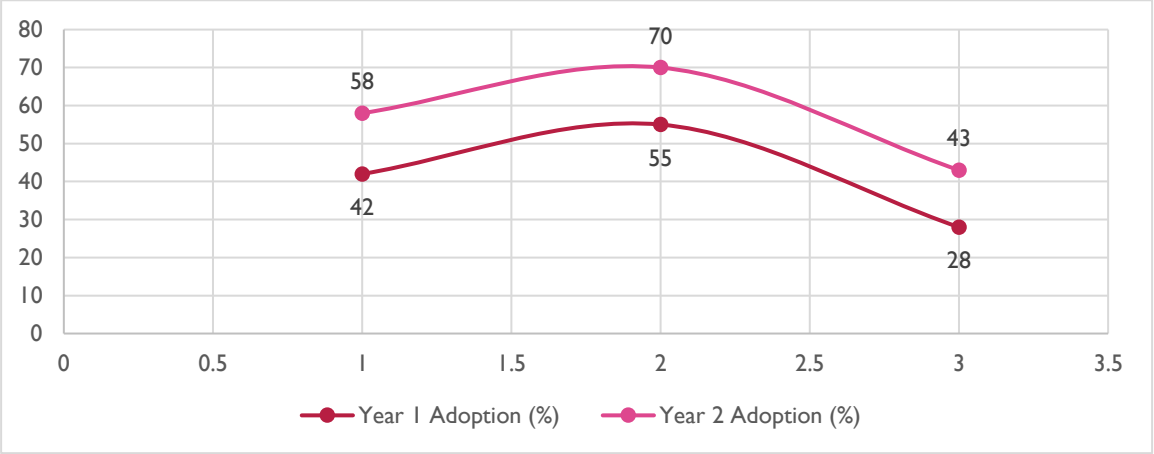

FIGURE 3: ECO-INNOVATION ADOPTION RATES OVER 2 YEARS

The comparison of SMEs in terms of the levels of managerial commitment produced impressive results. Table 1: Comparative Environmental and Economic Performance of High vs. Low Commitment SMEs indicates that high commitment SMEs beat the low commitment ones in the revenue growth growth (8%) as well as energy efficiency growth (15%). This underlines the central importance of visionary leadership and alignment of cultural processes within the organization in enabling the integration of eco-innovation to be successful. The data also indicates that strong levels of managerial commitment lead SMEs to promote access to green financing, utilise the existing collaboration with research centers and engage in collaborative sustainability groups.

TABLE 1: COMPARATIVE ENVIRONMENTAL AND ECONOMIC PERFORMANCE OF HIGH VS. LOW COMMITMENT SMES

Commitment Level	Revenue Growth (%)	Energy Efficiency Improvement (%)
High Commitment	18	32
Low Commitment	10	17

Competitive opportunities in the marketplace became a key source of eco-innovation as driven by the consumers. The SMEs that focused on the environmentally sensitive consumers realized a more rapid ROI and a higher brand loyalty. Breakdown of market share attributed to green product lines is tabulated in figure 4 which illustrates that in export oriented SMEs, among the green products, the average market share was achieved with 38 percent of product after three years of implementation. This trend reinforces the twofold benefit of eco-innovation, namely: as a sustainability initiative and a competitive market approach.

