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RESEARCH ARTICLE

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Strategic pathways to achieve Sustainable Development Goal 12 through Industry 4.0: Moderating role of institutional pressure

Mahak Sharma[1] | **Pratibha Singh**[2] | **Konstantinos Tsagarakis**[3]

[1]Faculty of Behavioural, Management and Social Sciences (BMS), Industrial Engineering & Business Information Systems (IEBIS), University of Twente, Enschede, The Netherlands

[2]Birla Institute of Management Technology, BIMTECH, Greater Noida, India

[3]School of Production Engineering and Management, Technical University of Crete, Chania, Greece

Correspondence
Mahak Sharma, Faculty of Behavioural, Management and Social Sciences (BMS), Industrial Engineering & Business Information Systems (IEBIS), University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands.
Email: m.sharma@utwente.nl

Abstract

Emerging economies, at the vanguard of extensive resource depletion and limited environmental stewardship, are worst-hit by climate change events, necessitating an extensive investigation of the relevance of I4.0 in attaining sustainable consumption and production patterns. This study focuses on Sustainable Production and Consumption (SDG12) and investigates how the implementation of I4.0 can contribute to the adoption of circular economy practices (CEPs) to incorporate elements of sustainable consumption and procurement into supply chains. Based on dynamic capabilities theory, institutional pressure, and the triple-bottom-line perspective, this study proposes an overarching research framework that presents the synergistic convergence of dynamic capabilities, I4.0, and the circular economy to achieve SDG12. This framework is empirically validated through a survey-based, cross-sectional research design by utilizing conditional process modeling. This study employed purposive sampling where respondents constituted 480 industry practitioners and professionals in digital supply chain and operations management from manufacturing firms based in the Baddi and Alwar districts in India. The findings demonstrate that I4.0 and CEPs sequentially mediate the impact of dynamic capabilities on SDG12, while mimetic pressure strengthens the impact of exploitation-oriented strategy on SDG12.

KEYWORDS

circular economy practices, Industry 4.0, institutional pressure, mimetic pressure, Sustainable Development Goal 12

1 | INTRODUCTION

Recent strides in industrial evolution have been concomitant with the advancing digital transformation paradigm, resulting in the demand for high-quality products (Kumar, Raut, et al., 2022). At the onset of the Fourth Industrial Revolution (I4.0), the introduction of cloud computing, cyber-physical systems, the Internet of Things, artificial intelligence, autonomous robots, big data, and intelligent computing transformed the dynamics of manufacturing and supply chain processes (Ghobakhloo et al., 2023; Kumar, Sharma, et al., 2022; Sharma, Sehrawat, et al., 2022) (Bag, Gupta, & Kumar, 2021; Sharma, Raut, et al. 2023). Fast-emerging economies are primarily responsible for the extensive resource depletion phenomenon owing to their limited environmental stewardship (Hanif et al., 2019; Mittal & Gupta, 2015), making them the most susceptible to the impact of climate change. Thus, firms are investing in the optimization of their operating systems, thereby transforming the existing industrial infrastructure through hyperconnected data-driven installations.

Within this new framework, firms strive to create a novel economic business model that eradicates end-of-life production patterns and instead relies on redesigning materials, products, and processes to optimize the consumption of limited resources. This includes reducing resource usage and designing ways to reuse, recycle, repair, and refurbish waste and by-products, which would ultimately converge into circular economy practices (CEPs). At the micro level, CEPs tend to prioritize business profitability and economic performance (Patyal et al., 2022), whereas, at the macro level, these practices help achieve the Sustainable Development Goals (SDGs) to address future environmental and social problems (Kirchherr & Piscicelli, 2019). The convergence of I4.0 and CEPs seeks to achieve "production and consumption sustainability" by providing practical solutions to "preserve and enhance natural capital" (Arranz et al., 2022), which directly aligns with SDG12, titled "Responsible Consumption and Production." The 17 SDGs are an "integrated and holistic" concept that recognizes the interlinkages among the biosphere, society, and economy (Dantas et al., 2021; Strazzullo et al., 2023). Notably, SDG12 encourages more sustainable consumption and production patterns through several measures, including policy frameworks and international agreements, to monitor the management of waste and by-products (Opoku et al., 2022). Moreover, CEPs are strategically positioned to empower firms to construct effective supply chain processes, thereby intertwining SDG12 with innovation and operational efficiency (Starik & Marcus, 2000). This allows firms the opportunity to capitalize on a range of benefits such as generating new revenue streams by creating competitive advantage through differentiation (Jayanti & Rajeev Gowda, 2014), building a strong reputation in terms of employer attractiveness and market outcomes through better environmental impact performance (Grover et al., 2019; Khan, Razzaq, et al., 2021), enhancing supply chain resilience by improving operational efficiency (Khan, Johl, & Akhtar, 2021), and building innovative business models (Grijalvo Martín et al., 2020). The 2023 Business & Sustainable Development Commission report asserts that attaining SDG12 will unveil USD 12 trillion in market opportunities in the four diverse economic systems of food and agriculture, cities, energy and materials, and health and well-being.

Online delivery and returns are other relevant instances where e-commerce retailers can be encouraged to achieve SDG12. Here, the opportunity lies in making returns operationally efficient and relatively emission-friendly with the appropriate integration of I4.0 into supply chain processes (Dantas et al., 2021). Based on the technical foundation of I4.0, seminal studies have posited that I4.0 technologies are positioned to solve these critical problems, thereby ensuring sustainable consumption and production patterns (de Paula et al., 2023). However, the proposition that adopting I4.0 can help manufacturers enhance their production capabilities and achieve the SDGs requires in-depth empirical investigation (Dantas et al., 2021; Sharma, Al Khalil, & Daim, 2022).

Since the business environment is increasingly operationally, tactically, and strategically agile, adopting I4.0 has become inevitable for organizations to survive and gain a competitive advantage (Bag, Telukdarie, et al., 2021; Sharma, Raut, et al., 2023). Digital transformation can be explored through the lens of dynamic capabilities, where firms embrace digital innovation by adopting either a replicative process, that is, using existing knowledge through an exploitation-oriented (EPO) strategy, or a generative process, that is, searching for new knowledge through an exploration-oriented (ERO) strategy (Inigo et al., 2017; Jafari-Sadeghi et al., 2021). Along with the interaction between industrial evolution and firms' resource configuration, governments, as an external mechanisms, often impose substantial pressure to coerce firms (Chen et al., 2022) to move toward digital innovation (Shibin et al., 2020). Firms experience significant institutional pressure in the form of legally binding policy frameworks to develop and rapidly adopt I4.0 know-how (referred to as coercive pressure [CP]) or benchmark themselves against competitors to deal with market uncertainty (referred to as mimetic pressure [MP]). In addition, normative pressure (NP) directs an organization to function within social boundaries by establishing codes of professionalism and formal codes of conduct, manifested as industry expectations (Bag, Gupta, & Kumar, 2021; Colwell & Joshi, 2013). State-run digital initiatives set specific objectives and employ performance indicators to enhance a firm's production competencies (Chaudhry & Amir, 2020). Considering the diverse spectrum of intervening influences, the present research further expounds upon a contemporary research avenue, that is, the I4.0 delivery system, that needs to be developed to overcome problems such as operational complexities, financial constraints, and skill gaps (Bag, Telukdarie, et al., 2021). Extant studies highlight the need to identify the most powerful institutional forces encouraging the adoption of I4.0 to comprehensively understand the industrial ecosystem in emerging economies such as India (Kamble et al., 2018; Rajput & Singh, 2019).

A considerable segment of the literature focuses on explaining the benefits of I4.0 from the perspective of CEPs (Awan et al., 2021; Gupta et al., 2021). Although seminal studies have linked I4.0 to CEPs (Pinheiro et al., 2022; Rosa et al., 2020; Tseng et al., 2018) and investigated the impact of CEPs on the SDGs (Daglis et al., 2023; Lahane & Kant, 2022; Sharma et al., 2021), most rely on a fragmented approach that does not integrate these concepts. Awan et al. (2021) have emphasized one aspect of I4.0 and presented a review that provides a multistakeholder perspective to enhance the implementation of IoT and circular economy. Few studies have theoretically highlighted that CEPs can play a critical role in the linkage between I4.0 and the SDGs (Akter et al., 2022; Dantas et al., 2021). Alcayaga et al. (2019) highlighted the need for developing a better understanding of how I4.0 facilitates sustainability by considering several external and internal elements for the successful implementation of CEPs. Building on this, Bai et al. (2022) utilized legitimacy theory to explain how technological innovation and circular economy collaboratively contribute to social sustainability by employing the DEMATEL method. However, they were unable to ascertain a causal relationship between I4.0 technology, circular economy, and SDGs. Furthermore, existing empirical research has predominantly focused on developed nations with enhanced infrastructure, leaving a significant void in the prevailing literature regarding the successful implementation of CEP in developing countries (Jawaad & Zafar, 2020; Moktadir et al., 2020). Notably, a huge surge in resource extraction is attributed to high living standards where substantial infrastructural investments are underway in developing and transitioning nations (Camilleri, 2020). This underscores the imperative to steer industries in emerging nations toward adopting CEPs and achieving SDG12.

Hence, this study fills these gaps by proposing an overarching research framework, which investigates the associations among I4.0, CEPs, and SDG12 in an emerging economy. Overall, most seminal works have used either qualitative studies or multicriteria decision-making techniques; however, studies that empirically validate these findings in emerging nations are lacking. Furthermore, there remains a paucity of theory-based empirical research that proposes research frameworks to understand the underlying phenomenon and implementation of I4.0 in the supply chain context. Seminal studies have primarily provided theoretical evidence advocating a convergence between CEPs and SDG12 (Dantas et al., 2021). Sharma, Antony, & Tsagarakis, (2023) applied a resource-based view to examine the causal linkages between I4.0, green logistics practices, and adoption of CEP in the context of manufacturing industry. However, the investigation did not investigate how these mechanisms are linked to the realization of SDGs. Hence, to address these prevailing gaps in the body of knowledge, this study investigates whether adopting I4.0 can enable the adoption of CEPs and help achieve SDG12. Accordingly, the present study endeavors to answer the following research questions:

RQ1. What is the impact of ERO and EPO strategies on the implementation of I4.0?

RQ2. How does I4.0 impact the adoption of CEPs and the achievement of SDG12?

RQ3. What is the moderating effect of institutional pressure (i.e., CP, NP, and MP) on the association between ERO and EPO strategies and I4.0?

