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RESEARCH ARTICLE

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Navigating a net-zero economy future: Antecedents and consequences of net-zero economy-based green innovation

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Abstract

The pursuit of net-zero economy goals and government emphasis on sustainable performance has compelled numerous firms to focus on sustainable production through the adoption of net-zero economy-based green innovation. The digital transformation of manufacturing systems and supply chains, supported by the utilization of big data and the adoption of net-zero economy-oriented lean practices in the presence of net-zero economy-based green practices, can converge to enhance net-zero economy-based green innovation in manufacturing firms. This convergence leads to an improvement in green competitive advantage and net zero-based green performance. To examine the aforementioned linkages using a framework based on the dynamic capabilities view paradigm, a time-lagged design was employed to collect data from 594 manufacturing firms. The empirical findings indicate that big data analytics capabilities and net-zero economy-oriented lean practices of firms significantly influence net-zero economy-based green innovation. Green organizational identity strengthens the effect of net zero-based green innovation on green competitive advantage and net zero-based green performance.

KEYWORDS
big data analytics capabilities, net zero-based green performance, net-zero economy-based green innovation, net-zero economy-oriented green practices, net-zero economy-oriented lean practices

Abbreviations: BDA, Big data analytics; BMC, Big data management capabilities; BTC, Big data talent capabilities; CFI, Comparative fit index; CMB, Common Method Bias; GCA, Green competitive advantage; GOI, green organizational identity; NZBGP, Net zero based green performance; NZGmI, Green managerial innovation; NZGP, Net zero economy oriented green practices; NZGPcI, Green process innovation; NZGPrI, Green product innovation; NZLP, Net zero economy oriented lean practices; RMSEA, Root mean square error of approximation; SDGs, Sustainable Development Goals; TLI, Tucker–Lewis index.

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1 | INTRODUCTION

In the pursuit of a net-zero emission economy by mid-century, lean, green, and digital innovations in supply chains can be major contributing factors when objectively focused on achieving net zero-based green performance and leveraging green competitive advantage (Sharma, Prakash, et al., 2021). The digital transformation of manufacturing systems and supply chains can be facilitated through the utilization of big data generated from digital information, communication, sensing, and characterization technologies (Almeida, 2018). The emergence and growth of big data have necessitated firms to develop and enhance their big data analytics (BDA) capabilities (Belhadi et al., 2019). These capabilities encompass BDA management (organization) capabilities (BMC) and BDA talent (human) capabilities (BTC), in addition to big data analytics infrastructure flexibility (Wamba et al., 2017). Firms with better BDA capabilities have improved sustainable performance (Belhadi et al., 2019; Kamble et al., 2020). Similarly, approaches to process improvement have evolved in the way firms manage the challenges of green and environmental performance (Cherrafi et al., 2018; Garza-Reyes, 2015; Khurshid et al., 2019). Lean and green practices have demonstrated significant potential for enhancing green and environmental performance (Cherrafi et al., 2018; de Freitas et al., 2017; Kamble et al., 2020). These practices are widely accepted in organizations as they embody a more practical and systematic approach to sustainable performance and green performance (de Freitas et al., 2017; Erdil et al., 2018; Kautish et al., 2019). Hence, the roles of BDA capabilities, net-zero economy-oriented lean practices (NZLPs), and net-zero economy-oriented green practices (NZGPs) in facilitating net-zero economy-based green innovations (NZGIs) in organizations should be explored, and their impact on the net zero-based green performance and green competitive advantage of firms must be assessed.

The application of modern information and communication technologies in businesses generates a vast amount of data, which challenges their capabilities and causes sustainability issues (Aydiner et al., 2019; Delen and Zolbanin, 2018). Firms are increasingly investing in BDA capabilities to enhance profitability and gain a competitive advantage (Akter et al., 2016; Constantiou and Kallinikos, 2015). Research and practitioners focus on BDA techniques and capabilities because of their potential to revolutionize business processes and the business environment (Barton and Court, 2012; George et al., 2014 . Firms believe that the information and crucial insights generated from BDA are unattainable through simple analytical techniques. Therefore, the information acquired through BDA is deemed essential for competing in a highly volatile business environment (Salehan and Kim, 2016). Initially, large firms like Google and Amazon pioneered the use of BDA, demonstrating improved performance due to their data processing capabilities compared to their competitors (Barton and Court, 2012). Nowadays, BDA is considered equally important for firms of all sizes and industries. According to a survey by General Electric Accenture, nearly 89% of firms consider BDA as a crucial technique for enhancing competitiveness and gaining market share (Jiao et al., 2021). BDA also supports competitive advantage through sustainable innovation and sustainable product development (Del Vecchio et al., 2018). BDA capabilities encompass management and talent capabilities, which help organizations strategically plan and navigate their path to success. Businesses can purposefully use these capabilities to promote NZGIs, which can manifest as green product innovations, green process innovations, and green managerial innovations (Chen, 2008; Chen et al., 2006; Valenta et al., 2023). NZGIs may contribute to the green competitive advantage of firms. Firms that adopt green innovations may develop a green organizational identity over time, which can further influence the industry's attitude toward environmental management and protection (Aslam et al., 2021). Firms may seek to strengthen their green identity by altering their management approach and business model to support net-zero economy-based green innovations, thereby enhancing their green competitive advantage and net zero-based green performance.

In today's business landscape, environmental challenges have become a pressing concern for manufacturing companies. In this regard, the lean manufacturing philosophy stands out as the prominent paradigm for organizations (Fercoq et al., 2016; Kivimaa & Kautto, 2010) striving to eliminate wasteful activities that do not add value (Verrier et al., 2014) and control costs (Sá et al., 2022; Dos Santos et al., 2019) by conducting efficient production in small batches (Lopes et al., 2019; Murmura et al., 2021). Lean practices in organizations are aimed at reducing eight types of waste: overproduction, overprocessing, defects, excess inventory, waiting time, transport, unnecessary movement (Verrier et al., 2014), and underutilization of workforce skills (Lopes et al., 2019). The literature demonstrates that lean tools and practices lead to improvements in production (Sanches Rodrigues et al., 2018; Teixeira et al., 2022). Firms can expedite their net zero-based green performance by adopting net-zero economy-oriented lean practices.

BDA capabilities and NZLPs may combine with NZGPs to focus on waste elimination (Chaudhary, 2020), primarily contributing to the conservation of environmental resources, such as materials, reduction in water and power usage, mitigation of pollution, and control of greenhouse effects and eutrophication (Verrier et al., 2014). These production and management practices result in products and system designs that reduce the consumption of materials and energy (Toke and Kalpande, 2019) as well as production resources, encompassing green products, processes, and managerial innovations. Lean practices have a positive influence on economic and operational performance (Henao et al., 2019), suggesting their positive impact on NZGIs and the net zero-based green performance of organizations through interaction with NZGP.

To explore the interaction of BDA capabilities (BMC and BTC) and NZLPs with NZGPs to influence NZGIs (product, process, and managerial), we can use the dynamic capability view (DCV) paradigm. DCV is an extension of the resource-based view. Dynamic capability is the ability of a business firm to identify (sense) opportunities in the environment, orchestrate resources to capture (seize) those opportunities, and adapt to change (transform) to attain a competitive advantage (Teece, 2023). Dynamic capabilities enable firms to utilize their resources in combination with external resources to leverage a competitive advantage (Waqas et al., 2021). They differ from ordinary capabilities (capabilities needed for the production and sale of a defined static set of products), as they enable firms to develop hypotheses about market and technology changes, orchestrate, and realign assets and competencies to respond to new requirements through transformation (Teece, 2023). BDA capabilities have been identified as dynamic capabilities in the literature because they enable firms to use them with other internal and externalcapabilities to attain sustainable performance (Bahrami et al., 2022; Dubey et al., 2018). Dynamic capabilities theory can help us understand how BDA capabilities collaborate with NZLPs in the presence of NZGPs to bring forth NZGIs (in products, processes, and managerial practices) to achieve green competitive advantage and improved net zero-based green performance.

By operationalizing BDA capabilities, lean and green practices to produce green innovation in products, processes, and managerial activities (Chen, 2008; Chen et al., 2006), a firm may attain a green identity over time. This green organizational identity is likely to transform the organization's approach to environmental concerns, prompting changes in its business model and management practices to promote green innovations (Chen, 2011). When such organizations encounter environmental challenges, they are likely to address these issues through green innovation (Begum et al., 2022; Chen & Chang, 2013; Zhang et al., 2020). Strategies adopted for green innovation are expected to result in green performance and a competitive advantage (Chang and Fong, 2010; Chen, 2011). Including NZGIs and net zero-based green performance in the organization's environmental parameters is necessary to achieve the net-zero emission goals set by various countries in the Paris Agreement. As India has pledged to achieve the net-zero goal by 2070 (McGrath 2021; Payab et al., 2023), Indian manufacturing SMEs can play a major role in the country's efforts to reach this goal because they require innovations and sustainability. BDA capabilities hold equal significance for large organizations and SMEs. Net-zero economy-oriented lean practices, in conjunction with the dynamic capabilities of SMEs in the context of net-zero economy-oriented green practices, can enhance net-zero economy-based green innovations in products, processes, and managerial practices. These innovations can lead to improved net zero-based green performance and green competitive advantage, particularly when a firm possesses a green organizational identity. The principal objective of this study is to investigate the interplay between BDA capabilities and NZLP, in conjunction with NZGP. Our aim is to elucidate how these interactions contribute to the enhancement of innovations in green product, green process, and green managerial practices. Furthermore, our study seeks to examine the symbiotic relationships among green product innovation, green process innovation, and green managerial innovation within the context of fostering a green organizational identity. Through these investigations, our overarching goal is to assess how these intricate dynamics synergistically bolster net zero-based green performance and how these factors collectively contribute to the attainment of a competitive advantage in the context of a net-zero economy, with a strong emphasis on sustainability.

