Chapter 2

Book Chapter

Role of Green Innovations in Fostering Environmental Awareness and Technology: Data-Driven Analysis

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Abstract

This study investigates the role of green innovations in fostering environmental awareness and technology adoption among SMEs. Employing a quantitative approach, a questionnaire was administered to a convenient sample of 320 SME respondents between January and March 2024. Data analysis was conducted using (Smart-PLS) to examine the relationships between green innovations, environmental awareness, and technology adoption. The study hypothesized that there is no significant relationship between green innovations and environmental awareness, and there is no significant impact of green innovations on technology adoption within SMEs. The findings revealed significant positive relationships between green innovations and both environmental awareness and technology adoption. This suggests that SMEs embracing green innovations are more likely to enhance their environmental consciousness and adopt advanced technologies. The study concludes emphasizing the importance of promoting green innovations to drive sustainability and technological advancement within the SME sector.

Keywords: Green Innovations. Environmental Awareness. Technology Adoption. Sustainability. Socio-economic factors. Small and Medium Enterprises (SMEs).

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1 Introduction

Environmental issues have emerged as significant obstacles to sustainable development, necessitating a transformation in development models to mitigate their negative impact on the environment. (Chen, 2023).The concept of sustainable development emerged almost half a century ago in response to global challenges related to resources and the natural environment.(Okr glicka, Mittal, & Navickas, 2023).The imperative for sustainable development has become increasingly apparent in recent years, propelling the global community toward a pivotal intersection where innovation and environmental stewardship converge. (Reficco et al., 2018; Rese, Baier, & Rausch, 2022). At the heart of this movement lies the transformative force of green innovations. These pioneering solutions, characterized by their commitment to reducing environmental impact while fostering economic growth, have emerged as catalysts for reshaping industries, policies, and societal norms worldwide. (Lu et al., 2020).The role of green innovations extends far beyond mere technological advancements; it embodies a paradigm shift in how we conceive, produce, and consume resources. From renewable energy technologies and eco-friendly materials to circular economy practices and nature-inspired design, green innovations encompass diverse strategies to harmonize human activities with the natural world. (Alam et al., 2023). In this era of unprecedented environmental challenges, ranging from climate change and biodiversity loss to resource depletion and pollution, the urgency to embrace sustainable alternatives has never been more pressing. Green innovations offer a promising pathway toward a more resilient, equitable, and ecologically balanced future, where the needs of present and future generations are met without compromising the integrity of planetary systems. (Haldar, 2019).

Green innovations play a pivotal role in fostering environmental awareness by highlighting the interconnectedness between human activities and the health of ecosystems. Through groundbreaking technologies and initiatives, these innovations bring to light the intricate balance required to manage natural resources and mitigate environmental degradation sustainably. (Jain, 2024). For instance, advancements in environmental monitoring systems provide real-time air and water quality data, empowering individuals and organizations to make informed decisions about their environmental impact. Additionally, educational campaigns and public outreach efforts centered around green innovations raise awareness about pressing environmental issues and inspire collective action toward conservation and sustainability. (Dadhich & Hiran, 2022). Moreover, green innovations serve as catalysts for developing and adopting cutting-edge technologies that offer sustainable alternatives to traditional practices. From renewable energy sources like solar and wind power to innovative waste management solutions such as recycling and composting, these advancements drive a transition toward a more circular and resource-efficient economy.(Shukla et al., 2024). By investing in research and development, governments,

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businesses, and research institutions can spur the creation of scalable, environmentally friendly technologies that reduce greenhouse gas emissions, conserve natural resources, and minimize ecological footprint across industries.

Furthermore, green innovations facilitate the integration of sustainability principles into various sectors, paving the way for more environmentally conscious practices and policies. In agriculture, precision farming techniques leverage data analytics and sensor technologies to optimize resource use, minimize chemical inputs, and enhance soil health, promoting sustainable food production while mitigating environmental impacts. Similarly, in urban planning and infrastructure development, green building design, and sustainable transportation solutions prioritize energy efficiency, carbon neutrality, and resilience, contributing to more livable and eco-friendly cities.(Dadhich, Rao, et al., 2023). Thus, green innovations raise environmental awareness and drive the development and adoption of transformative technologies that enable sustainable development. These innovations catalyze a global shift toward a more sustainable future by fostering collaboration between stakeholders, promoting knowledge-sharing, and incentivizing eco-friendly practices. However, realizing the full potential of green innovations requires continued investment, policy support, and public engagement to overcome barriers and scale up solutions that address humanity's pressing environmental challenges.