RQ4. What is the moderating effect of the IDS on the association between the implementation of I4.0 and the adoption of CEPs?

A survey-based, cross-sectional research design was employed to empirically validate the proposed framework. Data were collected through a questionnaire. The results suggest that all the proposed hypotheses for the main effects are supported. Furthermore, the serial mediation analysis reveals that the ERO and EPO strategies indirectly affect development goals through the implementation of I4.0 and the adoption of CEPs. However, for institutional pressure, only MP exerts a conditional moderating effect on the indirect impact of an EPO strategy on the SDGs. Based on this, the unique contribution of this study lies in presenting a more holistic account of the interplay among the I4.0, CE, and SDG12. This study integrated three critical theoretical underpinnings, namely, dynamic capabilities theory, triple bottom line perspective, and institutional theory to establish a robust foundation for proposing a conceptual framework that illustrates the causal relationships among the variables. From this perspective, this empirical study offers thought-provoking findings that bridge the gap between theory and practice by demonstrating that enhancing dynamic capabilities through the implementation of I4.0 enables CEPs in the value chain, thereby achieving SDG12. Moreover, I4.0 technologies facilitate real-time coordination and collaboration, thus introducing more robust control mechanisms and minimizing errors. This ensures resource utilization with utmost precision and minimization of waste.

Further, this study takes a novel stance by accentuating the moderating impact of mimetic pressure within the context of an emerging nation. It makes a compelling case for cultivating a competitive environment where the adoption of specific supply chain management practices is positively regarded in industry, thus motivating organizations to emulate successful competitors. This novel perspective contributes to the ongoing discourse on sustainable practices and strategic decision-making by emphasizing the role of external within the unique landscape of emerging economies.

Our findings offer diverse theoretical and practical implications to aid governments, manufacturers, and other related stakeholders in understanding the need to focus on CEPs and SDG12 while moving toward digitalization and industrialization. The findings suggest that firms attempt to implement new technologies and innovate; however, the lack of an adequate delivery system hampers successful implementation. Practitioners should invest in human resource training and recruit experienced and capable project managers. Firms should consider establishing cooperative agreements with their superior counterparts to implement EPO strategies. Additionally, they should use I4.0 to align with established norms and formulate a novel strategic direction that encourages sustainable CEPs using digital technologies for data governance, real-time information sharing, and enhanced traceability in supply chains. The government should give a voice to consumers by treating them as equal stakeholders in the sustainable innovation paradigm, in which the industry can find coherent ways to reuse waste as a valuable economic resource.

Section 2 presents the background literature and outlines the theoretical underpinnings. Section 3 presents the hypotheses, followed by Section 4 which demonstrates the research methodology. Section 5 illustrates the data analysis and results. Finally, Section 6 concludes the paper and presents the discussion, implications, and future research avenues.

2 | LITERATURE REVIEW

This section is divided into four subsections. The first two subsections introduce and explain I4.0, as well as the importance of CEPs and sustainable production and consumption. The next subsection discusses the theoretical underpinnings of the present work, thereby explaining the dynamic capabilities view and institutional theory. Finally, we present the knowledge gap that explains the need for this research.

2.1 | Industry 4.0

Although the growth of the manufacturing sector contributes to the global economy by boosting commerce and creating jobs, the linear model of production has been criticized for contributing to environmental issues, such as the depletion of natural resources and ecological degradation (Aftab et al., 2022). Climate change has led firms to mitigate their adverse impacts on the natural environment (Gupta et al., 2021). However, the literature on I4.0 accentuates the advantages of digitalization in supply chains, such as higher customer satisfaction, shorter responsiveness and cycle times, and reduced costs, with a focus on sustainability and CEPs (Gupta et al., 2021; Sharma et al., 2021). Sustainability refers to the principle of environmentalism; firms should focus on conserving ecological, social, and economic resources (Sharma, Raut, et al., 2023). Notably, I4.0 can enable sustainable practices that help manufacturers enhance efficiency and quality, leading to more profitable business models and safer workplace conditions (Mukhuty et al., 2022; Sharma et al., 2021; Margherita & Braccini, 2023). The relationship between sustainability and I4.0-enabled digital technologies can transform production systems globally; however, little attention has been paid to designing and empirically validating an overarching research framework from an emerging economy perspective (Sharma, Antony, & Tsagarakis, 2023).

2.2 | Adoption of circular economy practices and sustainable development goals

Construction, manufacturing, and production (agriculture and resource extraction) significantly affect the global environment. In technologically developed industrialized economies, production process innovations focus on measures that can help reduce industrial energy consumption and harmful pollutant emissions (Camilleri, 2020; Clark, 2007; Wang et al., 2019). Paradoxically, the trajectories that have been followed to advance the process for better environmental compatibility or augment economic returns have led to increased consumption (Tukker et al., 2008). However, recent developments in digitalization have shown that the manufacturing sector can perform better than it has done in the last four decades (Wang et al., 2019). Furthermore, I4.0 technologies minimize errors and provide fast prototyping abilities that not only ensure that resources are not wasted but also ascertain that CEPs and sustainable practices are followed (Gupta et al., 2021). Hence, firms are progressively engaging in a circular economy by adopting organizational sustainability strategies (Santa-Maria et al., 2021) and new business models (Lange, 2022). The transition to a circular economy is based on the basic concept of the several R strategies, practices, functions, conceptualizations, and approaches (Camilleri, 2019; Sawe et al., 2021; Tsironis et al., 2022). Notably, CEPs ensure that firms and communities favor renewable resource usage and prevent waste generation (Di Foggia & Beccarello, 2022; Mishra et al., 2022). Sustainable procurement is the solution to most existing problems, and the active participation of governments, local authorities, and other official institutions can change the present dynamics (Gupta et al., 2021; Qazi & Appolloni, 2022). Accordingly, SDG12 aims to improve the economy and generate and encourage market demand for sustainable goods and services (Clark, 2007).

The recent literature has integrated CEPs and I4.0 (Viles et al., 2022) to propose a hybrid framework for ethical and sustainable business performance (Gupta et al., 2021). This study emphasizes that the use of I4.0 technologies can chart the transition from a linear to a circular economy model through enhanced traceability, real-time information sharing, and clear visibility of products. This amalgamation of technology with CEPs enables the tracing and recovery of components and rare-earth materials for sustainable production and consumption. Furthermore, some scholars have used multicriteria decision-making to analyze and rank the barriers that hamper sustainable business operations when a firm adopts I4.0 and CEPs (Kumar, Raut, et al., 2022). A few recent studies have also used fuzzy AHP and fuzzy TOPSIS to determine the weights and relative ranks of circular economy-based key performance indicators in the agri-food supply chain to achieve sustainable consumption and production (Kumar, Sharma, et al., 2022). This study highlights that the environmental and economic dimensions are the most critical, followed by the circular and social dimensions. Hence, CEPs, which infer the "effectiveness of reverse logistics," are crucial for attaining sustainable consumption and production.

2.3 | Theoretical underpinning

2.3.1 | Dynamic capabilities theory

Increasing market volatility and competitive pressure have pushed firms to decide on the strategic relevance of their resources and capabilities (Chari et al., 2022). Ordinary capabilities, also called first-order capabilities, are usually associated with the routine operational deployment and replication of the existing system, whereas dynamic capabilities help firms integrate, build, and reconfigure their internal and external competencies (Teece et al., 1997). Dynamic capabilities theory includes higher order capabilities that encompass the knowledge, processes, procedures, organizational structures, assets, structural architectures, and strategies that help achieve sustainable competitive advantage (Eslami et al., 2021; Felsberger et al., 2022). Teece (2007) outlined three micro-foundations of dynamic capabilities, namely, "(1) to sense and shape opportunities and threats; (2) to seize opportunities; and (3) to reconfigure the business enterprise's intangible and tangible assets." A firm must strive to sense new opportunities to improvise or substitute existing aspects of business, mobilize its resources to address opportunities and threats, and reconfigure lower order capabilities to empower firms to respond to change

(Fischer et al., 2010). Further, a firm can develop dynamic capabilities through exploitative orientation, such as known knowledge acquisition, internalization, and dissemination as well as exploratory learning such as unknown knowledge search and experimentation (Dixon et al., 2014).

The exploitation strategy involves enhancing existing offerings and processes to achieve efficiency and maximize short-term profits (Bierly & Daly, 2007; March, 1991). This approach is aligned with businesses utilizing technology to improve efficiency across production, sales, and delivery processes (Gastaldi & Corso, 2012; He & Wong, 2004). On the other hand, exploration focuses on experimenting with innovative ideas for new products, services, and breakthrough technologies (Bierly & Daly, 2007). However, the outcomes of exploration strategies are less certain and more time-sensitive (March, 1991). In the contemporary business landscape, explorative firms are increasingly adopting “I4.0” technologies (Blanchet et al., 2014) to integrate and automate various work processes (Machado, Winroth, & da Silva, 2020). They also leverage these technologies to connect with products in the field (Porter & Heppelmann, 2014). Explorative firms are known for creating new products (He & Wong, 2004; Yalcinkaya et al., 2007) and exploring new opportunities in service businesses (Fischer et al., 2010). Notably, exploration plays a crucial role in developing advanced services, in contrast to exploitation, which is more closely associated with basic services (Kowalkowski & Kindström, 2014).

Specifically, in order to leverage existing knowledge and capabilities, firms are utilizing large data generated through multiple transactions and streamlining operations by adopting technologies that improve the optimization of production lines, automation of routine tasks, and the enhancement of existing systems to align with I4.0 principles. This could include the integration of IoT devices, real-time data analytics, and I4.0-based advanced algorithms to deploy advanced manufacturing (de Mattos Nascimento et al., 2024; Gadekar et al., 2022; Gandomi & Haider, 2015). Additionally, I4.0 employs 3D printing, blockchain, cloud computing, augmented reality, and mobile devices for varied purposes in day-to-day operations, ensuring quality and cost-effectiveness (Chen & Hao, 2022; Chiarini, 2021). Firms actively invest in exploring new technologies to enhance business operations (Rajapathirana & Hui, 2018), emphasizing the linkage between the orientation of firm dynamic capabilities and degree of I4.0 adoption (Díaz-Chao et al., 2021).