Our study contributes to the existing literature on BDA, green innovation, and environmental performance. The study is particularly important because manufacturing SMEs have a profound impact on the environment and, thus, the achievement of net-zero emission goals. Their business models and green innovation are pivotal factors in this regard. This study uses dynamic capabilities view (DCV) to explore the mechanism through which manufacturing SMEs can orchestrate their BDA capabilities (BMC and BTC) and NZLPs and NZGPs to channelize net-zero economy-based green innovation. This innovation, along with the presence of a green organizational identity, influences net zero-based green performance and green competitive advantage (Figure 1). Therefore, the study answers the two following research questions:

RQ1: How does the interaction of BDA capabilities and NZLPs with NZGPs lead to improvements in green product, green process, and green managerial innovations?

RQ2: How do green product, green process, and green managerial innovations interact with a green organizational identity to enhance net zero-based green performance and achieve green competitive advantage?

To investigate these research questions, we conducted a survey to collect data from Indian manufacturing SMEs. The survey assessed the current implementation status of BDA capabilities, NZLPs, GOI, and NZGP. Subsequently, empirical results were analyzed to examine their impact on the achievement of NZGIs, GCA, and NZGP.

The remaining sections of the paper are structured as follows: Section 2 provides a comprehensive literature review and develops the hypotheses. Section 3 outlines the methodology employed in this study. Section 4 encompasses the statistical analysis and presents the results. Section 5 discusses the findings, covering policy implications, theoretical implications, limitations, and future research directions in the subsections. The final section concludes the study.

2 | THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

This research is grounded in the theoretical framework of the DCV, which refers to a firm's ability to identify and leverage novel opportunities to make their business operations environmentally friendly

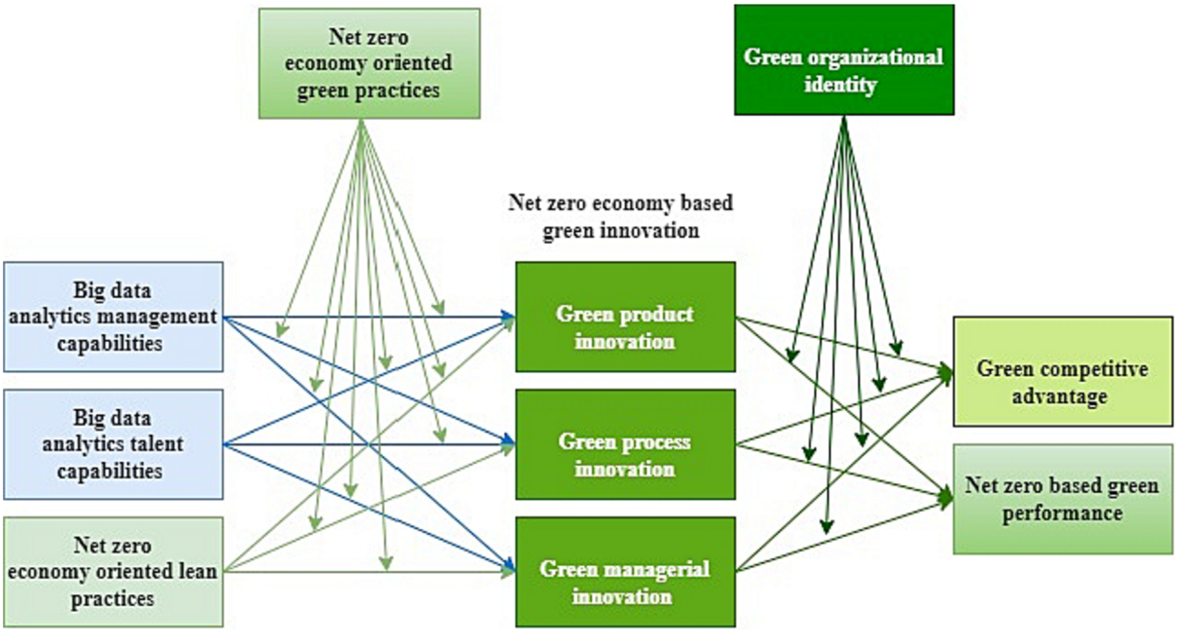

FIGURE 1 Theoretical model of the study.

(Teece, 2018), a necessity for achieving a net-zero emission economy. Firms can safeguard and reconfigure datasets, talent, and associated resources (Shamim et al., 2019) to achieve improved green performance (Rodrigo-Alarcón et al., 2018). Dynamic capabilities enable an industry to proficiently utilize various resources by either growing its internal capabilities or assimilating external resources, thereby enhancing its competitive advantage and green performance (Waqas et al., 2021). High-level managerial actions are a critical characteristic of dynamic capabilities, setting them apart from regular capabilities and assisting firms in producing green innovative products (Teece, 2014) necessary for improving competitive advantage and green performance. Dynamic capabilities enable firms to quickly enhance their abilities and competencies, making them adaptable to a dynamic business environment through effective and efficient management strategies (Teece et al., 1997). This adaptability is essential for the successful adoption of green innovations (Sun et al., 2020). Qiu et al. (2020) stated that firms with enhanced dynamic capabilities exhibit a greater inclination toward adopting green innovations, which helps them produce green products valued by customers, leading to an enhanced competitive advantage and improved green performance.

The DCV approach emphasizes the development of BDA capabilities, including BMC and BTC, to enhance a firm's competitiveness in the dynamic business environment (Schoemaker et al., 2018). This theory argues that firms can strengthen their dynamic capabilities to respond quickly to the growing importance of green innovation and green performance by investing in the enhancement of managerial and talent capabilities (Teece et al., 1997). Dubey et al. (2019) found that BDA capabilities improve a firm's dynamic capabilities, helping them attain a competitive advantage and enhance green performance. Dynamic capabilities enable firms' management to nurture employees' talents to discover innovative processes through which BDA capabilities influence competitive advantage and green performance (Dubey et al., 2019). Dynamic capabilities ensure the adoption of green process, management, and product innovations, assisting firms in achieving a net-zero waste and emission economy (Camisón & Monfort-Mir, 2012; Singh, Del Giudice, et al., 2022; Sadhukhan, 2022; Okorie et al., 2023). Using the DCV paradigm, the present study seeks to discover how firms can enhance their net zero-based green performance and green competitive advantage by adopting BDA capabilities (BMC and BTC) and NZLPs, with NZGIs as mediators and NZGPs and a green organizational identity as moderators.

2.1 | BMC and NZGIs

BDA capabilities enhance the decision-making, production, and services of firms, as this technique provides them with the opportunity to gain insights from larger datasets (Gupta et al., 2019). Firms utilizing this technique can understand their current and future requirements accurately, which helps them in producing innovative products and services (Lavalle et al., 2011). As discovered by Wamba et al. (2017), BDA capabilities substantially improve the innovative capabilities of firms, enabling them to procure green resources (Xin et al., 2023) and ultimately leading to improved competitive advantage and green performance. Companies can develop competitive insights by enhancing their BDA capabilities, which encompass BMC, BTC, and big data technological capabilities (Akter et al., 2016). However, the present work aims to identify the impact of BMC and BTC on the adoption of NZGIs by companies, which in turn leads to improved green competitive advantage and net zero-based green performance.

BMC denotes a firm's ability to manage BDA resources (Kim et al., 2012), which helps the managers in adopting effective and efficient strategies to produce more innovative and green products valued by their customers and stakeholders (Zhan et al., 2018). A firm's BMC determines its overall performance and the adoption of green innovations, including green products, green processes, and green managerial innovations, all of which enhance the competitive advantage and green performance of the firm (Benabdellah et al., 2021; Chiou et al., 2011). Firms can develop innovative green processes and green products with the help of BMC, thereby achieving green performance (Janssen et al., 2017). Operational excellence, which depends on senior management support, plays a crucial role in the successful adoption of green product innovation, giving firms a competitive edge in the market (Gunasekaran et al., 2017). Bag et al. (2020) opined that firms can make green innovation adoption a successful endeavor through the proper implementation of BMC, as they are positively related to each other. Based on the above discussion, this study postulates the following hypothesis:

H1. BMC has a direct positive impact on (a) green product, (b) green process, and (c) green managerial innovations.