2 Objectives of the Study

- To assess the level of environmental awareness and technology adoption among Small and Medium Enterprises (SMEs).
- To examine the extent of implementation of green innovations within SMEs.
- To investigate the relationship between green innovations and environmental awareness among SMEs.
- To analyze the impact of green innovations on technology adoption within SMEs.

3 Literature Review

Waqas et al.'s (2021) conducted a survey method was used to collect primary data, and the study hypotheses were assessed using Structural Equation Modeling (SEM). The results indicated that big data analytics (BDA) support achieving competitive advantage (CA) and environmental performance (EP). Green innovation (GI) and green human resource management practices (GHP) positively contribute to CA through a corporate green image (CGI). The study also confirmed the mediating roles of GI, GHP, and CA, as well as the moderating roles of organizational commitment (OC) and CGI within the underdeveloped context of the Chinese manufacturing industry. In the study by AL-Shboul's (2023) 436 usable online surveys were analyzed using a quantitative approach for data col-

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lection, utilizing structural equation modeling with the Smart-PLS software. The sample included middle- and senior-level managers and employees within MFs. Convergent and discriminant validity tests were conducted, and bootstrapping was applied. The authors incorporated GPI and GPrI as mediating factors and used data-driven competitive sustainability as a moderating factor. The findings revealed a significant positive effect of reliable big and cloud data analytics capabilities on comparative advantages, consistent with the proposed hypothesis. Additionally, the mediating factors (GPI and GPrI) were found to positively and significantly influence comparative advantage, and the moderating factor, data-driven competitive sustainability, also had a significant effect.

Employing a questionnaire survey of Chinese manufacturing firms, Dong et al.'s (2024) proposed and tested a holistic framework for comprehending the role of big data and external institutions on corporate green innovation and competitive advantage. Based on a moderated mediation analysis, the empirical results showed that both formal (e.g. government support) and informal (e.g. social legitimacy) institutions positively influenced corporate competitive advantage. Dadhich, Rathore, et al.'s (2023) examined the role of gender in the adoption of green innovations among microfinance beneficiaries in rural India. Their study found that women were more likely to adopt environmentally friendly technologies and practices, such as improved cookstoves and organic farming, than men. The research highlighted the importance of gender-sensitive approaches to green innovation promotion, recognizing women as key agents of change in fostering environmental awareness and technology adoption in rural communities.(see figure 1).

While a growing body of literature explores the relationship between green innovations and environmental outcomes, there remains a noticeable gap in understanding the specific mechanisms through which green innovations foster environmental awareness and technology adoption, particularly within the context of SMEs. Existing research often focuses on the general benefits of green practices without delving into the nuanced processes involved in fostering environmental consciousness and technological advancement within SMEs. Therefore, there is a need for empirical studies that elucidate the role of green innovations as catalysts for both environmental awareness and technology adoption, shedding light on the pathways through which SMEs can effectively integrate sustainable practices into their operations. These additional studies provide further insights into the complex interplay between socio-economic factors, environmental awareness, and technology adoption in the context of India, contributing to a more comprehensive understanding of the role of green innovations in driving sustainable development. Having studied the extensive literature review, the following hypotheses can be posited. H1: There is no significant relationship between green innovations and environmental awareness among SMEs. H2: Green innovations have no significant impact on technology adoption within SMEs.