Thus, this theory is relevant to innovation-based competitive ecosystems because it explores how and why firms succeed and fail. “Capabilities” are harnessed by discerning the participation of strategic management in acquiring, collating, and modifying an organization's internal and external functional capabilities, resources, and expertise to manage an unpredictable environment (Wójcik, 2015). This trajectory often warrants firms to engage in explorative actions that alter existing products and processes, as well as a range of competence-enhancing exploitative actions characterized by prediction, positivity, and proximity (Gupta et al., 2020; Jafari-Sadeghi et al., 2021). Firms often succumb to uncertainty, avoid experimenting with new platforms, and gradually upgrade their existing systems to implement I4.0. They need timely exploitation of internal and external proficiencies and exploration to create distinctive and difficult-to-imitate resource configurations (Gupta et al., 2020). Hence, they predominantly choose to either use their capabilities to exploit existing resources or proactively explore novel ways to conduct business in a rapidly evolving digital economy (Zhan & Chen, 2013).

Moreover, seminal work emphasizes that adopting sustainable practices generates tacit capabilities (Díaz-Chao et al., 2021) that can leverage I4.0 technologies to create unique and inimitable resource configurations. Consequently, a competitive advantage is generated for the firm from economic and environmental perspectives (Chari et al., 2022; Díaz-Chao et al., 2021; Ozusaglam et al., 2018). Thus, dynamic capabilities theory constitutes a suitable theoretical framework for exploring the complementary relationships between the EPO and ERO strategies, using I4.0, to achieve SDG12. Hence, this way, we intend to find whether exploitation, exploration, or both are associated with firms' pursuit of CEP and thus necessary for firms to develop such a strategy to realize SDG12.

2.3.2 | Institutional theory

Institutional theory offers a multifaceted assessment of a firm's behavior (Zhang & Dhaliwal, 2009). It advocates that firms in an institutional setting must adapt in accordance with the social expectations, regulations, and mutual standards levied by the state, society, stakeholders, and institutions to maintain their legality and acquire essential and unique resources (Huo et al., 2013). From an institutional perspective, firms are affected by a diverse range of pressures from both the external environment and the internal firm setting. Hence, contemporary decision-makers prioritize institutional expectations over financial competencies (Laosirihongthong et al., 2020). Firms must now focus on their reasonability, acceptability, and supportiveness, which need to be in line with society, governments, and their own stakeholders (e.g., suppliers and customers) (Liao, 2018). Violating such regulations or expectations may jeopardize a firm's existence and long-term development (Bhuiyan et al., 2023). To survive in this dynamic world, a firm must enhance its agility and flexibility to better adapt to its surroundings and meet government and consumer requirements.

DiMaggio and Powell (1983) professed that organizations become remarkably similar due to a shift in the forces of rationalization and bureaucratization driven by the state and professions. Despite actors intending to bring change, they inadvertently make organizations more alike. Three isomorphic processes forcing individual organizations to resemble other organizations facing similar environmental conditions are coercive, mimetic, and normative. Henceforth, fueling this convergence, institutional pressure has three key dimensions: CP, NP, and MP (Gupta et al., 2020; Hofman et al., 2020; Jain et al., 2020). It is noteworthy that NP is connected to professional values; CP is levied because of political influence and firm legitimacy, regularly imposed through laws, regulations, and accreditation processes (or outside agency requirements); and MP is primarily due to replication or imitation actions resulting from a firm's response to uncertainty (Caravella, 2011). Few scholars have empirically investigated institutional pressure in the supply chain digitalization context (Gupta et al., 2020). Recent studies show that institutional pressure significantly influences firms' supply chain management (Liao, 2018; Zhang & Dhaliwal, 2009). Generally, institutional pressure is used to elucidate whether to adopt an innovation or the intention to do so (Teo et al., 2003). However, the focal lens of digitalization requires empirical investigation to understand the influence of institutional pressure on supply chain innovation.

2.3.3 | Triple bottom line (TBL) perspective

Sustainability has garnered immense global interest by presenting meaningful solutions for environmental conservation (Khan, Johl, & Akhtar, 2021). Elkington (2013) used the TBL perspective to design a suitable framework for measuring corporate performance by including unconventional measures of profitability such as the environmental and social dimensions. The three pillars of the TBL perspective are economic sustainability, which relates to profit achievement (Schulz & Flanigan, 2016); social sustainability, which strives toward the well-being of humanity and society; and environmental sustainability, which endeavors to preserve natural resources (Zafrilla et al., 2019). These dimensions often interact, and it is critical to ensure the progressive development of these areas within the TBL framework. Notably, I4.0 and sustainability can combine to form a synergetic alliance wherein firms can benefit immensely by engaging in sustainable production (Bai et al., 2022). Moreover, I4.0 brings myriads of disruptive technological systems that can create a robust foundation for firms to survive under fluctuating market conditions and concurrently contribute to the sustainable development of society (Schulz & Flanigan, 2016). The TBL perspective indicates that the economic aspects of sustainability decrease setup and labor costs, optimize lead times, and raise organizational profits (Khan, Johl, & Akhtar, 2021; Margherita & Braccini, 2020).

Furthermore, I4.0 technologies can optimize energy consumption (Khan et al., 2023; Sharma et al., 2021) and aid energy conservation (Urban et al., 2020). Additionally, smart industry technologies safeguard the health and safety of employees by enabling the predictive maintenance of the workplace (Çınar et al., 2020), stimulating job satisfaction by decreasing boredom, and shifting degrading and alienating tasks (Berx et al., 2022; Eickemeyer et al., 2021). Hence, the TBL perspective can provide a pathway through which I4.0 technologies can radically shift the evolving paradigm of the industrial ecosystem toward the SDGs (Khan et al., 2023). Notably, SDG12 focuses on sustainable consumption and production patterns through the efficient management of waste and by-products. Hence, the TBL concept affords industry with the much-needed motivation to strategically use I4.0 to develop effective supply chain processes, thereby intertwining SDG12 with innovation and operational efficiency.

2.4 | Research gap and relevance of the study

Seminal studies have explained the synergistic convergence of the two distinct yet interconnected facets of the industrial ecosystem, namely, I4.0 technologies and CEPs (Akter et al., 2022). Dantas et al. (2021) posit that this strand of the literature has attempted to combine the concepts of the circular economy, I4.0, and SDGs. Among previous empirical investigations, Dev et al. (2020) have explored how I4.0 tools can enhance firm performance by focusing on reverse supply chains. Belaud et al. (2019) emphasize the strategic advantages of implementing big data in agricultural supply chains. Puntillo (2023) presents a case study investigating how CEP-based business models can help achieve the SDGs by recycling waste into recyclable materials. However, the association between CEPs and the SDGs remains unexplored. Bag, Gupta, & Kumar (2021) propose a framework that demonstrates 13 enablers of I4.0, which can boost supply chain sustainability. Ahmed et al.'s (2022) recent review article focused on applying cyber-physical systems within the CEP stages to achieve the SDGs. Although these notable studies offer significant insights into the intersecting phenomena, a paucity of empirical investigations evidencing the theorized interlinkages among I4.0 technological tools, CEPs, and achievement of the SDGs remains (Akter et al., 2022). Hence, the circular economy–I4.0–SDG connection is at the crossroads of industrial evolution, making it a promising research avenue for linking disruptive technologies to system-wide shifts in economic and industrial models.

To the best of our knowledge, this study is the first to examine the linkages between the EPO and ERO strategies, I4.0, CEPs, and SDG achievements. Given the dearth of empirical evidence, this study takes a novel stance by exploring the underlying mediating effects of the adoption of CEPs on the relationship between the implementation of I4.0 and sustainable production and consumption. This study makes two notable theoretical contributions to the literature. First, we contextually integrate and use dynamic capabilities theory, institutional theory, and the TBL perspective to investigate the enablers and subsequent effects of I4.0 on SDG12 (refer to Figure 1). Second, by testing the influence of several types of context-specific pressures as moderating variables, we provide in-depth insights into the distinct nature of the implementation of I4.0. This study highlights that digitalization and industrialization are critical for the better utilization of existing resources, thus ensuring that present needs can be fulfilled without compromising future ones.

2.5 | Conceptual framework

This study puts forth a comprehensive model encompassing a serial causal relationship by integrating the two facets of dynamic capabilities, I4.0, CEP, and SGD12. Considering the first linkage, dynamic capabilities theory proposes the association between exploitative, explorative orientation and I4.0 as firms optimize their production lines, automate routine tasks, and enhance existing systems to align with I4.0 principles. Firms also actively invest in exploring new technologies to enhance business operations (Rajapathirana & Hui, 2018), accentuating the linkage between I4.0 adoption and exploratory orientation of firm's dynamic capabilities. Thus, this elucidates what set of internal factors are associated with firms' orientation toward degree of I4.0 implementation.

Next, an institutional theory is being leveraged to understand the role of isomorphic processes forcing individual organization to resemble other organizations by investigating the moderating effects of MP, CP, and NP. Thus, this reveals what external factors moderate this dynamic capability degree of I4.0 relationship. Further, we extend the TBL perspective to provide a holistic framework linking I4.0, CEP, and SDG12. Economically, I4.0 technologies can lead to decreased setup and labor costs and optimized lead time facilitating operational efficiency and efficient resource utilization, thus aligning with circular practices that reduce costs. Environmentally, I4.0 enables better monitoring for reduced environmental impact, thus complementing circular economy principles of resource conservation. Socially, I4.0 can enable predictive maintenance of the workforce by aligning with SDG12's focus on inclusive industrialization and innovation. This integrated approach addresses economic, environmental, and social dimensions, thereby contributing to sustainable consumption, production, and industrialization, as delineated in SDG12. In summary, the conceptual framework encompasses causal associations based on robust theoretical underpinning to develop insight into the internal (i.e., dynamic capabilities) and external (i.e., environmental pressure) factors that influence strategic decision-making related to the realization of SDG12.

2.6 | Hypothesis development

This section presents the research hypotheses. Initially, the direct effects of strategy orientation, implementation of I4.0, and adoption of CEPs are proposed. The mediating effects of the implementation of I4.0 and the adoption of CEPs are then presented. Finally, we develop hypotheses for the moderating role of the IDS and institutional pressure on the sequential mediating effects. Based on the hypotheses, the conceptual framework has been illustrated in Figure 1.