2.2 | BTC and NZGIs

BTC helps firms improve the abilities and skills of their employees to manage, analyze, and maintain large datasets efficiently and effectively (Akter et al., 2016). This capability reduces resistance among employees toward BDA adoption, enabling them to develop innovative ideas (Rialti et al., 2019). Firms can enhance the innovative capabilities and skills of their employees through BTC, as it is effective in improving employees' leadership qualities (Malik & Singh, 2014). Leaders emphasize the production of innovative products and services, giving firms a competitive advantage in the market (Marshall et al., 2015). BTC enhances employees' competencies, creating a learning and innovative internal environment in firms that facilitates the delivery of green innovative services and products (Lundkvist & Gustavsson, 2018). BTC influences employee performance and competencies, contributing to the production of innovative green products that enhance the competitive advantage and green performance of companies (Shamim et al., 2019). Thus, we propose the following:

H2. BTC has a direct positive impact on (a) green product, (b) green process, and (c) green managerial innovations.

2.3 | NZLPs and NZGIs

Industries adopt lean practices with the aim of achieving net-zero waste, reducing production costs, and creating innovative products that provide value to customers (Lase et al., 2023; Nicoletti, 2015). This demonstrates that lean practices promote green innovation, including green product, green process, and green managerial innovations (He et al., 2017). Lean practices consider the voice of customers and generate ideas to meet their needs through product, process, and managerial innovations (Sin et al., 2010). Companies that implement lean practices can cultivate an innovative culture that inspires members to think creatively and achieve improvement goals through innovative products, management, and processes (Sin et al., 2010). Several previous studies have discussed the likelihood of a positive relationship between lean practices and green product innovations (Afum et al., 2021). Ferro (2013) argued that product innovation cannot be practically achieved by companies without the systematic adoption of lean practices. Johansson and Sundin (2014), in their meta-analysis, found that lean practices automatically lead to green product innovations.

Lean practices, when combined with process innovation, substantially enhance the competitive advantage and green performance of companies (Cherrafi et al., 2018). Previous studies have discussed the likelihood of a relationship between lean practices and green process innovations, as the latter amplifies the effectiveness of lean practices (Cherrafi et al., 2018). Lean practices lead to green process innovations and green management innovations, as the former helps companies generate novel business information that can be applied to produce green innovative products (Sokovic et al., 2010). He et al. (2017) found that lean practices influence the adoption of managerial, product, and process innovations. Therefore, companies that implement lean practices can embrace innovative practices, ideas, and methods, resulting in the creation of green innovative products, processes, and management that satisfy the needs of environmentally oriented customers (Welo et al., 2012). Based on the findings from the literature, we hypothesize the following:

H3. NZLPs have a direct positive impact on NZGIs in (a) green product, (b) green process, and (c) green management.

2.4 | NZGIs and green competitive advantage

Innovations enable firms to deliver products and services valued by customers (Kwak et al., 2018), which greatly affect their reputation and help improve competitive advantage and green performance (Efrat et al., 2018). An innovation is considered green when it contributes to making a company's performance environmentally friendly by enhancing energy efficiency, promoting waste recycling, controlling pollution, optimizing product design, refining processes, and developing managerial skills (Chen et al., 2006). Green innovation identifies and leverages available resources to manufacture high-value products at minimal costs, a critical requirement for achieving a competitive advantage (Gürlek & Tuna, 2018). Green innovation supports the production of cleaner products and services, enhances firms' production efficiency, and helps them gain a competitive advantage in an uncertain market environment (Asadi et al., 2020). Several studies have indicated that the adoption of green innovation by numerous manufacturing industries worldwide has improved their competitiveness in the market (Sellitto & Hermann, 2019). Ge et al. (2018) identified that firms can achieve sustainable competitive advantage by embracing green innovation, which encompasses green product, green process, and green management innovations.

Green product innovation is defined as the improvement in the design of a product to reduce its negative environmental impact during the product life cycle (Chiou et al., 2011). It provides companies with novel opportunities that help them make their performance environmentally friendly and green (Bocken et al., 2014). This enables firms to produce and deliver products using fewer toxic substances, fewer resources, and less energy, thereby minimizing production costs and achieving waste net zero (Kammerer, 2009). Green process innovation also involves the adoption of techniques that reduce the negative environmental impact during material procurement, production, and delivery (Chiou et al., 2011). It reduces water and energy consumption and enhances firms' energy and resource efficiency (Salvadó et al., 2012) by applying innovative production techniques (Ma et al., 2019), which can help firms attain a competitive advantage (Rezende et al., 2019). Moreover, green process innovation can help businesses reduce operating costs through waste recycling and energy savings (Saunila et al., 2018). The success of green process innovations depends on green management innovation, which helps firms utilize resources efficiently (Albloushi et al., 2023; Li et al., 2017). The support of managers is required to implement these innovations and manage the internal environment successfully (Hamel & Prahalad, 1989). Green process and management innovations can help firms increase their revenue by reducing external costs and transferring innovative technology and knowledge to gain a competitive advantage (Fernando & Wah, 2017). Hence, based on findings from the literature, we hypothesize the following:

H4. Green product innovation has a direct positive impact on green competitive advantage.

H5. Green process innovation has a direct positive impact on green competitive advantage.

H6. Green management innovation has a direct positive impact on green competitive advantage.

2.5 | NZGIs and net zero-based green performance

Green performance is a measure of the interaction between the environment and businesses (Sharma, Shahbaz, et al., 2021). Prior literature has identified a link between green innovations and the green performance of companies (Singh et al., 2020; Singh, Pandey, et al., 2022). Adegbile et al. (2017) found that green innovations stimulate the environmental agenda of firms, leading to improved environmental performance. Green innovation helps firms meet the pollution targets set by the government, ultimately resulting in net-zero emissions (Carrion-Flores & Innes, 2010; Khalifa et al., 2022). Firms can increase the productivity of their resources by enhancing their green innovation capabilities, which in turn leads to improved environmental performance (Chen et al., 2006). Green innovation capabilities, including green product innovation, green process innovation, and green managerial innovation, minimize negative environmental externalities by reducing waste generated by firms to net zero (Alkatheeri, Jabeen, Mehmood & Santoro, 2021; Weng et al., 2015). Green innovation encourages employees and managers within firms to continuously make efforts to learn green skills and techniques, thereby reducing the environmental consequences of their activities and leading to improved green performance (Liang et al., 2022).

Green product innovation improves resource utilization efficiency and assists firms in recycling waste into new products (Porter & Van der Linde, 1995), ultimately leading to net-zero waste. Li et al. (2023) established the significant role of green product innovation in improving the sustainable performance of firms. Sharma, Prakash, et al. (2021) found that firms can enhance their green performance through green product innovation, which is identified as a crucial factor in improving the economic, social, and environmental performances of firms (Afum et al., 2021). Singh et al. (2020) established that green product and process innovations are critical constructs for improving the environmental performance of firms. Green process innovation helps firms conserve resources, water, and energy (Imran et al., 2021; Salvadó et al., 2012), which are essential components of green performance. Green process innovation, combined with green managerial innovation, promotes resource conservation through efficient utilization (Li et al., 2017), contributing to waste reduction and enhancing the green performance of firms. Therefore, the adoption of green innovation capabilities by firms can reduce the environmental consequences of their activities and lead to improved green performance and a net-zero economy through net-zero waste and emissions. We propose the following:

H7. Green product innovation has a direct positive impact on net zero-based green performance.

H8. Green process innovation has a direct positive impact on net zero-based green performance.

H9. Green management innovation has a direct positive impact on net zero-based green performance.

2.6 | Moderating role of NZGPs

Green practices provide companies with a direction to enhance their green innovation capabilities (Guo et al., 2020) by adopting tools and techniques such as BDA and lean practices, which help minimize the environmental impact of their operations (Farrukh et al., 2022; Govindan et al., 2015). Green practices boost the adoption of green innovation (Yang & Lin, 2020), which is positively influenced by BDA capabilities (Waqas et al., 2021) and lean practices (Afum et al., 2021).

This suggests that the presence of green practices can amplify the impact of BDA capabilities and lean practices on green innovation adoption. Cherrafi et al. (2018) established that green practices strengthen the relationship between lean practices and green innovation. Green practices encourage employees and managers to acquire eco-friendly skills and knowledge, creating a conducive internal environment for the adoption of green innovation (Yousaf, 2021). A positive association exists between BDA capabilities and green practices (Belhadi et al., 2020), which is positively linked to GI (Yousaf, 2021). Firms with green practices respond positively to environmental concerns through techniques such as BDA and lean practices, resulting in increased efficiency in green innovation (Chou, 2013). In addition, a positive relationship is observed between green practices and lean practices (Augier & Teece, 2009; Inman & Green, 2018), which is positively associated with the innovative capabilities of firms (Dixit et al., 2022). Based on the findings from the literature, we argue that the presence of green practices can enhance the impact of BMC, BTC, and lean practices adopted by firms to improve their green innovation capabilities. Accordingly, we propose the following:

> **H10.** : NZGPs enhance the impact of BMC on (a) green product innovation, (b) green process innovation, and green managerial innovation.