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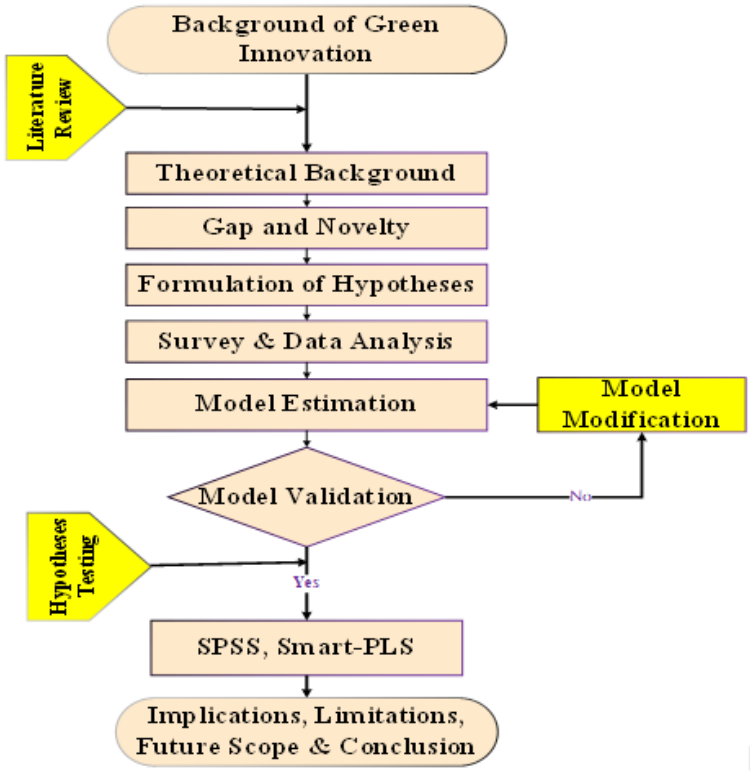

Figure 1. Research Framework

4 Research Methodology

This research aims to examine the role of green innovations in promoting environmental awareness and technology adoption among Small and Medium Enterprises (SMEs). In recent years, businesses have increasingly emphasized sustainable practices, and SMEs play a crucial role in driving innovation and sustainability. This study investigates how green innovations influence environmental consciousness and technological advancement within SMEs.

- Research Design: This study adopts a quantitative research design to gather and analyze numerical data. A structured questionnaire was used as the primary data collection instrument.(Singh & Dadhich, 2023). The questionnaire was administered to a convenient sample of 320 SMEs in Delhi-NCR. The data collection period spans from January to March 2024.

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- Sampling Technique: A convenient sampling technique was employed due to practical considerations such as accessibility and time constraints. SMEs within the researcher's reach were invited to participate in the study. This sampling method allows for data collection from readily available respondents, ensuring feasibility and efficiency.
- Data Collection Instrument: The primary data collection instrument was a structured questionnaire designed to gather information on various aspects of green innovations, environmental awareness, and technology adoption within SMEs. The questionnaire was distributed electronically using Google Forms, providing easy access and convenience for respondents.
- Data Filtering Techniques: Several filtering techniques were employed to ensure the reliability and validity of the data collected. This includes attention checks within the questionnaire to identify and filter out inconsistent or unreliable responses. Additionally, incomplete surveys/responses with significant missing data were excluded from the analysis.
- Data Analysis Method: The collected data was analyzed using Smart-PLS employing structural equation modeling. It is a widely used statistical technique for analyzing complex relationships among variables in structural models. It allows for the examination of both direct and indirect effects, making it suitable for exploring the relationships between green innovations, environmental awareness, and technology adoption.
- Dependent and Independent Variables: Dependent Variable: Environmental Awareness and Technology Adoption. Independent Variable: Green Innovations

5 Analysis and Discussions

Table 1 presents descriptive statistics summarizing various demographic characteristics and awareness levels among respondents. The distribution by gender shows that 65.60% of the sample comprised male respondents, while 34.40% were female. Regarding age, the majority (50.00%) fell within the 20-30 age group, followed by 29.70% in 30-50 age range and 20.30% above 50. In terms of income, 48.40% reported an income of less than 5 lakhs, 33.40% reported 5-8 lakhs, and 18.20% reported an income above 8 lakhs. Regarding education, 51.60% were graduates, 29.00% held a P.G. qualification, and 19.40% had a professional qualification. Most respondents (95.30%) were aware of green innovations, while 92.20% were aware of environmental issues. Thus, these statistics provide valuable insights into respondents' demographic composition and awareness levels regarding green innovations and environmental concerns.

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Table 1. Descriptive Statistics

Factors	Classification	Freq.	%
Gender			
	Male	210	65.60
	Female	110	34.40
	Total	320	100.00
Age			
	20-30	160	50.00
	30-50	95	29.70
	Above 50	65	20.30
	Total	320	100.00
Income			
	< 5 lakhs	155	48.40
	5-8 lakhs	107	33.40
	> 8 lakhs	58	18.20
	Total	320	100.00
Education Level			
	Graduate	165	51.60
	P.G.	93	29.00
	Professional	62	19.40
	Total	320	100.00
Awareness of Green Innovations			
	Yes	305	95.30
	No	15	4.70
	Total	320	100.00
Awareness of Environmental Awareness			
	Yes	295	92.20
	No	25	7.80
	Total	320	100.00

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Table 2 summarizes the reliability analysis results for three constructs: Green Innovations, Environmental Awareness, and Technology Advancement. The Cronbach's alpha coefficients indicate high internal consistency reliability for all constructs, with values of 0.865, 0.818, and 0.796, respectively. The AVE values are 0.509, 0.560, and 0.695, demonstrating that the underlying constructs explain a substantial proportion of the observed variables' variance. Additionally, the Composite Reliability (CR) values of 0.553, 0.508, and 0.612 signify good reliability. These findings suggest that the constructs are reliable measures and suitable for further analysis in the research study.