2.7 | Direct relationships

2.7.1 | Exploration-oriented (ERO) strategy and degree for I4.0 implementation (DII)

Drawing upon the dynamic capabilities theory, organizations gradually determine nascent prospects for refining or substituting prevailing facets of their business. Subsequently, firms strategically mobilize resources to navigate and address these identified opportunities and challenges (Fischer et al., 2010). Firms aim to invest carefully when making adoption decisions as a part of nuanced and measured investment strategy that aligns with the dynamic capabilities inherent in the organizational framework, especially those related to disruptive technologies (Sharma, Al Khalil, & Daim, 2022). In recent years, manufacturers have adopted digital technologies to fit the I4.0 framework (Bag, Gupta, & Kumar, 2021). To mitigate instability, these firms seek to upgrade their dynamic capabilities by exploring or exploiting their existing assets (Gupta et al., 2020). It is noteworthy that I4.0 is an amalgamation of key technologies, such as big data, cloud computing, artificial intelligence, augmented reality, the Internet of Things, blockchain, and three-dimensional (3D) printing, which can address different distribution and service issues in manufacturing processes by engendering novel approaches. Blockchain makes supply chains transparent and traceable (Sharma, Al Khalil, & Daim, 2022). The Internet of Things helps monitor, control, plan, and optimize supply chains in real time to build, implement, and incorporate an integrated solution to enhance the flow of goods, information, and capital among stakeholders (Kumar, Sharma, et al., 2022). Mass production and customization can be achieved using a large volume of available customer data, big data analytics, and integrated artificial intelligence to respond to customer demands with a more precise estimation (Gupta et al., 2020;

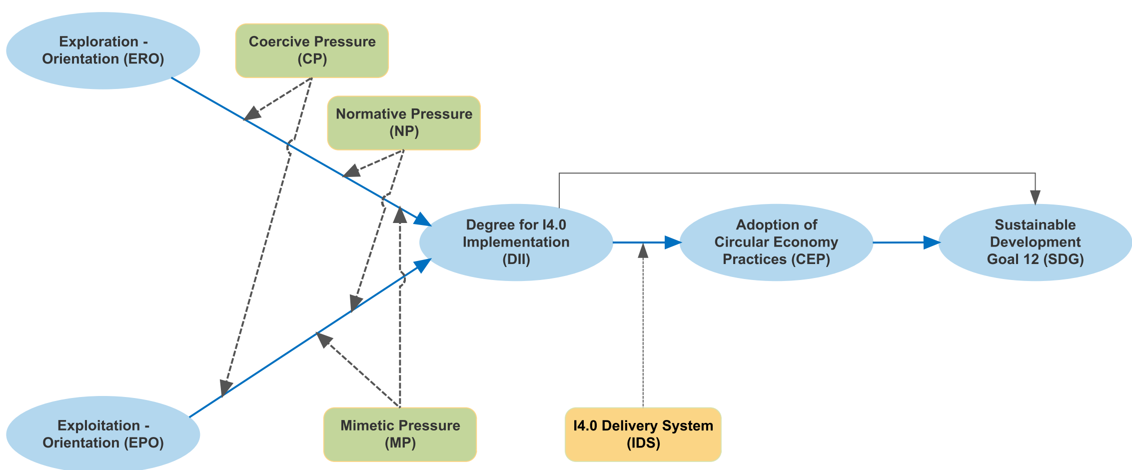

FIGURE 1 Conceptual model.

Truby, 2020). Manufacturers with a high degree of I4.0 implementation (DII) have an advantage over their competitors when using front-end and base technologies, thereby enhancing their operational effectiveness, efficiency, and flexibility (Bag, Telukdarie, et al., 2021). Globally, firms are exploring how I4.0 can aid their operations and provide environmentally friendly and sustainable solutions (Sharma, Antony, & Tsagarakis, 2023). Therefore, we hypothesize the following:

H1. The ERO strategy positively impacts the DII.

2.7.2 | Exploitation-oriented (EPO) strategy and degree for I4.0 implementation (DII)

According to dynamic capabilities theory, a firm can strategically embrace exploitative orientation by encompassing the acquisition, internalization, and dissemination of established knowledge. Simultaneously, pursuing exploratory learning endeavors involves searching for novel knowledge and experimentation (Dixon et al., 2014). However, orchestrating such a paradigm shift can engender heightened uncertainty and risk. Nevertheless, exploiting superior external knowledge often opens promising avenues for increasing market share (Denford, 2013). Further, firms sometimes need more resources, a skilled workforce, or time to experiment and explore new options to address current issues (Gupta et al., 2020); hence, they try to focus on exploiting their current capabilities and resources. Manufacturing and automobile firms that have already moved toward digital technologies and adopted the I4.0 framework are enjoying a first-mover advantage (Sharma et al., 2021; Yu et al., 2022) and reaching a broader consumer base (Rosário & Dias, 2022). Hence, when a company implements I4.0 comprehensively, it is the outcome of effective EPO strategies that engender a stronger forecasting ability to understand the demands of stakeholders. Therefore, we propose the following hypothesis:

H2. The EPO strategy positively impacts the DII.

2.7.3 | Degree of I4.0 implementation, adoption of circular economy practices, and sustainable development goals

Contemporary businesses are focusing heavily on CEPs and sustainability. In the digital world, corporate sustainability is imperative for businesses to survive; it is no longer simply a strategic option (Ghobakhloo, 2020). Notably, I4.0 offers provisions to assist and expedite the adoption of CEPs in which sustainability is the backbone of the manufacturing process (Dev et al., 2020; Khan, Johl, & Akhtar, 2021). The TBL perspective provides pathways that interconnect I4.0, CEP, and SDG12. From an economic standpoint, the adoption of I4.0 technologies can result in reduced setup and labor costs, streamlined lead times enhancing operational efficiency, and optimized resource utilization, thereby aligning with CEP (Sharma, Antony, & Tsagarakis, 2023). On an environmental front, I4.0 facilitates enhanced monitoring through smart manufacturing to reintroduce waste as a source leading to a diminished environmental impact, thus harmonizing with circular economy principles and sustainable production (de Sousa Jabbour et al., 2023; Sharma, Antony, & Tsagarakis, 2023). Socially, I4.0 contributes to predictive maintenance of the workforce and supply chain by extending data analytics and machine learning algorithms to minimize downtime and avoid unexpected breakdowns, thus aligning with the inclusive industrialization through democratic access to innovation as emphasized in SDG12 (Bai et al., 2022). Similarly, remanufacturing, recycling, reuse, and green purchasing play pivotal roles when a firm adopts the I4.0 framework (Sharma et al., 2021). These transformational technologies improve manufacturing efficiency, flexibility, and green production through real-time information capturing and sharing across the supply chain. They can also facilitate flexible production and customization, thereby better using existing resources and ultimately reducing resource wastage. Information automation positively affects the environment because it can help lower error rates and production faults, thereby reducing waste and increasing sustainable consumption (Santa-Maria et al., 2021). Furthermore, 3D printing and smart manufacturing enable collaboration and timely interaction among firms, stakeholders, and customers, thus ensuring optimized resource usage (Santa-Maria et al., 2021). Human–machine interactions can improve the disassembly process, ensuring closed-loop dynamics (Santa-Maria et al., 2021). Moreover, I4.0 eases a firm's reverse logistics process by integrating radio-frequency identification tags into remanufactured goods. Hence, the firm can better synchronize demand and lead times and ensure sustainable consumption. Accordingly, we propose the following hypotheses:

H3. The DII positively affects the adoption of CEPs.

H4. The DII positively affects the SDG12.

2.7.4 | Adoption of circular economy practices and sustainable development goals

It is noteworthy that CEPs work on the principle of opposition to an open-ended system to carefully use the resources at hand to avoid problems such as resource scarcity and waste disposal. Furthermore, CEPs are primarily an economic paradigm focused on the "waste cycle" (Santa-Maria et al., 2021). They are the only promising solutions to the complications arising from the ever-increasing resource demands worldwide, raw material shortages, and price volatility (Rodriguez-Anton et al., 2019). They also state that a firm should minimize and optimize resource exploitation. In particular, firms should move toward renewable resources by replacing non-renewable resources.

Furthermore, CEPs focus on not only reducing emissions and material residuals but also promoting component reuse to retain product value. Recent studies have reinforced the idea that the circular economy bridges the pathway for sustainable production and consumption (SDG12). Extending TBL perspective, the primary focus of the circular economy is on enhancing environmental and economic value, while sustainable development focuses more on environmental and social concerns. Hence, this bridge will benefit the present and future generations (Kirchherr & Piscicelli, 2019). Thus, we hypothesize the following:

H5. The adoption of CEPs positively impacts the SDGs.

2.8 | Serial mediation

A higher degree of diversification in search activities leads to greater exploration (Li et al., 2008). Furthermore, experimentation with novel, radical concepts can advance and broaden the realms of innovation to better assist new consumers. Exploitation is the deepening of technological capabilities, and it primarily involves not only refining and leveraging current knowledge but also concentrating on existing skills and capabilities (Li et al., 2008). Dynamic capabilities theory states that to be successful, firms must develop their capabilities to explore, exploit, and capture market opportunities (Agarwal & Selen, 2009). The ever-evolving consumer demand forces firms to be agile, resilient, innovative, and reactive. In the manufacturing sector where firms focus on the 10R CEPs and SDG12, the optimum utilization of resources is crucial. In order to leverage existing knowledge and capabilities, firms can harness extensive data generated from routine transactions, strategically applying these insights to optimize production lines through the adoption of I4.0 technologies, thereby contributing to the overarching goals of SDG12 related to sustainable consumption and production. Firms attempt to work in closed loops and follow reverse logistics practices to minimize waste. External stakeholders and most consumers are also sensitive to such demands and require strict regulations and policies to protect the environment. Hence, firms must develop such capabilities to survive. Notably, I4.0 can meet these demands by ensuring real-time information sharing and error-free automation to optimize resource utilization and reduce waste. In this context, expanding and developing these competencies and skills using I4.0 technologies deserve special attention. Hence, we propose the following hypotheses:

H6a. The DII and adoption of CEPs sequentially mediate the positive effect of the ERO strategy on the SDGs.

H6b. The DII and adoption of CEPs sequentially mediate the positive effect of the EPO strategy on the SDGs.

2.9 | Moderated sequential mediation

2.9.1 | I4.0 delivery system (IDS)

To ensure the seamless implementation of I4.0 technologies, an IDS must be developed. We focus on four critical dimensions, namely, "top management support," "training resources," "project resources," and "support of research institutes and universities," to help firms implement I4.0 technologies and move toward CEPs (Bag, Telukdarie, et al., 2021). The existing literature in the manufacturing domain highlights that a robust delivery system improves implementation (Bag, Telukdarie, 2021). Importantly, I4.0 is grounded in sustainability, technology, and organizational dynamics (Sharma et al., 2021; Sharma, Antony, & Tsagarakis, 2023). However, to the best of our knowledge, no study has provided empirical evidence on whether a better IDS can strengthen the impact of the ERO and EPO strategies on CEPs and SDGs via the DII. Hence, we posit as follows:

H7a. The IDS moderates the sequential indirect effect of the ERO strategy through the DII and adoption of CEPs on the SDGs.