> **H11.** : NZGPs enhance the impact of BTC on (a) green product innovation, (b) green process innovation, and green managerial innovation.

> **H12.** : NZGPs enhance the impact of lean practices on (a) green product innovation, (b) green process innovation, and green managerial innovation.

2.7 | Moderating role of green organizational identity

Firms aiming to effectively implement net-zero strategies and policies need to combine green innovation with a green organizational identity, as they improve the green performance and competitive advantage of companies (Amores-Salvadó et al., 2014). These are considered complementary assets that may assist companies in implementing net-zero emission practices through improved green performance (Christmann, 2000; da Silva, Lohmer, Rohle & Angelis, 2023). Chen (2008) suggested that the successful implementation of environmentally proactive policies by firms depends on the effective adoption of green innovation capabilities and the construction of a strong green organizational identity. Companies with a higher green organizational identity are more motivated to adopt green innovation to achieve a competitive advantage and enhance green performance. Enterprises with a stronger green organizational identity may attract more green consumers and suppliers, influencing the firms' competitive advantage and green performance (Tang et al., 2012; Yin et al., 2023). Organizations with a better green identity are more likely to attract funds from public and private financial institutions (Qiu et al., 2020). It helps companies build a positive public image, increasing sales and stock prices (Zhu & Sarkis, 2006), and thus enhancing overall firm performance. Kaur and Singh et al. (2020) and Soewarno et al. (2019) discovered that firms with an outstanding green organizational identity attract more primary resources needed for green innovation and gain a competitive advantage in India (Waqas et al., 2021). Therefore, the current research hypothesizes that:

> **H13.** Green organizational identity moderates the positive relationship between green product innovations and (a) green competitive advantage and (b) net zero-based green performance such that the relationship is stronger when green organizational identity is at a high level versus a low level.

> **H14.** : Green organizational identity moderates the positive relationship between green process innovation and (a) green competitive advantage and (b) net zero-based green performance such that the relationship is stronger when green organizational identity is at a high level versus a low level.

> **H15.** : Green organizational identity moderates the positive relationship between green managerial innovations and (a) green competitive advantage and (b) net zero-based green performance such that the relationship is stronger when green organizational identity is at a high level versus a low level.

3 | METHODOLOGY

3.1 | Data collection and procedure

The United Nations member countries adopted the Sustainable Development Goals (SDGs), known as the 2030 agenda, in 2015. These 17 SDGs are global targets to be achieved by 2030. India has been actively working toward these goals and has committed to carbon neutrality to protect the environment. The SDGs also include important objectives for manufacturing firms. In accordance with the "Make in India" initiative, the Indian government aims to increase the contribution of manufacturing firms to the country's GDP from the current 16% to 25% by 2025 (India Brand Equity Foundation, 2022). This research focuses on a sustainable production strategy to help manufacturing SMEs achieve this goal. In the context of the Indian manufacturing sector, the need for enhanced resource efficiency and a reduction in waste production is pressing. India is currently one of the leading contributors to greenhouse gas emissions, putting significant pressure on the domestic manufacturing industry. Therefore, manufacturers are racing against time to explore and adopt innovative, renewable, and cleaner technologies to replace outdated and environmentally harmful practices. Surprisingly, the scarcity of comprehensive studies that systematically identify the key drivers and enablers of sustainable and green practices within the Indian manufacturing sector is noticeable. This research addresses this gap by empirically investigating the hypotheses proposed within the research model, particularly in the context of Indian manufacturing SMEs.

The data used in this study are from manufacturing SMEs (ISO 14001 certified) and consist of survey-based questionnaires distributed to senior-level managers in these firms. These managers are either focused on or planning to focus on big data analytics capabilities, net-zero economy-oriented lean practices, and green practices. Convenience sampling was used to administer the survey-based questionnaires. The study involved senior-level managers from each SME, who received a comprehensive briefing on the research objectives and data collection procedures. A time-lagged approach, in line with recent empirical studies (Mehmood, Zia, et al., 2023; Shah et al., 2023), was adopted to gather data at different time intervals. This approach is widely recognized in contemporary research as it permits researchers to conduct surveys for specific research objectives at multiple time intervals. To ensure the content validity of the constructs, a pilot test was conducted to evaluate the reliability of the questionnaire scales. Minor adjustments were made based on feedback from the respondents. Three waves of data collection at one-month intervals were used to minimize common method bias. The survey was distributed to all the enterprises and representatives (Khan et al., 2023; Mehmood et al., 2022; Mehmood, Iftikhar, et al., 2023; Podsakoff et al., 2003). This study's respondents were senior-level managers or higher experience. Zhu and Sarkis (2006) found that senior-level managers like operation and production managers can at least facilitate incremental adoption of environmentally friendly practices.

Out of the total 800 questionnaires administered, 710 unique and usable responses from manufacturing SMEs were received during the first-wave survey (T1), resulting in a response rate of 88.75%. During this wave, respondents were asked to provide demographic information and respond to questions related to BMC, BTC, NZGPs, NZLP, and GOI. In the second-wave survey (T2), conducted one month later, 710 participants were requested to report on NZGPrI, NZGPcI, and NZGmI. A total of 642 responses containing usable information were obtained, yielding a response rate of 90.42%. Finally, during the third-wave survey (T3), respondents were asked to provide information regarding GCA and NZBGP. This wave garnered 594 valid responses, resulting in a response rate of 92.52%. The distribution of survey respondents of final sample is shown in Table 1. We followed the multivariate analysis of variance approach of Goodman and Blum (1996) to analyze the systematic variations in the responses of those respondents who completed all three waves of survey and those who finished only the first or only the first and second surveys. No significant variation was observed in industries, firm size, or experience across the groups. Consequently, our study effectively mitigated attrition bias, indicating that nonresponse bias does not seem to be a significant concern (Hair et al., 2010).

TABLE 1 Demographics information.

Demographics	Frequency	%
Gender		
Male	389	65.49
Female	205	34.51
Age (in years)		
20–25	73	12.29
26–30	247	41.58
31–35	183	30.81
36 and above	91	15.32
Qualification		
Diploma/technical	193	32.49
Undergraduate	270	45.45
Postgraduate	131	22.05
Firm size (in employees)		
Less than 200	80	13.47
201–400	347	58.42
401–600	108	18.18
601 and above	59	9.93
Experience (in years)		
Less than 5 years	76	12.79
6–10 years	275	46.30
11–20 years	136	22.90
21–30 years	51	8.59
Above 30 years	56	9.43
Operating sector		
Energy	132	22.22
General manufacturing	219	36.87
Chemical and miscellaneous products	158	26.60
Electronic and electric equipment	85	14.31

3.2 | Measures

Alongside demographic variables, the questionnaire incorporated scales adapted from previous research to measure the constructs under investigation. Respondents rated their responses on a five-point Likert scale, ranging from 1 (indicating "strongly disagree") to 5 (indicating "strongly agree"). The data for this study were collected in India, and the measurements utilized were originally developed in English. To ensure the equivalence of meaning, one of the authors translated all the measures from English into Hindi, and another author performed back-translation into English, following the method proposed by Brislin (1980). BMC (six items) and BTC (nine items) were examined using the items from Akter et al. (2016). NZGIs (NZGPrI: four items, NZGPcI: three items, and NZGmI: two items) were analyzed using the items from Chiou et al. (2011). GCA was analyzed based on four items from Chen and Chang (2013). GOI was measured using six items from Chen (2011). NZLPs were analyzed using six items from Kuo and Lin (2020). NZGPs (six items) were examined using the items from Agyabeng-Mensah et al. (2020). NZBGP was measured using six items from Yakovleva et al. (2012) and later used by Mishra et al. (2021). The constructs and their corresponding measurement items are presented in Appendix A.

3.3 | Common method bias (CMB)

We employed a combination of procedural and statistical remedies to mitigate CMB. First, we implemented procedural measures. To minimize the potential for socially desirable responses, we ensured respondents' complete anonymity, as explained in the survey cover letter (Podsakoff et al., 2003). Second, to enhance clarity and reduce item ambiguity, we provided clear definitions for scale items and formulated questions that were straightforward and specific (Podsakoff et al., 2003). Third, we took precautions such as not labeling variables based on reported constructs and avoiding the grouping of items by variables, which minimized the likelihood of respondents making educated guesses or consciously linking variables (Parkhe, 1993). Fourth, respondents were explicitly informed that there were no definitive right or wrong answers to the survey questions. We emphasized that their responses would be treated with the utmost confidentiality. Fifth, we adopted a statistical approach and used the CFA procedure to further examine the potential CMB in this study. The single-factor model yielded a poor fit to the data: $\chi^2 = 6275.341$, $df = 1{,}274$, $\chi^2/df = 4.926$, CFI = .476, TLI = .428, and RMSEA = .237. These indices suggest the absence of CMB. To further evaluate the presence of CMB, we conducted Harman's single-factor test, a commonly utilized technique (Ullah et al., 2021). This test was applied to all 10 constructs included in our research model to assess the potential impact of CMB on our results. The findings from the unrotated factor solution, using the principal axis factoring method, indicated that the first factor accounted for only 23.31% of the variance. We concluded that CMB is not a great concern in our survey (Mehmood, Jabeen, et al., 2023; Shang et al., 2022). The sample adequacy indicator, with a value of .893, exceeded the acceptable threshold of .80, affirming the adequacy of our sample size.