Table 2. Reliability Analysis

Constructs	Cron. alpha	AVE	CR
Green Innovations	0.865	0.509	0.553
Environmental Awareness	0.818	0.560	0.508
Technology Advancement	0.796	0.695	0.612

The outcomes of the Fornell-Larcker analysis, which evaluates the discriminant validity of constructs by comparing the square root of the Average Variance Extracted (AVE) for each construct with the correlations between constructs.(see table 3).The results of green innovation, environmental awareness and technological advancement have been explained below.

1. Green Innovations (GRI): The square root of the AVE for Green Innovations is 0.823. This value suggests that Green Innovations has a strong and distinct presence within the data, as it exceeds the correlations with Environmental Awareness (0.785) and Technological Advancement (0.832).

2. Environmental Awareness (ENA): The square root of the AVE for Environmental Awareness is 0.433. This value indicates a moderate level of discriminant validity, as it is lower than the correlation with Green Innovations (0.785) but higher than the correlation with Technological Advancement (0.710).

3. Technological Advancement (TCA): The square root of the AVE for Technological Advancement is 0.745, indicating strong discriminant validity. This value surpasses the correlations with both Green Innovations (0.832) and Environmental Awareness (0.710), demonstrating that Technological Advancement is distinct from the other constructs.(Dadhich, Purohit, et al., 2023). Thus, this analysis suggests that Green Innovations and Technological Advancement exhibit clear discriminant validity, while Environmental Awareness shows a moderate level of discriminant validity, warranting further exploration.

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Table 3. Constructs and their corresponding values

Constructs	GRI	ENA	TCA
Green Innovations	0.823		
Environmental Awareness	0.785	0.433	
Technological Advancement	0.832	0.710	0.745

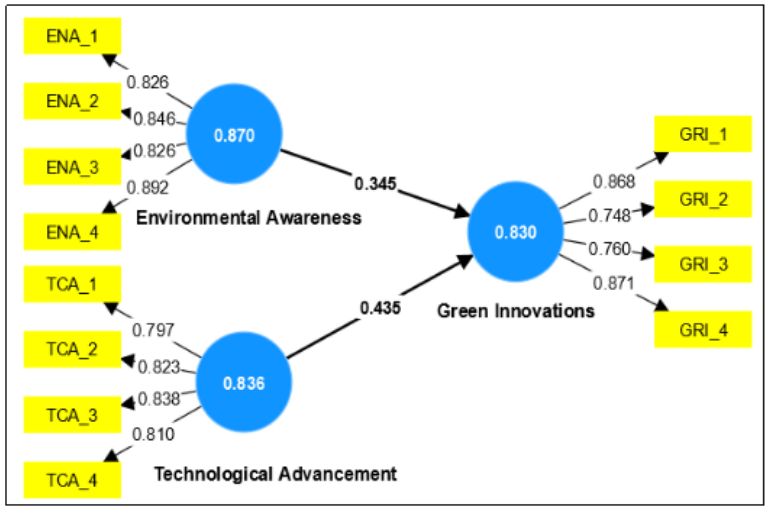

Figure 2. SEM Framework for Green Innovation

Figure 2 serves as a roadmap for understanding the intricate relationships within the context of Green Innovation, contributing to both theoretical understanding and practical applications in fostering sustainable practices.

By visually representing the path coefficients between constructs such as Green Innovations, Environmental Awareness, and Technological Advancement, Figure 3 offers insights into these factors' direct and indirect effects on each other. Path coefficient analysis helps to identify significant pathways and causal relationships within the model, providing valuable information for theory development and practical implementation.(Bhati et al., 2023). It underlines the mechanisms driving the relationship between Green Innovation and its outcomes, thereby informing strategies for promoting sustainability and innovation in various domains.(see figure 4).