H7b. The IDS moderates the sequential indirect effect of the EPO strategy through the DII and adoption of CEPs on the SDGs.

2.9.2 | Coercive pressure (CP)

Institutional theory underscores the isomorphic processes that compel individual organizations to emulate their counterpart. Extending this, CP originates from compelling pressure, including formal and informal communications and interactions as well as business dealings (Masocha & Fatoki, 2018). In addition, CP arises from the exchange relationships between a firm and its stakeholders, competitors, and resource-dominant firms, the latter of which must follow regulations to maintain their relationships and safeguard their survival (Chen et al., 2011). Firms generally depend on certain customers and suppliers. Chief supply chain partners may create inducements, and firms must follow such demands (Chen et al., 2011). Such partners have predetermined mandates that translate into CP, which may define the future course of action, whether related to setting standards or adopting future technology. Hence, CP plays a critical role in understanding the adoption and diffusion of technological innovations (Masocha & Fatoki, 2018). In the present context, firms either describe the surviving infrastructure incrementally or implement I4.0 technologies through radical revolution (Gupta et al., 2020). Thus, we posit the following hypotheses:

H8a. CP strengthens the positive indirect impact of the ERO strategy on the SDGs through the DII and adoption of CEPs.

H8b. CP strengthens the positive indirect impact of the EPO strategy on the SDGs through the DII and adoption of CEPs.

2.9.3 | Normative pressure (NP)

The second micro foundation of institutional theory constitutes NP which is primarily concerned with the professional values, norms, ethics, and standards imposed on stakeholders and customers in an industry (Liao, 2018). It focuses on the socialization of a firm by providing explicit societal legalization that guides or sometimes restricts its behavior in line with the established precedents, norms, principles, and expectations of external stakeholders, as well as ensuring conformity with institutional requirements (Hofman et al., 2020). If a firm repels NP, it may encounter problems with business deals, be removed from industry associations, or even suffer lower trading prospects (Liao, 2018). Hence, even without enforced laws and directives, NP has a bearing on a firm's environmental innovation (Liao, 2018). Norms and codes of conduct lead to a precise professional demeanor, especially among manufacturers (Gupta et al., 2020). This helps firms to abide by well-defined institutional norms. A normative environment helps firms build a digital supply chain under I4.0 (Bag, Telukdarie, et al., 2021). Hence, NP moderates the relationship between the ERO and EPO strategies and sustainable development through the implementation of I4.0 and the adoption of CEPs. Therefore, we propose as follows:

H9a. NP strengthens the positive indirect impact of the ERO strategy on the SDGs through the DII and adoption of CEPs.

H9b. NP strengthens the positive indirect impact of the EPO strategy on the SDGs through the DII and adoption of CEPs.

2.9.4 | Mimetic pressure (MP)

As posited by DiMaggio and Powell (1983), organizations tend to converge significantly due to the influence of rationalization driven by the nature of industry practices. Despite the intentions to instigate change, their efforts unintentionally contribute to the homogenization of organizations. For instance, a manufacturer might engage in collaborative ventures with research and development institutes to unearth innovative technological opportunities (Li et al., 2008). Moreover, firms can acquire new resources or knowledge by venturing into diverse areas. A firm may explore or exploit its resources, or gain new knowledge, thereby increasing its knowledge base. Its future course of activities is influenced by its generated knowledge. If a firm only attempts to imitate, MP, which is caused by uncertain conditions, especially when a firm attempts to replicate or imitate innovations or resources, is triggered. It occurs primarily when firms react to the stimuli imposed by internal and external environments and compete to enhance their performance (Latif et al., 2020). It also responds to competitors' activities and achievements. Since MP leads to the better implementation of new technologies in line with international demands or standards (Latif et al., 2020), it may lead to a sustainable environment. Hence, we propose the following hypotheses:

H10a. MP strengthens the positive indirect impact of the ERO strategy on the SDGs through the DII and adoption of CEPs.

H10b. MP strengthens the positive indirect impact of the EPO strategy on the SDGs through the DII and adoption of CEPs.

3 | RESEARCH METHODOLOGY

This section presents the variables employed and research design adopted in the study (refer to Figure 2), along with the techniques and tools used to interpret and analyze the gathered data.

3.1 | Modeling

To systematically explore the hypothesized relationships, conditional process modeling was conducted using the SPSS 26.0 preprogrammed PROCESS macro (Model 6 for the serial mediation, and Models 91 and 83 for the moderated serial mediation). PROCESS is chosen as an appropriate computational tool to examine the contingent nature of the underlying mechanisms because it simplifies the estimation of complex relationships by adopting a macro-analytical approach that tests a complete research model (Hayes, 2018) and generates a moderated mediation index for that model (Hayes, 2018).

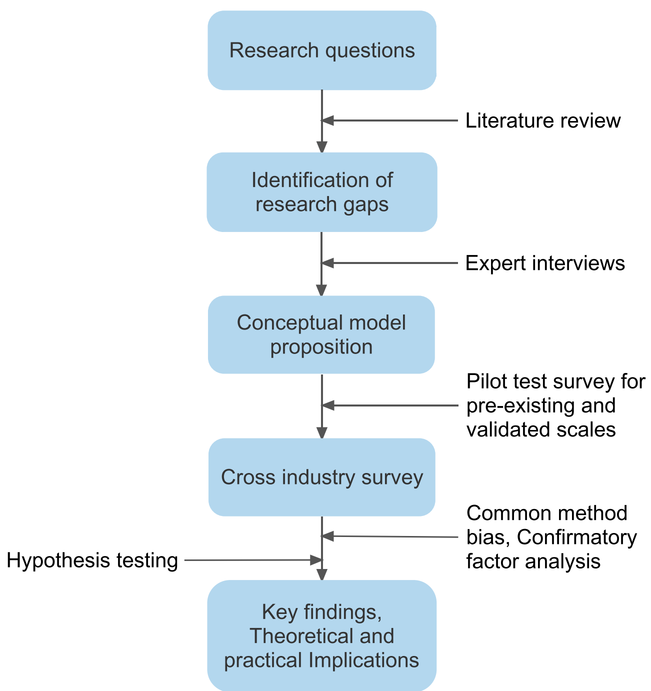

FIGURE 2 Research methodology.

Hence, the moderated mediation index is considered to be the most direct and comprehensive test of moderated mediation for this study (Nel & Boshoff, 2019).

3.2 | Survey measures and data collection

A survey questionnaire was designed based on the focal constructs by adapting pre-existing and validated scales from the seminal literature to the context of the current study. The abbreviations used for the focal constructs are presented in Table A1, and the scale items and their sources are described in Table A2. Our EPO and ERO measures were adapted from Tamayo-Torres et al. (2014) and contained six and five items, respectively. Our DII and IDS measures were taken from Bag, Telukdarie, et al. (2021). Furthermore, three items were adapted from Zeng et al. (2017) to measure the adoption of CEPs (CEP) and five items were adapted from Leal Filho et al. (2021) to assess the achievement of SDG12 (SDG). Finally, the multi-item scales used to measure MP, NP, and CP were adopted from Wang et al. (2019).

Although the study adopted pre-validated scales, a rigorous questionnaire development procedure was undertaken whereby the content validity of the survey instrument was examined (Jabeen et al., 2022). The questionnaire was sent to 35 executives working in digital supply chain and operations management. Based on their feedback, minor modifications were made to a few items to enhance the clarity of the statements in the final questionnaire. Furthermore, a pre-test was conducted with 60 industry practitioners working in the area of sustainable manufacturing through an online survey, which confirmed the reliability of the measurement constructs (Cronbach's alpha 0.801–0.911).

Finally, cross-sectional research was conducted by empirically analyzing the data collected through a cross-industry survey based in India by adopting purposive sampling, as there was no definite sampling frame (Kirchherr et al., 2017). The sample respondents were industry practitioners and professionals in digital supply chain and operations management. Executives and senior managers from manufacturers operating in the Baddi district of Uttarakhand and the Alwar district of Rajasthan were approached. Participating firms had to follow CEPs to achieve their sustainable production and consumption goals. A screening criterion was introduced to reach the target respondents who were asked if their organization took steps toward reducing, reusing, and recycling materials, waste, and by-products. This was in line with the European Academies' Science Advisory Council (2016), which reported that a company should be able to select and optimize its products and materials by reducing, reusing, and recycling them. This criterion helped us identify the target respondents, as per recent literature that avers circular economy includes 3R philosophy and demands industry to redesign its processes toward sustainability. A total of 710 responses were obtained from September to December 2022, whereof 480 were complete and retained for the analysis. Table A3 presents the respondents' sample characteristics.

3.3 | Common method bias

Before examining the validity and reliability of the constructs, the absence of common method bias was ensured by conducting Harman's single-factor test (Podsakoff et al., 2012). A single factor accounted for 28.75% of the variance, which was below the threshold of 50%. Hence, the analysis was not subject to the risk of common method bias.

4 | EMPIRICAL ANALYSIS AND RESULTS

This section discusses the results of the empirical model. The first subsection discusses the analysis of the measurement model, followed by three subsections that present the results of the hypothesis testing of the direct effects, serial mediation, and moderated serial mediation.

4.1 | Measurement model

Confirmatory factor analysis was used to examine the dimensionality of the observed measures and their corresponding constructs. The factor loadings of all the items were assessed. Among the 45 items, 39 demonstrated adequate loadings. The number of items was reduced (based on the lower factor loadings) by systematically dropping one item each from ERO, SDG, and MP, two from NP, and five from IDS. All the standardized factor loadings above the minimum value of 0.50 signified satisfactory construct validity. The reliability of the constructs was assessed using Cronbach's alpha values, which ranged from 0.765 to 0.978 (Table 1) (Nunnally, 1978).

Additionally, the composite reliability of each construct was appraised, and their values were above the threshold of 0.70 (Table 2) (Hair et al., 2010). Convergent validity was determined by observing the average variance extracted (AVE) values of each construct. The AVE values were above 0.50, hence confirming adequate convergent validity. The Fornell–Larcker criterion was adopted to test for discriminant validity. The square roots of the AVE values were compared with the inter-construct correlations. The observed AVE values were above the squares of the corresponding correlation coefficients, thus indicating discriminant validity. Finally, the goodness-of-fit indices were assessed to determine the fit of the measurement model: CMIN/DF = 1.543, incremental fit index = 0.965, normed fit index = 0.906, Tucker–Lewis index = 0.961, and comparative fit index = 0.965. In agreement with recent studies, all the observed values exceeded the cut-off of 0.90 (Hair et al., 2010).