4 | EMPIRICAL RESULTS

The collected data were analyzed using SPSS 24.0 and Mplus 7.0 software, following the guidelines outlined by Muthén and Muthén (2012). The analysis involved assessing the measurement model, testing data quality, and conducting checks for reliability and construct validity through CFA.

4.1 | Descriptive statistics

Table 2 presents the correlation matrix and descriptive statistics. The correlations observed among the study variables offer initial validation of our proposed model.

4.2 | CFA analysis

In accordance with the guidance provided by Muthén and Muthén (2012), we conducted CFA employing Mplus to assess the distinctiveness of the variables under investigation. To evaluate the discriminant validity of the measurement model, we compared the baseline model and nine alternative models. As displayed in Table 3, the results of CFA clearly indicate that the baseline-model, which comprises 10 distinct factors, offers a good fit: ($\chi^2/df = 1785.432/1229 = 1.453$; CFI = .986; TLI = .977; and RMSEA = .032) compared with the nine-factor model

TABLE 2 Correlation matrix and descriptive statistics.

Variables	Mean	SD	α	1	2	3	4	5	6	7	8	9	10
1. NZBGP	4.304	.922	.879	(.752)									
2. GCA	4.015	.896	.847	.417**	(.766)								
3. GOI	3.724	.804	.908	.177**	.508**	(.807)							
4. NZGPrI	4.347	.983	.793	.236**	.173**	.387**	(.710)						
5. NZGPcI	4.255	.917	.881	.405**	.207**	.305**	.184**	(.834)					
6. NZGmI	3.931	.866	.717	.277**	.262**	.371**	.240**	.216**	(.738)				
7. NZLP	4.006	.898	.857	.109*	.137**	.248**	.161**	.143**	.294**	(.723)			
8. BMC	4.321	.953	.893	.198**	.229**	.130**	.136**	.113**	.260**	.231**	(.784)		
9. BTC	4.191	.901	.931	.217**	.268**	.353**	.155**	.166**	.368**	.388**	.173**	(.758)	
10. NZGP	3.994	.883	.879	.398**	.403**	.347**	.223**	.206**	.234**	.313**	.255**	.432**	(.752)

Notes: Square roots of AVE for each variable are exhibited in parentheses; Cronbach alpha = α; $N = 594$; **$p < .01$, *$p < .05$; big data management capabilities = BMC; big data talent capabilities = BTC; green organizational identity = GOI; green product innovation = NZGPrI; green process innovation = NZGPcI; green managerial innovation = NZGmI; net-zero economy-oriented lean practices = NZLP; net-zero economy-oriented green practices = NZGP; net zero-based green performance = NZBGP; green competitive advantage = GCA.

TABLE 3 Evaluation results of the overall model comparison.

Models	χ^2	*df*	χ^2/df	$\Delta\chi^2$ (Δdf)	TLI	CFI	RMSEA
Baseline model	1785.432	1,229	1.453		.977	.986	.032
9-factor model: Combining BTC, GOI, NZGPrI, NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA	1937.114	1,238	1.565	151.682 (9)	.915	.947	.071
8-factor model: Combining GOI, NZGPrI, NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA	2257.073	1,246	1.811	471.641 (17)	.897	.902	.075
7-factor model: Combining BMC, BTC, GOI, NZGPrI, NZGPc, NZBGP, and GCA	3027.170	1,253	2.416	1241.738 (24)	.853	.868	.088
6-factor model: Combining NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA	3788.876	1,259	3.009	2003.444 (30)	.789	.824	.093
5-factor model: Combining BMC, BTC, NZGP, NZBGP, and GCA	4129.211	1,264	3.267	2343.779 (35)	.713	.748	.101
4-factor model: Combining NZGPrI, NZGmI, NZGP, and GCA	4602.873	1,268	3.630	2817.441 (39)	.697	.707	.109
3-factor model: Combining NZGP, NZBGP, and GCA	4966.754	1,271	3.908	3181.322 (42)	.626	.648	.112
2-factor model: Combining BMC and BTC	5324.369	1,273	4.183	3538.937 (44)	.591	.603	.187
1-factor model	6275.341	1,274	4.926	4489.909 (45)	.428	.476	.237

Notes: $N = 594$, big data management capabilities = BMC; big data talent capabilities = BTC; green organizational identity = GOI; green product innovation = NZGPrI; green process innovation = NZGPcI; green managerial innovation = NZGmI; net-zero economy-oriented lean practices = NZLP; net-zero economy-oriented green practices = NZGP; net zero-based green performance = NZBGP; green competitive advantage = GCA.

in which BTC, GOI, NZGPrI, NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA were combined (χ^2/df = 1937.114/1238 = 1.565; CFI = .947; TLI = .915; and RMSEA = .071); eight-factor model in which GOI, NZGPrI, NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA were combined (χ^2/df = 2257.073/1246 = 1.811; CFI = .902; TLI = .897; and RMSEA = .075); seven-factor model in which BMC, BTC, GOI, NZGPrI, NZGPc, NZBGP, and GCA were combined (χ^2/df = 3027.170/1253 = 2.416; CFI = .868; TLI = .853; and RMSEA = .088); six-factor model in which NZGPc, NZGmI, NZLP, NZGP, NZBGP, and GCA were combined (χ^2/df = 3788.876/1259 = 3.009; CFI = .824; TLI = .789; and RMSEA = .093); five-factor model in which BMC, BTC, NZGP, NZBGP, and GCA were combined (χ^2/df = 4129.211/1264 = 3.267; CFI = .748; TLI = .713; and RMSEA = .101); four-factor model in which NZGPrI, NZGmI, NZGP, and GCA were combined (χ^2/df = 4602.873/1268 = 3.630; CFI = .707; TLI = .697; and RMSEA = .109), three-factor model in which NZGP, NZBGP, and GCA were combined (χ^2/df = 4966.754/1271 = 3.908; CFI = .648; TLI = .626; and RMSEA = .112); two-factor model in which BMC and BTC were combined (χ^2/df = 5324.369/1273 = 4.183; CFI = .603; TLI = .591; and RMSEA = .181); and one-factor model in which all variables were combined (χ^2/df = 6275.341/1274 = 4.926; CFI = .476; TLI = .428; and RMSEA = .237). The outcome affirms the discriminant validity of the constructs. As illustrated in Table 4, all observed items displayed significant ($p < .01$) loadings on their respective factors, thereby affirming the convergent validity of the constructs. These findings contribute additional support to the discriminant validity of the aforementioned set of variables. As a result, our model is considered appropriate for conducting subsequent hypothesis testing.

4.3 | Hypothesis validation

As presented in Table 5, H1a, which posits a positive relationship between BMC and NZGPrI, received support with an estimate of [β = .248, SE = .038, 95% CI (.1478, .3047)]. Additionally, H1b, which proposes a positive association between BMC and NZGPcI, was also supported, as indicated by an estimate of [β = .473, SE = .041, 95% CI (.3568, .5014)]. Furthermore, the unstandardized coefficient estimates demonstrated a positive link between BMC and NZGmI [estimate = .103, SE = .043, 95% CI (.0047, 1,523)], providing support for H1c. H2a predicts that BTC is positively linked with NZGPrI [estimate = .321, SE = .034, 95% CI (.2854, .3674)], which was supported. H2b, which claims that BTC is positively related with NZGPrI [estimate = .175, SE = .037, 95% CI (.1024, .1954)], was also supported. The unstandardized coefficient estimates revealed a positive relationship between BTC and NZGmI, with an estimate of [β = .110, SE = .023, and a 95% CI of (.0259, .1482)], thus providing support for H2c. H3a predicts that NZLPs is positively linked with NZGPrI [estimate = .227, SE = .056, 95% CI (.1428, .2687)], and it was supported. H3b, regarding how NZLPs is positively related with NZGPcI [estimate = .376, SE = .046, 95% CI (.3011, .4225)], was also supported. The unstandardized coefficient estimates indicated a positive association between NZLPs and NZGmI, with an estimate of [β = .162, SE = .066, and a 95% CI of (.1009, .1993)], thus providing support for H3c.

In assessing the impact of NZGPrI, we found that NZGPrI was significantly and positively linked with GCA [estimate = .146, SE = .063, 95% CI (.1021, .1788)], supporting H4. Similarly, considering the impact of NZGPcI, we found that NZGPcI was significantly related with GCA [estimate = .250, SE = .033, 95% CI (.1657, .2997)],

TABLE 4 Factor loadings and reliabilities of constructs.