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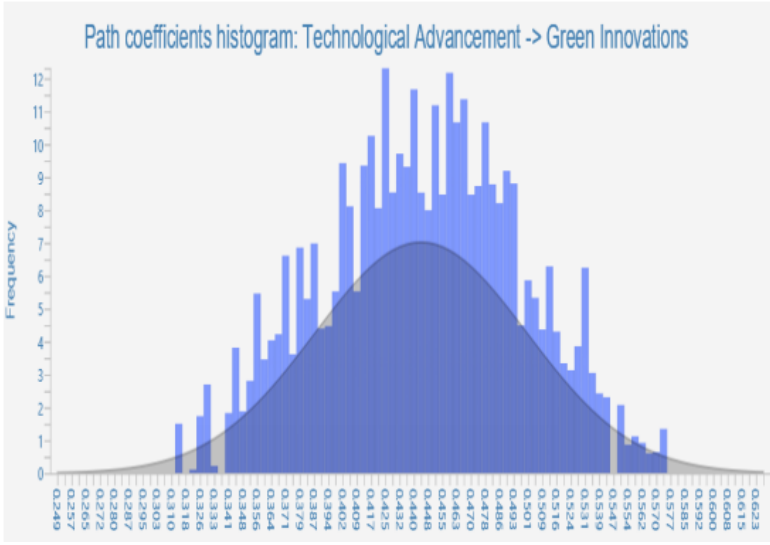

Figure 3. Path Coefficient Analysis (Technological Advancement)

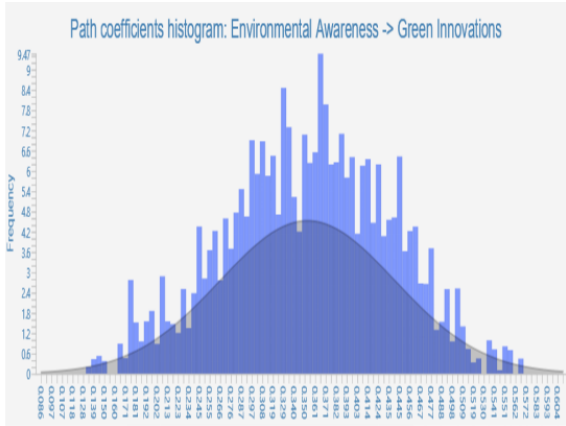

Figure 4. Path Coefficient Analysis (Environmental Awareness)

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The findings present reveal significant positive relationships between Environmental Awareness and Green Innovations, as well as between Technological Advancement and Green Innovations. These results contribute to our understanding of the factors driving the adoption of green innovations within the SME sector.(see table 4)

The coefficient (B.stat.) for this path is 0.551, indicating a positive relationship between Environmental Awareness and Green Innovations. The mean (X mean) of Environmental Awareness is 0.418, with a standard deviation (Sigma) of 0.095. The calculated t-statistic is 4.114, and the associated p-value (Sig.) is 0.000, indicating that the relationship is statistically significant at the 0.05 significance level.The positive relationship between Environmental Awareness and Green Innovations aligns with previous research emphasizing the role of environmental consciousness in driving sustainable practices and innovation. For example, Shen et al.'s (2022) found that heightened environmental awareness among SME owners positively influenced their adoption of green practices and innovations. Similarly, the study by Aboelmaged and Hashem's (2019) highlighted the importance of environmental awareness as a catalyst for green innovation adoption in SMEs. Our findings corroborate these earlier studies, suggesting that SMEs with a stronger environmental awareness are more likely to embrace green innovations as part of their business strategies.

Table 4. Hypotheses Testing

Manifests	B.stat.	X mean	Sigma	T-stat	Sig.
Environmental Awareness → Green Innovations	0.551	0.418	0.095	4.114	0.000
Technological Advancement → Green Innovations	0.309	0.325	0.155	3.225	0.001

This path's coefficient (B.stat.) is 0.309, suggesting a positive relationship between Technological Advancement and Green Innovations. The mean (X mean) of Technological Advancement is 0.325, with a standard deviation (Sigma) of 0.155. The calculated t-statistic is 3.225, and the associated p-value (Sig.) is 0.001, indicating that the relationship is statistically significant at the 0.05 significance level. Moreover, the positive association between Technological Advancement and Green Innovations underscores the significance of technology-driven solutions in fostering sustainability within SMEs. Additionally, the study by Valdez-Juárez and Castillo-Vergara's (2021) demonstrated that SMEs with higher technological capabilities are more inclined to invest in green innovations to enhance their competitiveness and environmental performance. Our results are consistent with these studies, suggesting that SMEs leveraging technological advancements are better positioned to integrate green innovations into their operations.