4.2 | Hypotheses testing: the direct effect

This study implemented a moderated mediation approach in which Hayes' PROCESS macro (Models 6, 83, and 91) was used to

TABLE 1 Measurement properties, sources, and items.

Construct (source)	Items	Factor loadings	Cronbach's alpha
Exploitation orientation strategy (EPO) (Tamayo-Torres et al., 2014)	EPO1	0.665	0.869
	EPO2	0.788	
	EPO3	0.750	
	EPO4	0.689	
	EPO5	0.750	
	EPO6	0.701	
Exploration orientation strategy (ERO) (Tamayo-Torres et al., 2014)	ERO1	0.783	0.831
	ERO2	0.863	
	ERO3	0.654	
	ERO4	0.678	
Degree for I4.0 implementation (DII) (Bag, Telukdarie, et al., 2021)	DII1	0.790	0.875
	DII2	0.804	
	DII3	0.920	
Adoption of circular economy practices (CEPs) (Zeng et al., 2017)	CEP1	0.769	0.801
	CEP2	0.807	
	CEP3	0.702	
Sustainable Development Goals (SDGs) (Leal Filho et al., 2021)	SDG1	0.963	0.978
	SDG2	0.956	
	SDG3	0.962	
	SDG4	0.950	
I4.0 delivery system (IDS) (Bag, Telukdarie, et al., 2021)	IDS1	0.776	0.883
	IDS2	0.770	
	IDS3	0.769	
	IDS4	0.688	
	IDS5	0.694	
	IDS6	0.672	
	IDS7	0.684	
Mimetic pressure (MP) (Wang et al., 2019)	MP1	0.779	0.765
	MP2	0.782	
	MP3	0.615	
Normative pressure (NP) (Wang et al., 2019)	NP1	0.789	0.912
	NP2	0.839	
	NP3	0.789	
Coercive pressure (CP) (Wang et al., 2019)	CP1	0.769	0.886
	CP2	0.758	
	CP3	0.718	
	CP4	0.777	
	CP5	0.740	
	CP6	0.747	

test the proposed hypotheses (Hayes, 2018). Overall, the model's predictive accuracy was satisfactory, as the total variance explained (R^2) was 56% for SDG (Das et al., 2022; Singh et al., 2024). As depicted in Table 3, the analysis revealed the significant positive effects of ERO on DII ($\beta = 0.307$, $p < .001$), EPO on DII ($\beta = 0.298$, $p < .001$), DII on CEP ($\beta = 0.568$, $p < .001$), CEP on SDG ($\beta = 0.352$, $p < 0.001$), and DII on SDG ($\beta = 0.493$, $p < 0.001$). Thus, H1–H5 were supported. Furthermore, firm size and firm age were controlled for to test their confounding effects on SDG, as operating years and number of employees can enhance the ability of firms to improve productivity (Bag, Gupta, & Kumar, 2021). The results demonstrated no evidence of statistically significant confounding effects on the outcome variable, SDG.

TABLE 2 Validity and composite reliability measures.

	CR	AVE	SDG	EPO	CP	DII	ERO	CEP	IDS	MP	NP
SDG	0.978	0.917	**0.958**								
EPO	0.869	0.526	−0.084	**0.725**							
CP	0.886	0.565	−0.090	0.311	**0.752**						
DII	0.877	0.706	−0.050	−0.024	0.020	**0.840**					
ERO	0.835	0.561	−0.028	0.219	0.433	0.031	**0.749**				
CEP	0.804	0.578	−0.095	0.258	0.443	−0.017	0.441	**0.761**			
IDS	0.884	0.523	−0.080	−0.009	0.010	0.030	0.017	0.045	**0.723**		
MP	0.771	0.532	0.041	−0.019	−0.128	−0.046	−0.058	−0.111	−0.042	**0.730**	
NP	0.872	0.629	0.006	0.114	0.129	−0.074	0.039	0.103	0.058	−0.055	**0.793**

Note: The square root of the AVE value is shown on the diagonal of the matrix (bold), and the items below the bold elements exhibit the squared correlation values.
Abbreviations: AVE, average variance extracted; CR, composite reliability.

TABLE 3 Results of the main effects.

Causal relationship	Beta (β) coefficient	SE	****p*	LL 95% CI	UL 95% CI	Result	Hypothesis
ERO → DII	.5102	.0423	.0000	.4272	.5932	Significant	H1 supported
EPO → DII	.5133	.0411	.0000	.4325	.5942	Significant	H2 supported
DII → CEP	.3491	.0375	.0000	.2754	.4228	Significant	H3 supported
DII → SDG	.4612	.0369	.0000	.3887	.5337	Significant	H4 supported
CEP → SDG	.3520	.0370	.0000	.2074	.3704	Significant	H5 supported

Note: 95% CI = lower/upper limit of the 95% percentile bootstrap confidence interval with 5000 samples.
$^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$.

4.3 | Hypotheses testing: serial mediation

To test the hypotheses of the serial mediation, the PROCESS macro (Hayes, 2018) Model 6 was used, and the 95% bias-corrected bootstrapping procedure with 5000 samples was applied. The model tested whether DII and CEP serially mediated the causal effects of EPO and ERO on SDG, as shown in Figure A1a. With regard to the predictor variable ERO, the direct and indirect effects of the first mediator, DII, and the second mediator, CEP, on SDG are reported in Table 4. The direct effect ($\beta = -0.0771$, 95% CI [−0.2085; 0.0542]) was not significant, whereas the indirect effect ($\beta = 0.0378$, 95% CI [0.0223, 0.0562]) was statistically significant, indicating a full mediating effect. Hence, DII and CEP sequentially mediate the effect of ERO on SDG. Therefore, H6a was supported. Furthermore, for the predictor variable EPO, the direct and indirect effects of DII and CEP on SDG, direct effect ($\beta = 0.1474$, 95% CI [0.0718; 0.2231]) and indirect effect ($\beta = 0.0491$, 95% CI [0.0307; 0.0711]), were statistically significant, thereby presenting evidence of partial mediation and supporting H6b.

4.4 | Hypotheses testing: moderated serial mediation

To investigate the conditional moderating effects of IDS proposed in H7a and H7b, two moderated sequential mediation models were tested for the two independent variables (EPO and ERO) using PROCESS macro Model 91 (Hayes, 2018), as shown in Figure A1b. ERO was defined as the predictor variable, DII as the first mediator, CEP as the second mediator, and SDG as the dependent variable, while IDS was introduced as a moderator affecting the relationship between DII and CEP. A similar approach was adopted, with EPO as the predictor variable (Table 5). The bootstrapping results demonstrated a significant moderated sequential mediation for ERO (Index = 0.0091; 95% CI [0.0013; 0.0180]). Specifically, the effect of ERO on SDG, sequentially mediated by DII and CEP, was significantly stronger at high levels of IDS ($\beta = 0.0472$; 95% CI [0.0278; 0.0703]) than in the low IDS condition ($\beta = 0.0291$; 95% CI [0.0147; 0.0476]). Hence, H7a was supported. Using EPO as the independent variable, the sequentially mediated effect on SDG was also significant at both IDS levels. The results indicated that the effect of EPO on SDG was significantly stronger at high IDS levels ($\beta = 0.0588$; 95% CI [0.0361; 0.0857]) than at low IDS levels ($\beta = 0.0386$; 95% CI [0.0013; 0.0204]). Furthermore, the overall moderated mediation index was also significant (Index = 0.0102; 95% CI [0.0013; 0.0204]). Hence, H7b was supported.

Furthermore, the conditional moderating effects of CP, NP, and MP, proposed in H8a, H8b, H9a, H9b, H10a, and H10b, were investigated by testing six moderated serial mediation models for the two independent variables, EPO and ERO, using PROCESS macro Model 83 (Hayes, 2018; Nel & Boshoff, 2019), as shown in Figure A1c. The

TABLE 4 Results of the serial mediation analysis (first mediator: DII, second mediator: CEP) (PROCESS macro Model 6).

Predictor variable	Path associations	β	SE	LL 95% CI	UL 95% CI	Hypothesis
ERO	ERO → SDG (direct effect)	−0.0771	0.0668	−0.2085	0.0542	H6a supported (full mediation)
	ERO → DII → CEP → SDG (indirect effect)	0.0378**	0.0087	0.0223	0.0562	
EPO	EPO → SDG (direct effect)	0.1474	0.0385	0.0718	0.2231	H6b supported (partial mediation)
	EPO → DII → CEP → SDG (indirect effect)	0.0491***	0.0102	0.0307	0.0711	

Note: bootstrap sample size = 5000.
Abbreviations: CI, confidence interval; LL, lower limit; SE, standard error; UL, upper limit; β = beta.
**p* < 0.05, ***p* < 0.01, and ****p* < 0.001.

result showed that for the predictor variable ERO (Table 5), there was no evidence of any moderated mediating effect in the presence of CP (Index = 0.0004; 95% CI [−0.051; 0.0069]), NP (Index = 0.0001; 95% CI [−0.0045; 0.0059]), and MP (Index = 0.0019; 95% CI [−0.0048; 0.0089]). Hence, H8a, H9a, and H10a were not supported. When EPO was used as the predictor variable, there was also no evidence of any moderated mediating effect in the presence of CP (Index = 0.0016; 95% CI [−0.0051; 0.0099]) or NP (Index = −0.0020; 95% CI [−0.0081; 0.0045]). Hence, H8b and H9b were not supported. However, the results indicated that MP strengthened the positive indirect relationship between EPO and SDG via DII and CEP, as the overall moderated mediation index was significant (Index = 0.0122; 95% CI [0.0039; 0.0226]). Hence, H10b was supported. The results indicated that the effect of EPO on SDG was significantly stronger at high MP levels (β = 0.0632; 95% CI [0.0489; 0.0050]) than at low MP levels (β = 0.0389; 95% CI [0.0228; 0.0582]).

5 | DISCUSSION

The manufacturing sector contributes significantly to the global economy (Sharma, Antony, & Tsagarakis, 2023) by providing low-cost mass production and generating jobs, while simultaneously being accountable for mounting environmental distress (Sahu et al., 2022). Firms must re-evaluate their policies and practices to not only survive in this context but also gain competitiveness in the long run because stakeholders and consumers are conscious of protecting the environment (Aftab et al., 2022). Procuring and deploying technical resources can prepare a manufacturer for a digital future; however, it also involves critical concerns such as training existing human resources and restructuring business developments that demand initiatives from top management.