Constructs	Coding	λ	CRs	AVE
Net-zero economy-oriented green practices			.884	.566
	NZGP 1	.618		
	NZGP 2	.754		
	NZGP 3	.908		
	NZGP 4	.857		
	NZGP 5	.688		
	NZGP 6	.641		
Big data analytics management capability			.904	.615
	BMC 1	.708		
	BMC 2	.917		
	BMC 3	.683		
	BMC 4	.647		
	BMC 5	.781		
	BMC 6	.923		
Big data analytics talent capability			.924	.576
	BTC 1	.838		
	BTC 2	.657		
	BTC 3	.617		
	BTC 4	.780		
	BTC 5	.699		
	BTC 6	.817		
	BTC 7	.806		
	BTC 8	.848		
	BTC 9	.733		
Net-zero economy-oriented lean practices			.867	.524
	NZLP 1	.904		
	NZLP 2	.675		
	NZLP 3	.681		
	NZLP 4	.627		
	NZLP 5	.659		
	NZLP 6	.763		
Green product innovation			.801	.505
	NZGPrI 1	.605		
	NZGPrI 2	.817		
	NZGPrI 3	.738		
	NZGPrI 4	.663		
Green process innovation			.873	.697
	NZGPcI 1	.862		
	NZGPcI 2	.729		
	NZGPcI 3	.904		
Green managerial innovation			.705	.545
	NZGmI 1	.879		
	NZGmI 2	.928		
Green organizational identity			.917	.652
	GoI 1	.778		

(Continues)

TABLE 4 (Continued)

Constructs	Coding	λ	CRs	AVE
	GoI 2	.851		
	GoI 3	.697		
	GoI 4	.664		
	GoI 5	.906		
	GoI 6	.913		
Net zero-based green performance			.898	.597
	NZBGP 1	.757		
	NZBGP 2	.622		
	NZBGP 3	.691		
	NZBGP 4	.875		
	NZBGP 5	.882		
	NZBGP 6	.776		
Green competitive advantage			.850	.587
	GCA 1	.774		
	GCA 2	.713		
	GCA 3	.838		
	GCA 4	.733		

Notes: composite reliabilities = CRs; λ = factor loadings; All factor loadings are significant and no cross-loadings; Average variance extracted = AVE.

supporting H5. Furthermore, the results demonstrated that NZGmI was significantly related with GCA [estimate = .379, SE = .021, 95% CI (.3100, .3991)], supporting H6. In assessing the impact of NZGPrI, we found that NZGPrI was significantly and positively linked with NZBGP [estimate = .501, SE = .044, 95% CI (.4622, .5771)], supporting H6. Likewise, considering the impact of NZGPcI, we found that NZGPcI was significantly related with NZBGP [estimate = .477, SE = .069, 95% CI (.4009, .5235)], supporting H7. Furthermore, the results indicated that NZGmI was significantly related with NZBGP [estimate = .139, SE = .034, 95% CI (.0588, .1663)], supporting H8.

4.4 | Analysis of GCI as a moderator

The results for all moderating effects are presented in Table 5. H10a posits that NZGP moderates the positive effect of BMC on NZGPrI, indicating that this positive effect is enhanced with a high level of NZGP. For NZGPrI (β = .328, p < .001), the interaction term (NZGP * BMC) was significant and positive. H10b posits that NZGP moderates the positive effect of BMC on NZGPcI, strengthening this positive relationship with a high level of NZGP. For NZGPcI (β = .214, p < .001), the interaction term (NZGP * BMC) was significant and positive. For H10c, NZGP moderates the positive effect of BMC on NZGmI, with this positive impact being reinforced with a high level of NZGP. For NZGmI (β = .095, p < .05), the interaction term (NZGP * BMC) was significant and positive.

H11a predicts that NZGP moderates the positive effect of BTC on NZGPrI, indicating that this positive effect is enhanced with a high level of NZGP. For NZGPrI (β = .251, p < .01), the interaction term (NZGP * BTC) was significant and positive. H11b predicts that NZGP moderates the positive effect of BTC on NZGPcI, strengthening this positive relationship with a high level of NZGP. For NZGPcI (β = .377, p < .001), the interaction term (NZGP * BTC) was significant and positive. For H11c, NZGP moderates the positive effect of BTC on NZGmI, such that this positive effect is strengthened with a high level of NZGP. For NZGmI (β = .108, p < .05), the interaction term (NZGP * BTC) was significant and positive. H12a predicts that NZGP moderates the positive effect of NZLP on NZGPrI such that this positive effect is strengthened with a high level of NZGP. For NZGPrI (β = .321, p < .01), the interaction term (NZGP * NZLP) was significant and positive. H12b predicts that NZGP moderates the positive effect of NZLP on NZGPcI such that this positive effect is strengthened with a high level of NZGP. For NZGPcI (β = .166, p < .01), the interaction term (NZGP * NZLP) was significant and positive. For H12c, NZGP moderates the positive effect of NZLP on NZGmI such that this positive effect is strengthened with a high level of NZGP. For NZGmI (β = .134, p < .01), the interaction term (NZGP * NZLP) was significant and positive.

Furthermore, H13a predicts that GOI moderates the positive effect of NZGPrI on GCA such that this positive effect is strengthened with a high level of GOI. For GCA (β = .172, p < .001), the interaction term (GOI * NZGPrI) was significant and positive. Similarly, H13b predicts that GOI moderates the positive effect of NZGPrI on NZBGP such that this positive effect is strengthened with a high level of GOI. For NZBGP (β = .288, p < .001), the interaction term (GOI * NZGPrI) was significant and positive. H14a predicts that GOI moderates the positive effect of NZGPcI on GCA such that this positive effect is strengthened with a high level of GOI. For GCA (β = .207, p < .01), the interaction term (GOI * NZGPrI) was significant and positive. Similarly, H14b predicts

TABLE 5 Hypotheses results.

Hypotheses	β	95% CI LLCI	ULCI	S.E.	P value
Direct effects					
H1a: BMC → NZGPrI	.248**	.1478	.3047	.038	< .010
H1b: BMC → NZGPcI	.473**	.3568	.5014	.041	< .001
H1c: BMC → NZGmI	.103*	.0047	.1523	.043	< .050
H2a: BTC → NZGPrI	.321***	.2854	.3674	.034	< .001
H2b: BTC → NZGPcI	.175**	.1024	.1954	.037	< .010
H2c: BTC → NZGmI	.110*	.0259	.1482	.023	< .050
H3a: NZLP → NZGPrI	.227**	.1428	.2687	.056	< .001
H3b: NZLP → NZGPcI	.376**	.3011	.4225	.046	< .001
H3c: NZLP → NZGmI	.162**	.1009	.1993	.066	< .010
H4: NZGPrI → GCA	.146**	.1021	.1788	.063	< .001
H5: NZGPcI → GCA	.250**	.1657	.2997	.033	< .050
H6: NZGmI → GCA	.379**	.3100	.3991	.021	<. 001
H7: NZGPrI → NZBGP	.501**	.4622	.5771	.044	< .050
H8: NZGPcI → NZBGP	.477**	.4009	.5235	.069	< .001
H9: NZGmI → NZBGP	.139**	.0588	.1663	.034	< .001
Moderating effects					
H10a: NZGP * BMC → NZGPrI	.328**	.2633	.3714	.048	< .001
H10b: NZGP * BMC → NZGPcI	.214**	.1411	.2678	.035	< .001
H10c: NZGP * BMC → NZGmI	.095*	.0427	.1641	.017	< .050
H11a: NZGP * BTC → NZGPrI	.251**	.1881	.3242	.048	< .010
H11b: NZGP * BTC → NZGPcI	.377**	.3069	.4122	.055	< .001
H11c: NZGP * BTC → NZGmI	.108*	.0577	.1358	.026	< .050
H12a: NZGP * NZLP → NZGPrI	.321**	.2683	.3696	.043	< .010
H12b: NZGP * NZLP → NZGPcI	.166**	.1033	.1983	.049	< .010
H12c: NZGP * NZLP → NZGmI	.134**	.0259	.1637	.031	< .010
H13a: GOI * NZGPrI → GCA	.172**	.1223	.1990	.029	< .001
H13b: GOI * NZGPrI → NZBGP	.288**	.2174	.3358	.037	< .001
H14a: GOI * NZGPcI → GCA	.207**	.1458	.2569	.026	< .010
H14b: GOI * NZGPcI → NZBGP	.268**	.1993	.2779	.034	< .001
H15a: GOI * NZGmI → GCA	.251**	.2009	.2966	.045	< .001
H15a: GOI * NZGmI → NZBGP	.355**	.2993	.3967	.053	< .001

Notes: *p < .05; **p < .01; ***p < .001; unstandardized estimate = β; CIs-LL = confidence interval's lower level, CIs-UL; N = 594, big data management capabilities = BMC; big data talent capabilities = BTC; green organizational identity = GOI; green product innovation = NZGPrI; green process innovation = NZGPcI; green managerial innovation = NZGmI; net-zero economy-oriented lean practices = NZLP; net-zero economy-oriented green practices = NZGP; net zero-based green performance = NZBGP; green competitive advantage = GCA.

that GOI moderates the positive effect of NZGPcI on NZBGP such that this positive effect is strengthened with a high level of GOI. For NZBGP (β = .268, p < .001), the interaction term (GOI * NZGPcI) was significant and positive. H15a predicts that GOI moderates the positive effect of NZGmI on GCA such that this positive effect is strengthened with a high level of GOI. For GCA (β = .251, p < .001), the interaction term (GOI * NZGmI) was significant and positive. Similarly, H15b predicts that GOI moderates the positive effect of NZGmI on NZBGP such that this positive effect is strengthened with a high level of GOI. For NZBGP (β = .355, p < .001), the interaction term (GOI * NZGmI) was significant and positive.