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6 Implications of the Study

- Policy Development: Data-driven analysis of the role of green innovations in fostering environmental awareness and technology adoption can provide valuable insights for policymakers. These insights can inform the development of targeted policies and regulatory frameworks to incentivize green innovation investment, promote technology diffusion, and foster environmental literacy among various stakeholders.
- Investment Prioritization: By identifying key drivers and barriers to green innovation adoption, data-driven analysis can help investors and funding agencies prioritize investments in technologies and initiatives with the greatest potential to accelerate environmental sustainability. This can lead to more efficient allocation of resources and increased support for innovative solutions that address pressing environmental challenges.
- Education and Outreach: Data-driven insights into the effectiveness of environmental education programs and outreach efforts can guide the development of tailored interventions to enhance environmental awareness among different demographic groups. Educators and advocacy groups can disseminate information and promote behavioral change toward more sustainable practices by leveraging technology and communication channels, such as social media and online platforms.
- Industry Transformation: Data-driven analysis can catalyze industry-wide transformation by highlighting best practices, benchmarking performance, and identifying collaboration and knowledge sharing opportunities. Businesses can use this information to streamline operations, reduce environmental impact, and gain a competitive edge in the growing green economy. Moreover, data-driven insights can facilitate partnerships between academia, industry, and government to foster innovation ecosystems that support the development and commercialization of green technologies.
- Global Collaboration: Given the interconnected nature of environmental challenges, data-driven analysis can facilitate international collaboration and knowledge exchange to address shared sustainability goals. By pooling data and expertise from diverse geographic regions, countries can identify common challenges, share lessons learned, and develop coordinated strategies for leveraging green innovations to achieve collective environmental objectives. Thus, data-driven analysis of the role of green innovations in fostering environmental awareness and technology adoption holds immense potential to inform decision-making, drive systemic change, and catalyze global efforts toward a more sustainable future.

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7 Conclusion

The role of green innovations in fostering environmental awareness and technology adoption is undeniable, yet our understanding of their impact remains dynamic and evolving. While data-driven analysis has provided valuable insights into this nexus, it also reveals gaps and challenges that warrant further exploration. Despite limitations such as data availability constraints and contextual complexities, promising avenues for future research offer hope for deeper understanding and more effective strategies. By embracing longitudinal studies, cross-sectoral analysis, and advanced analytics techniques, researchers can unlock new insights and address critical questions surrounding the adoption of green innovations. Moreover, fostering stakeholder engagement and collaboration will be essential in translating research findings into meaningful actions that propel us towards a more sustainable future. As we navigate these challenges and opportunities, it becomes increasingly evident that the transformative potential of green innovations lies in technological advancements and our collective commitment to fostering environmental awareness and driving positive change.

8 Limitations and Future Scope

Data-driven analysis of the role of green innovations faces several limitations that hinder the comprehensive understanding of their impact on environmental awareness and technology adoption. Firstly, data availability and quality present significant challenges, particularly in regions or sectors with limited monitoring and reporting mechanisms. This limitation may introduce biases and inaccuracies into the analysis, compromising the reliability and generalizability of the findings. Additionally, conducting longitudinal studies to track the long-term effects of green innovations is resource-intensive and time-consuming, making it challenging to accurately assess trends and causal relationships. Moreover, the contextual complexity of factors influencing green innovation adoption, including cultural norms and institutional frameworks, presents further challenges in capturing nuanced interactions through data analysis.

Despite these limitations, there are promising avenues for future research to enhance our understanding of the role of green innovations. Longitudinal studies tracking the evolution of environmental awareness and technology adoption over time can provide deeper insights into trends and critical inflection points. Furthermore, cross-sectoral analysis exploring the transferability of green innovations across different contexts and advanced analytics techniques, such as machine learning, offer opportunities to extract actionable insights from large datasets. Engaging stakeholders in the research process can also enhance the relevance and impact of data-driven analysis, fostering greater collaboration and knowledge exchange to drive sustainable innovation and practice. By addressing

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these limitations and pursuing future research, scholars can contribute to a more holistic understanding of how green innovations foster environmental awareness and adoption of technology.

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