This empirical study offers thought-provoking findings that bridge the gap between theory and practice by demonstrating that enhancing dynamic capabilities through the implementation of I4.0 triggers CEPs in the value chain, thereby achieving SDG12. Furthermore, I4.0 technologies allow for real-time coordination and collaboration to devise better control mechanisms and lower error rates, thus ensuring that resources are used carefully with little or no waste. In addition, I4.0 enables quick communication among machines and between humans and machines. It provides the ability to make informed decisions by analyzing the enormous volume, variety, veracity, value, variability, and visualization of data.

This study attempts to answer four critical research questions, as stated earlier. To answer the first research question, we proposed H1 and H2. The analysis showed that both hypotheses were supported. The results imply that to move toward industrial digitalization, firms must perform distant as well as near search tasks and try to understand and respond to market needs. This strategy enables firms to make informed decisions based on data. Furthermore, automation increases the speed and ease of conducting business. It also reduces operating and capital expenditures, thereby increasing stakeholder and job satisfaction.

To answer the second research question, we proposed three hypotheses (H3, H4, and H5), which were also significant. Notably, I4.0 offers front-end and base technologies for smoother industrialization. Moreover, such technologies enable firms to improve their efficiency, performance, and business strategies (Huang et al., 2022) by encouraging them to follow reverse logistics and closed-loop practices. Technology can be categorized into three maturity levels for sustainable practices: standard, variety, and diverse. Standard technology is accessible and commonly used in recycling and waste management practices. Variety indicates that different categories of technology are available for waste collection, transportation, and treatment. Diverse technology is used for sustainability practices and is a diverse, definite, and exclusive technology (Fatimah et al., 2020) that helps attain the SDGs, whereby SDG12 focuses on decreasing toxic waste, radiation, and waste through sustainable procurement and via CEPs such as refurbishing, recycling, remanufacturing, and reuse.

To answer the third research question, we tested six moderated mediations to investigate whether NP, CP, and MP strengthened the positive indirect impact of the ERO and EPO strategies on the SDGs through the DII and adoption of CEPs. Of these, we found that H10b was significant. Institutional theory has been extensively applied to

TABLE 5 Results of the moderated serial mediation through DII and CEP (PROCESS macro Model 91 in which IDS is the moderator and Model 83 in which NP, MP, and CP are the moderators).

Path associations	Level of IDS	β	SE	LL 95% CI	UL 95% CI	Conditional indirect effect	Hypothesis
Moderated serial mediation analysis for IDS as moderator through DII and CEP (Model 91 of the PROCESS macro)							
ERO → DII → CEP → SDG	High (+1SD)	0.0472	0.0108	0.0278	0.0703	Significant	H7a supported
	Low (−1SD)	0.0291	0.0084	0.0147	0.0476		
Index of moderated mediation	Index = 0.0091		0.0042	0.0013	0.0180		
EPO → DII → CEP → SDG	High (+1SD)	0.0588	0.0129	0.0361	0.0857	Significant	H7b supported
	Low (−1SD)	0.0386	0.0094	0.0218	0.0577		
Index of moderated mediation	Index = 0.0102		0.0049	0.0013	0.0204		
Moderated serial mediation analysis for CP as moderator through DII and CEP (Model 83 of the PROCESS macro)							
ERO → DII → CEP → SDG	High (+1SD)	0.0296	0.0082	0.0157	0.0477	Insignificant	H8a not supported
	Low (−1SD)	0.287	0.0074	−0.0160	0.0448		
Index of moderated mediation	Index = 0.0004		0.0030	−0.051	0.0069		
EPO → DII → CEP → SDG	High (+1SD)	0.0426	0.0106	0.0242	0.0658	Insignificant	H8b not supported
	Low (−1SD)	0.0394	0.0103	−0.0212	0.0185		
Index of moderated mediation	Index = 0.0016		0.0038	−0.0051	0.0099		
Moderated serial mediation analysis for NP as moderator through DII and CEP (Model 83 of the PROCESS macro)							
ERO → DII → CEP → SDG	High (+1SD)	0.0265	0.0075	−0.0141	0.0436	Insignificant	H9a not supported
	Low (−1SD)	0.262	0.0068	0.0142	0.0410		
Index of moderated mediation	Index = 0.0001		0.0026	−0.0045	0.0059		
EPO → DII → CEP → SDG	High (+1SD)	0.0420	0.0135	−0.0216	0.0749	Insignificant	H9b not supported
	Low (−1SD)	0.0460	0.0142	−0.0236	0.0795		
Index of moderated mediation	Index = −0.0020		0.0032	−0.0081	0.0045		
Moderated serial mediation analysis for MP as moderator through DII and CEP (Model 83 of the PROCESS macro)							
ERO → DII → CEP → SDG	High (+1SD)	0.0397	0.0096	−0.0226	0.0601	Insignificant	H10a not supported
	Low (−1SD)	0.0359	0.0087	0.0208	0.0548		
Index of moderated mediation	Index = 0.0019		0.0033	−0.0048	0.0089		
EPO → DII → CEP → SDG	High (+1SD)	0.0632	0.0136	0.0489	0.0050	Significant	H10b supported
	Low (−1SD)	0.0389	0.0091	0.0228	0.0582		
Index of moderated mediation	Index = 0.0122		0.0047	0.0039	0.0226		

Note: bootstrap sample size = 5000.
Abbreviations: CI, confidence interval; LL, lower limit; ns = not significant; SE, standard error; UL, upper limit; β = beta.
*p < 0.05. **p < 0.01. ***p < 0.001.

examine environmentally friendly behaviors. Institutional pressure drives firms to embrace shared ideas and procedures. The government's strategic plans, competitors' moves, industry alliances, media, and local communities can drive organizations to integrate elements of sustainability into their supply chains (Ali et al., 2023; Rentzelas et al., 2020).

In India, societal norms and professional policies do not play a significant role when a firm attempts to implement innovative technologies. In this country, dominant firms design and implement procedures, policies, and sanctions that then serve to guide other firms and stakeholders. Firms that lack a clear strategy tend to follow the more successful firms in their respective sectors. Furthermore, a firm may attempt to imitate any resource to survive or gain a competitive advantage in uncertain environments, thereby facing MP. We find that most firms are pushed to explore and invest in I4.0 in an environment characterized by MP because innovative firms are more successful and become frontrunners, whereas other firms then attempt to mimic their functioning to succeed. This finding contradicts those of Gupta et al. (2020), who highlight that while implementing I4.0 or any digital initiative, especially in the supply chain context, MP and NP do not have an influence during the initial stages. However, our work highlights that to survive during its initial years, when a firm does not have digital supremacy, MP pushes it and its stakeholders to abide by the prevailing rules, policies, and procedures.

To answer the last research question, we proposed two hypotheses, H7a and H7b, both of which were significant. We argue that I4.0 technologies help integrate CEPs, which eventually improve performance (Sahu et al., 2022). As I4.0 technologies use resources effectively and efficiently, energy consumption is minimized, thus creating opportunities for sustainable manufacturing in a firm's value chain (Kayikci et al., 2022; Martelli & Hayirli, 2018). Our work emphasizes that to have a seamless experience with the latest technologies, manufacturers must have a robust IDS. This system requires support and continuous monitoring by both top management and stakeholders. A firm pursues the ERO and EPO strategies in an uncertain environment and under resource constraints. Meanwhile, I4.0 technologies can help with this because their primary focus is to procure and use resources carefully. Thus, firms must develop market-oriented capabilities to use both the EPO and ERO strategies in dynamic markets, when faced with fierce rivalries, and under rapid technological obsolescence (Sahi et al., 2020). Hence, connecting the IDS to the production system reduces the inputs exploited, which subsequently improves quality of life and resource use efficiency (Huang et al., 2022).

5.1 | Theoretical implications

The findings of this study have several theoretical implications. The convergence of sustainability and I4.0 technologies is based on how firms design their internal and external processes in alignment with sustainable innovation. Building on the foundations of dynamic capabilities theory, institutional theory, and the TBL perspective, this study integrates I4.0 and SDG12. Additionally, no prior research has empirically investigated the process through which I4. can strategically lead to the achievement of SDG12 in emerging nations. Moreover, the present study bridges a significant gap in sustainability research on the implementation of I4.0 by considering the effects of three types of institutional pressure. To ensure methodological rigor, this study presents an exhaustive framework that links the four causal relationships through a linear mechanism by adopting a cross-sectional survey design. The analysis shows that MP moderates the relationship between dynamic capabilities and I4.0, whereas the IDS moderates the association between the DII and CEPs. Previous research has shown that adopting both the ERO and EPO strategies simultaneously may lower complexity (Gupta et al., 2020). In this study, we investigate not only the ERO strategies that emphasize novel technologies and innovations but also the EPO strategies that focus on the transformation of the current workforce and its prevailing skills. The direct and indirect effect of EPO reinforces that dynamic capabilities theory is relevant to innovation-based competitive ecosystems as it can reveal how and why firms succeed and fail in the wake of I4.0. Through active participation of strategic management in acquiring, collating, and modifying an organization's internal and external functional capabilities, the findings further extend dynamic capabilities theory to showcase the trajectory that warrants firms to engage in explorative as well as a range of competence-enhancing exploitative actions to realize SDG12 through I4.0 and CEP. However, the partial complementary mediation for the EPO strategies found in this study suggests that an omitted mediator could explain the direct path, which could be pursued in future research (Zhao et al., 2010). Future research could also build on this framework and search for other mediators that could lead to the development goals.

Further, the significant moderating effect of MP provides robust empirical evidence to extend institutional theory to the fourth industrial revolution where firms embrace I4.0 as an intra- and inter-firm enabling mechanism to achieve SDG12 to derive from uncertainty. Finally, serial mediations support the causal chain of associations, delineating a clear pathway through which I4.0 technologies can reshape the evolving paradigm of the industrial ecosystem toward SDG12. Within the purview of the TBL perspective, the findings demonstrate its significance for firms embracing I4.0 with an aim to adopt CEP. This strategic alignment extends beyond mere technological advancement, translating into tangible effects that effectively address economic, environmental, and social dimensions. Consequently, this concerted approach contributes substantially to the overarching goals of sustainable consumption, production, and industrialization as delineated in SDG12. The findings contextualize the TBL perspective to indicate that I4.0 through the best combination of tools, technologies, and processes can help a firm achieve its vision of digital industrialization with sustainable procurement and resource usage and concurrently contribute to the sustainable development of society.