5 | DISCUSSION

This study examines how firms can achieve a net-zero emission economy through BDA capabilities, which comprise BMC and BTC, as well as NZLPs, NZGIs, NZGPs, and green organizational identity. We propose that BDA capabilities and lean practices influence net zero-based green performance and green competitive advantage in manufacturing SMEs through NZGIs. This research also seeks to discover how BMC, BTC, and NZLPs influence green innovation adoption in the presence of NZGPs, and how the green organizational identity of firms stimulates the relationship between NZGIs and net zero-based green performance and green competitive advantage. The proposed relationships between these constructs were analyzed using the DCV paradigm as the conceptual framework. The Indian government's commitment to achieving a net-zero economy has necessitated stringent production regulations and industry standards. This commitment has driven Indian manufacturing SMEs to adapt their products and production processes to align with environmental sustainability. This adaptation involves the utilization of innovative approaches enabled by BDA capabilities, NZLPs, NZGPs, NZGIs, and fostering a Green Organizational Identity, which, in turn, leads to enhanced green competitive advantage and net zero-based green performance, aligning with the objectives of a net-zero economy. The study yielded several significant outcomes, validating all proposed hypotheses. The results indicate that BDA capabilities, including BMC and BTC, and NZLPs significantly contribute to driving Indian manufacturing SMEs toward a net-zero waste and emission economy through the adoption of NZGPs, NZGIs, ultimately enhancing green competitive advantage and net zero-based green performance.

The study yielded several significant outcomes and validated all proposed hypotheses. The results indicated that the constructs comprising BDA capabilities, NZLPs, NZGPs, and NZGIs significantly improve the green competitive advantage and net zero-based green performance of Indian manufacturing SMEs. Furthermore, the role of green organizational identity as a moderator between NZGIs and green competitive advantage and net zero-based green performance was found to be significant. These findings support the conclusions of Al-Khatib (2022), demonstrating the pivotal role of BDA capabilities in enhancing firms' environmental performance. By utilizing dynamic capabilities, manufacturing SMEs can harness the insights hidden within big data, enabling the development and implementation of NZGIs, thus improving green competitive advantage and net zero-based green performance, which ultimately contributes to a net-zero waste and emission economy. BDA capabilities, NZLPs, and NZGPs can empower manufacturing SMEs to gain a deeper understanding of customer and market demands, thereby enhancing operational performance and resulting in improved green competitive advantage and net zero-based green performance.

This empirical evidence is consistent with prior research (Bag et al., 2020) and underscores the effectiveness of the DCV paradigm in explaining the relationship between NZGIs and BDA capabilities. According to the DCV paradigm, firms can cultivate innovative capacities by effectively leveraging their dynamic capabilities, ultimately leading to the adoption of NZGIs, which in turn enhances their green competitive advantage and net zero-based green performance. The utilization of BDA capabilities and NZLPs by firms acts as a catalyst for the adoption of NZGIs, a critical aspect of achieving green competitive advantage and net zero-based green performance. These results are consistent with previous research findings that have identified a similar positive association (Belhadi et al., 2020). Therefore, BDA capabilities and lean practices emerge as crucial assets in waste reduction, recycling, and the mitigation of environmental degradation (Al-Khatib, 2022). These elements are pivotal for the sustainability of a net-zero economy. Previous studies have also emphasized the significance of fostering green innovation as a means to curtail waste, pollution, and costs (Tu & Wu, 2021), which are essential prerequisites for achieving a net-zero economy. Firms that invest in green practices stand to gain a competitive edge, as the results indicate that green practices positively moderate the relationship between BDA capabilities and NZLPs and NZGIs (including green product innovation, green process innovation, and green managerial innovation), ultimately leading to enhanced green competitive advantage and net zero-based green performance. This observation aligns with the findings of Teixeira et al. (2022) discovery, who noted a similar connection between lean practices and competitive advantage. Green practices, in particular, enable firms to cultivate a positive image among stakeholders and customers, providing them with a distinct advantage over their competitors.

5.1 | Theoretical implications

This study offers several noteworthy contributions to both the literature and theory in the domain of green innovation, dynamic capabilities, and environmental sustainability within SMEs. First, it advances the existing body of knowledge by delving into the interrelationships among the three categories of green innovation, encompassing green product, green process, and green managerial innovations, in conjunction with green competitive advantage and net zero-based green performance within SMEs. The study introduces the DCV paradigm as a pivotal concept that signifies a firm's capacity to identify and exploit novel opportunities for environmentally responsible business operations (Teece, 2018). This highlights the potential for businesses to enhance their competitive positioning by adopting environmentally conscious production practices, furthering our understanding of how SMEs can contribute to a net-zero emission economy.

Second, by empirically testing the direct impacts of BMC and BTC on NZGIs, this study contributes to the literature on net zero-based green innovation. The findings underscore the substantial positive influence of BMC and BTC on NZGIs, encompassing product, process, and managerial innovations. Prior research has also indicated the significant beneficial effects of BDA capabilities on innovation and the learning process (Bag et al., 2020; Siddiqui et al., 2023). However, no previous study has conclusively demonstrated a relationship between BMC: BTC on green product, green process, and green managerial innovations. This study provides comprehensive evidence of the relationship between BMC and BTC with various facets of green innovation. In line with these findings, BMC and BTC are identified as valuable skills that Indian manufacturing firms can employ to incorporate NZGIs into their products, processes, and management practices, expediting the adoption of green innovation aligned with a net-zero economy.

Third, this study introduces the concept of NZGPs as a crucial moderating factor in the relationship between BDA capabilities (BMC and BTC) and NZLPs with NZGIs (product, process, and managerial). The research applies the DCV paradigm to explain the linkages in the proposed model, indicating that SMEs can sustain BDA capabilities and implement NZLP, strategically integrating them with NZGPs to enhance the impact of NZGIs. This strategic alignment enables SMEs not only to survive but to thrive in an evolving business landscape, where larger competitors are already harnessing these dynamic resources and capabilities to their advantage.

Furthermore, this study not only illustrates the impact of BMC, BTC, and NZLPs on green competitive advantage and net zero-based green performance through NZGIs but also underscores the moderating role of green organizational identity in the relationship between NZGIs and green competitive advantage as well as net zero-based green performance. Building upon this finding regarding the moderating influence of green organizational identity, we infer that, for SMEs, green organizational identity serves as a facilitator in channeling NZGIs toward the creation of green competitive advantage and improved net zero-based green performance. Therefore, the green organizational identity of a firm serves as a catalyst for NZGIs and enhances net zero-based green environmental performance. Similarly, the adoption and implementation of NZGIs within manufacturing companies, especially in the presence of a robust green organizational identity, exhibit a higher likelihood of enhancing their green competitive advantage within their respective markets. These theoretical implications expand our understanding of how SMEs can leverage their organizational identity for achieving sustainable and competitive advantages in a net-zero economy.

5.2 | Practical implications

The findings of this study offer valuable insights and practical implications for policymakers and managers within manufacturing SMEs in developing countries, providing a roadmap to achieve a green competitive advantage and contribute to the goal of a net-zero economy through net zero-based green performance. First, dynamic capabilities, exemplified by BDA, represent a powerful toolset that incorporates cutting-edge technology, innovative resources, and operational methodologies. These capabilities can be harnessed by manufacturing organizations to develop creative solutions for effective big data management. By strategically utilizing BDA, SMEs can significantly enhance their performance and sustainability while actively contributing to the realization of a net-zero economy in their respective regions.

Second, managers in SMEs can leverage BMC and BTC to expedite the adoption of NZGIs. By integrating these capabilities with lean practices tailored to a net-zero economy, such as waste reduction and operational efficiency improvements, SMEs can expedite the integration of NZGIs. This strategic alignment fosters green product, process, and managerial innovations, creating a pathway to sustainable development.

Third, managers are encouraged to recognize the facilitative role of NZGPs, which possess the potential to augment the NZGIs within organizations. These practices, aligned with the principles of a net-zero economy, focus on emissions reduction, energy conservation, and resource efficiency through strategies like reduction, recycling, and reuse. By promoting NZGPs, organizations can inspire innovation in green product and process design and managerial approaches, enhancing their overall sustainability.

Fourth, fostering a culture of knowledge sharing within business firms is crucial for the effective promotion of BMC, BTC, and NZGIs. Upper-level management should implement policies that encourage knowledge exchange among team members. This collaborative approach not only advances NZGIs but also contributes to broader organizational objectives related to green competitive advantage and net zero-based green performance. This emphasis on knowledge sharing can help SMEs develop unique NZGIs concepts, providing them with a sustainable competitive advantage that is challenging for other firms to replicate in the short term.