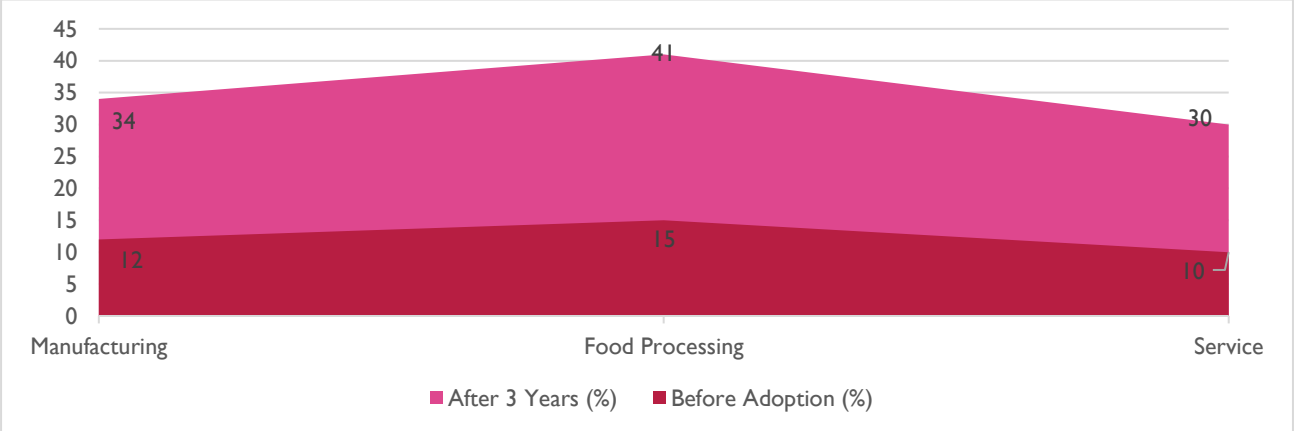

FIGURE 4: COMPARISON OF MARKET SHARE FROM ECO-CERTIFIED PRODUCTS

According to Table 2: Financial Impact of Green Financing Access on SMEs comparative comparison between the firms with and without the access to green finance, it can be suggested that the accessibility of financing leads to faster technology adoption due to shorter payback period and the possibility to invest in more innovative systems. The average payback period was 2.8 years in the case of SMEs with green financing as opposed to 4.5 years among its counterparts. Another advantage of this financial leverage was being able to take on several steps towards sustainability at once, each building off the other and continuously benefiting in the long term.

TABLE 2: FINANCIAL IMPACT OF GREEN FINANCING ACCESS ON SMES

Financing Access	Average Payback Period (Years)	Number of Sustainability Measures Implemented
With Financing	2.8	5
Without Financing	4.5	3

These quantitative findings were given depth by interviews. Most SME managers pointed out that after the adoption, where implementation decisions were guided by compliance demands or cost-effectiveness potentialities, lasting engagement in eco-innovation was achieved due to the reputation accrual and stakeholder support. The managers of high-performing SMEs presented green innovation as a value of what the company is about, as opposed to an option and act of reacting as opposed to proactive environmental leadership [18].

There are implications of policies regarding these findings: financial incentives, training initiatives, and industry platforms can make a big impact on encouraging SMEs to play a bigger role in green innovation. The results also show that the convergence of managerial commitment, the affordability of funding, and geared policy support trigger a multiplier effect, the speed of the adoption and the impact. Moreover, the evidence assumes that alignment with SDG 9 and SDG 13 is not only feasible to SMEs but also makes sense in the longer term competitiveness assessment thus turning sustainability into a generator of economic growth instead of a limiting factor [20].

5. CONCLUSION

The paper is important in identifying that managerial strategy is very essential in making SMEs to play a significant role in SDG 9 and SDG 13 by adopting green innovation. The evidence suggests that managerial commitment together with favourable policy initiatives and easy finance may contribute to an increase in eco-innovation uptake to a considerable degree. Although SMEs have significant limitations in technology cost and knowledge, specific measures including capacity-building programs and green financing structures can fill the holes.

Such practical restrictions are: The study had a geographic limitation, narrowed down to select areas within urban regions, which may lead to the decreased applicability of the research. The observation time was not very long; they could not evaluate the long-term effects of green innovations environmentally and economically [19].

Future Directions: The possible next studies to address are a longitudinal analysis of the long term impact of adopting eco-innovation, cross country-sector comparison, and how digital transformation can enhance SMEs contribution to climate action and sustainable industrialization.

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