Fifth, the study underscores the significance of cultivating a green organizational identity within manufacturing firms. BMC, BTC, and NZLPs influence green competitive advantage and net zero-based green performance, with NZGIs acting as mediating factors and green organizational identity as moderating factors. Strengthening the green organizational identity can enhance the contribution of organizations to net zero-based green performance, making them eligible for government incentives aimed at fostering net-zero economy-based firm performance.

Finally, recognizing the equal importance of NZGIs in product, process, and management innovations is essential for achieving a superior green competitive advantage and enhanced net zero-based green performance. Managers should allocate efforts evenly across all three dimensions of NZGIs by harnessing data derived from production and management facets to formulate innovative product and process designs that adhere to green criteria. Investments in technologies for data quality, storage, and processing capabilities are crucial. Even though SMEs may face financial constraints compared to larger competitors, net-zero-oriented lean practices can enable them to allocate resources for the adoption of advanced technologies, ultimately gaining a green competitive advantage and improving net zero-based green performance. This, in turn, can enhance profitability and provide further resources for continued progress.

In summary, by strategically implementing these multifaceted practical implications, manufacturing SMEs in developing countries can position themselves as key contributors to the net-zero economy while simultaneously securing a sustainable competitive advantage in the global business landscape.

5.3 | Limitations and direction for future research

This research has certain limitations that warrant attention from future researchers. The study's outcomes are based on a relatively small sample size and a time-lagged design centered on Indian manufacturing SMEs. These findings must be validated through similar research conducted in other developing countries. Additionally, although the study relies on the DCV paradigm to conceptualize the influence of BDA capabilities, NZLPs, and NZGPs on green competitive advantage and net zero-based green performance, future research may explore this relationship using more complex theoretical models. Furthermore, future studies have the potential to delve into the impact of BDA technological capabilities on NZGIs across product, process, and management dimensions, as well as their influence on competitive advantage and green performance. Subsequent investigations could also scrutinize and substantiate the connection between green production and employment development, as well as the relationship between green learning innovation and net-zero-compatible green performance.

The survey in this study exclusively collected responses from senior-level managers in ISO-certified Indian manufacturing firms. Although this choice aimed to emphasize the significance of BDA capabilities, lean practices aligned with a net-zero economy, and green practices, the findings may not readily generalize to non-ISO-certified manufacturing firms. Therefore, future research could broaden its scope to encompass a more diverse range of perspectives, including non-ISO-certified manufacturing firms, to enrich the empirical landscape. Additionally, future research endeavors may explore additional constructs relevant to the net-zero economy, which were not addressed in this study or the existing literature. Generalization of the findings to manufacturing SMEs in different developing countries should be considered cautiously and only after validation through studies conducted in those countries, using identical sample sizes drawn from manufacturing firms.

5.4 | Conclusion

The pursuit of a net-zero economy has become a prominent global objective, reflecting a commitment to sustainability. This transformation toward sustainability is driven by the adoption of NZGIs, facilitated by digital transformation in manufacturing systems and supply chains. Digital transformation is further reinforced by the strategic use of BDA and the implementation of net-zero-oriented lean practices and green practices. The empirical evidence presented in this study, based on the DCV paradigm, sheds light on the significant impact of these strategic initiatives on manufacturing firms. The research, conducted through a time-lagged design with 594 manufacturing firms, highlights several key findings. It shows that BDA capabilities and net-zero-oriented lean practices have a substantial influence on the development of NZGIs within these organizations. Additionally, the study emphasizes the vital role of green organizational identity in enhancing the effects of NZGI, particularly in terms of green competitive advantage and NZBGP. The synergy created by these interconnected elements is crucial for navigating the contemporary business landscape, characterized by a growing emphasis on sustainability and environmental responsibility. This research offers practical guidance on how firms can align with net-zero economy goals while simultaneously enhancing their competitiveness through sustainable practices. It underscores the significance of a multifaceted approach to sustainability, where digital transformation, data-driven decision-making, lean practices, and a strong green organizational identity come together to drive innovation and foster sustainable performance. As firms aim to align with net-zero economy goals and governmental mandates, these findings provide valuable insights into the strategic imperatives that can guide them toward a future of enhanced competitiveness, ecological responsibility, and contributions to a net-zero economy.

AUTHOR CONTRIBUTIONS

Khalid Mehmood: Conceptualization, literature review, draft writing, data collection, analysis.
Pradeep Kautish: Conceptualization, literature review, draft writing.
Sachin Kumar Mangla: Conceptualization, draft writing, supervision, editing.
Ahsan Ali: Conceptualization, literature review, draft writing, data collection, supervision, analysis.
Yigit Kazancoglu: Conceptualization, draft writing, supervision.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX A

Construct	Items
Big Data Analytics Capabilities (Akter et al., 2016)	
Big data analytics management capability	1. "We continuously examine the innovative green opportunities for the strategic use of BDA." 2. "We enforce adequate plans for the introduction and utilization of BDA." 3. "We perform BDA planning processes in systematic and formalized ways." 4. "We frequently adjust BDA plans to better adapt to changing environmental conditions." 5. "In our company, business analysts and design people meet frequently to discuss important issues both formally and informally." 6. "In our company, information is widely shared between business analysts and line people so that those who make decisions or perform jobs have access to all available know-how."
Big data analytics talent capability	1. "Our company has standardized operational processes which are clear and well understood by employees and customers." 2. "Most of the processes in our company are automated, fool-proof, and minimize human error chances." 3. "Our company has the latest technology and equipment to serve our customers more effectively and efficiently." 4. "Our system allows us to inspect and track key processes that are critical to the company." 5. "Our company regularly evaluates and improves our business processes to ensure quality."
Net-Zero Economy-Based Green Innovations (Chiou et al., 2011)	
Green product innovation	1. "Using less or non-polluting/toxic materials (using environmentally friendly material that reduces emissions to achieve net-zero goals)." 2. "Improving and designing environmentally friendly packaging (e.g., less paper and plastic material used) for existing and new products." 3. "Recovery of company's end-of-life products and recycling." 4. "Using eco-labeling."
Green process innovation	1. "Low energy consumption for net-zero goals such as electricity, gas, and petrol during production/use/disposal." 2. "Recycle, reuse, and remanufacture material." 3. "Use of cleaner technology to make savings and prevent pollution for net-zero goals (such as energy, water, and waste)."
Green managerial innovation	1. "Redefine operation and production processes to ensure internal efficiency that can help to implement green supply chain management." 2. "Re-designing and improving product or service to obtain new environmental criteria or directives such as net zero goals."
Green Competitive Advantage (Chen & Chang, 2013)	
	1. "The company has the competitive advantage of low cost about environmental management or green innovation compared to its major competitors." 2. "The quality of the green products or services that the company offers are better than that of its major competitors." 3. "The company is more capable of environmental R&D and green innovation than its major competitors." 4. "The company is more capable of environmental management than its major competitors."
Green Organizational Identity (Chen, 2011)	
	1. "The company's managers and employees have a sense of pride in the company's environmental goals and missions in direction of achieving net-zero goals of the country." 2. "The company's managers and employees have a strong sense of the company's history about environmental management and protection." 3. "The company's managers and employees feel that the company has carved out a significant position with respect to environmental management and protection and contribution to net-zero goals of the country." 4. "The company's managers and employees feel that the company has formulated a well-defined set of environmental goals and missions." 5. "The company's managers and employees are knowledgeable about the company's environmental traditions and cultures." 6. "The company's managers and employees identify strongly with the company's actions with respect to environmental management and protection."

Construct	Items
Net Zero-Based Lean Practices (Kuo & Lin, 2020)	
	1. "Our company uses its resources in a rational way." 2. "Our company reduces its unnecessary and or redundant activities to eliminate waste in context of net-zero emissions goals." 3. "Our company promotes objective training, information, and awareness actions for the correct performance of its activities." 4. "Our company promotes good management practices, such as cleaning, tidiness, organization, standardization, and discipline." 5. "Our company standardizes the activities performed by its employees and suppliers in order to standardize their processes." 6. "In our company, we have systems to reduce the time to prepare for new activities."
Net Zero-Based Green Practices (Agyabeng-Mensah et al., 2020)	
	1. "Our company develops products and/or services in an ecological way to support net-zero goals of our country." 2. "Our company promotes training, information, and awareness actions on good environmental practices for its employees and suppliers." 3. "Our company defines environmental requirements in context of net-zero goals for its employees and suppliers." 4. "In our company, there are good practices in environmental management in context of net-zero goals, according to the normative reference ISO 14001:2015." 5. "In our company, there is a waste management system, as well as identified and approved environmental procedures." 6. "Our company holds its hierarchies and employees accountable for improving their environmental practices in context of net-zero goals."
Net Zero-Based Green Performance (Mishra et al., 2021; Yakovleva et al., 2012)	
	1. "Air emission drop" 2. "CO_2 emission drop" 3. "Excess water drop" 4. "Solid wastes drop" 5. "Decrement of consumption of poisonous materials" 6. "Improvement of ecological condition"