5.2 | Practical implications

This empirical study also has several critical practical implications. First, the analysis indicates that the orientation of the strategy pursued to develop firms' dynamic capabilities to adopt I4.0 is important. In today's dynamic business environment, firms should invest in ERO strategies to create new niches and develop new products and/or technologies. Furthermore, when striving for efficiency and increasing process reliability and accuracy, enhancing workers' skills should be the prime area of focus under exploitative measures when adopting I4.0 (Sharma, Raut, et al., 2023). Under EPO strategies, firms may develop greater routing flexibility by creating alternative sustainable paths in their production systems for manufacturing a specific variety of products. Overall, stakeholders must strike a balance between the

ERO and EPO strategies by considering geography-, sector-, and industry-specific characteristics.

Second, MP moderates the relationship between exploiting existing competencies and adopting I4.0 technologies. This relationship emphasizes the critical role of firms' imitative behavior (i.e., copying the successful actions of competitors) in emerging economies. Hence, governments should provide firms with conducive ecosystems by formulating appropriate legal frameworks to not only penalize non-adopters but also incentivize adopters of novel technologies. Firms devising appropriate EPO strategies should consider establishing cooperative agreements with their superior counterparts to engage in effective learning processes. As the proposed research framework highlights the interactions among I4.0, CEPs, and the SDGs, it is logical for policymakers to focus on creating the right competition by attracting foreign-owned subsidiaries of multinational companies to stimulate superior performance in local organizations.

Third, this research provides empirical evidence that I4.0 makes a firm more sustainable because disruptive technologies help it reduce waste, close the loop, engage in sustainable procurement, and improve resource utilization. It is important to understand the implications of I4.0 on sustainability efforts when implementing changes. While I4.0 technologies have the potential to improve efficiency and productivity, they may also damage the environment if not implemented thoughtfully. Hence, considering the lifecycle of products and processes is crucial when adopting I4.0 technologies, including those pertaining to the energy and resource inputs required for production and end-of-life disposal processes. In addition, practitioners should prioritize the use of renewable energy sources and sustainable materials during their operations. This provides a clear picture that I4.0 will not only make a firm a digital native but also make it ready to face critical resource scarcity in the future. Firms should use I4.0 technologies to align with established norms and formulate a novel strategic direction that fosters sustainability and CEPs using digital technologies for data governance, real-time information sharing, and enhanced traceability in supply chains. However, leveraging the effects of CEPs through I4.0, where business models can be structured around the digitalization of a product like a service, can be a game changer (Nica et al., 2020). Companies or consumers should only pay for the services they use without owning the product, thereby promoting a sharing economy. Furthermore, states in alliances with industrial bodies should aim to benchmark recycling rates to enable firms to conduct lifecycle assessments of their products. As the initial costs of implementing CEPs are considerable, resulting in supply chain complexity, business-to-business cooperation and adequate information sharing through I4.0 technologies are mandatory to bridge the existing skill gaps and design advanced manufacturing systems.

Fourth, I4.0 technologies such as 3D printing, blockchain for authentication, and fraud detection should be embraced by firms to ensure the standardization and easy traceability of processes and operations. Testing beta prototypes in smaller batches and using distributed and collaborative computer-aided design could lead to the better creation, adaptation, and optimization of a design; decrease resource wastage; and devise more precise responses to demand changes. Finally, as SDG12 also reflects the consumption choices of consumers, international agencies, the state legislature, consumer groups, and social economy organizations should work together to inspire and propose new consumption and behavioral patterns by ensuring consumers' rights. Consumers should be encouraged to change by implementing rights awareness programs and structured educational frameworks as well as by including sustainable consumption within consumer policies. The government should give a voice to consumers by treating them as equal allies in the sustainable innovation paradigm in which the industry can find coherent ways to reuse waste as a valuable economic resource. All these actions would help enterprises and societies embrace the transformation from the "make/use-it-once" and "sell/throw-it away" mentality of linear business models to the holistic circular economy model that can accomplish SDG12.

5.3 | Implications for policy

The study offers critical implications for policymakers, regulatory bodies, and sustainable governance authorities. As both exploitation- and exploration-oriented strategies are crucial for the realization of SDG12, government should implement comprehensive skill development programs that focus on advancing existing skills and developing new skills through policies specifically geared toward enhancing the degree of I4.0 implementation. This will ensure a workforce adept in a spectrum of competencies crucial for I4.0. From a policy intervention perspective, this can involve ensuring that plants, divisions, and functional levels across different geographical regions possess the capability to apply I4.0 technologies. Further, in order to strengthen I4.0 delivery systems, measures like promoting top management support, realistic implementation schedules, and collaboration with research institutes and universities should be promoted by offering incentives and support programs. Further, to encourage firms to implement a strategic orientation toward embracing circular economy practices and SDG12, policymakers must understand the firm's specific motivations rather than focusing only on regulatory mechanisms (Liu et al., 2020). In line with the findings, policymakers should be mindful of mimetic pressures within industries. They should aim to foster a competitive environment where adopting certain supply chain management practices is positively perceived, thus encouraging organizations to emulate successful competitors. Hence, there is a need to develop a regulatory framework that addresses mimetic pressures in supply chain management by involving guidelines for effective downstream value recovery process, fair competition through ethical practices, and transparent communication nurturing a business environment where companies are recognized for working toward SDG12. As Sawe et al. (2021) suggested, adopting CEP necessitates a cultural transformation in business models. This transformation underscores the importance of policymakers facilitating comprehensive training programs in green project management. Furthermore, the concerted efforts of local governments and environmental authorities are crucial in elevating organizations' environmental consciousness. Notably, this implies that policymakers must recognize the impact of cultural values and societal beliefs as effective tools for promoting SDG12. To steer the discourse away from the traditional open-loop model, active involvement of marketplace stakeholders, suppliers, and distributors becomes imperative for successfully adopting CEP and realizing SDG12 objectives (Camilleri, 2019). Finally, from the perspective of demand side mechanism, soft policy measures like launching extensive consumer education campaigns highlighting the importance of responsible consumption to educate consumers are more likely to support businesses that adhere to sustainable practices (Dhanda et al., 2022). These policy implications collectively aim to create an ecosystem that supports the adoption of advanced technologies, circular economy practices, and innovation that contribute to the realization of SDG12.

6 | CONCLUSIONS

Dynamic capabilities are grounded in strategic management and market positioning. Dynamic capabilities theory helps a firm advance by enabling it to choose suitable options in response to internal or external events. Firms can either update their current capabilities or transform and explore new resources. Some firms perform both actions but on specific activities, such as updating the existing workforce by providing training and transforming the digital space by moving toward I4.0. To accomplish such initiatives, a firm first checks the compatibility of the prevailing organizational and industrial infrastructure as well as the extent to which it can create supply chain competence. Adopting I4.0 transcends digital proficiency; rather, it entails securing a sustainable future in the face of limited resources. Companies must prioritize sustainability and adopt I4.0 to align themselves with best practices to enhance supply chain traceability and streamline their operations. Incorporating I4.0 principles into CEPs can strategically position organizations at the forefront of innovation while implementing advanced techniques in reverse logistics and the comprehensive 6R framework, comprising reduction, recycling, redesign, renovation, recovery, and reevaluation, for enhanced sustainability and operational efficiency. This approach should allow companies to structure their offerings around digital products, thereby making them more ubiquitous, accessible, and affordable through effective resource utilization.

Henceforth, this study makes significant contributions by offering a holistic understanding of the interconnected dynamics among I4.0, CE, and SDG12. It integrates dynamic capabilities theory, triple bottom line perspective, and institutional theory to establish a robust conceptual framework elucidating causal relationships. The empirical findings bridge the gap between theory and practice by showcasing that firms through exploitative and exploratory-oriented strategies can enhance the degree of I4.0 implementation to foster CEPs, which in turn facilitates the realization of SDG12 as I4.0 technologies enhance real-time coordination, robust control mechanisms, and precision in resource utilization, minimizing errors and waste. Notably, the study introduces a novel perspective on the moderating impact of mimetic pressure, particularly in emerging economies, contributing to the discourse on sustainable practices and strategic decision-making. Overall, the research offers insightful implications for organizations navigating the intersection of technology, sustainability, and circular practices.

7 | LIMITATIONS AND FUTURE RESEARCH AVENUES

The present work makes numerous significant theoretical and managerial contributions that should be considered in light of its limitations. Our work used a sample from India; hence, its findings cannot be generalized to all developed economies or other developing economies, such as China, where manufacturing supply chain issues are more alarming. In addition, although a large sample was used, covering many and the most important industries, there may be variations from some minor industries not represented in our sample. However, this opens up future research avenues for scholars to explore the same or similar frameworks in developing-country settings. Second, while this work concentrated on SDG12, I4.0 could also help achieve other SDGs. Hence, future studies could explore these SGDs in detail. Third, this work could use longitudinal data to investigate different sectors and regions to be better able to generalize the results.

ORCID

Mahak Sharma https://orcid.org/0000-0001-9457-9292

Konstantinos Tsagarakis https://orcid.org/0000-0003-4340-6118

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APPENDIX A

This appendix includes Table A1 with a list of abbreviations. Table A2 presents in detail the constructs, their sources, and items. Table A3 presents the respondents' sample identities. Figure A1 illustrates the nested mediation and moderated mediation models. Figure A1a illustrates Model 6 of PROCESS macro, where serial mediation is shown between the predictor variables (EPO and ERO) and the outcome variable (SDG) through DII and CEP. Figure A1a elucidates Model 91, where nested mediation for moderated serial mediation through DII and CEP is shown for IDS as the moderating variable for the relationship between the predictor variables (EPO and ERO) and the outcome variable (SDG). Finally, Figure 1c explicates Model 91 of the PROCESS macro, where nested mediation for moderated serial mediation is highlighted, and the moderating variable constitutes the different institutional pressures (CP, MP, and NP) affecting the relationship between the predictor variables (EPO and ERO) and the outcome variable (SDG) through DII and CEP.

TABLE A1 List of abbreviations.

Abbreviations	Terminologies
EPO	Exploitation orientation strategy
ERO	Exploration orientation strategy
DII	Degree for I4.0 implementation
CEP	Adoption of circular economy practices
SDG	Sustainable development goals
IDS	I4.0 delivery system
MP	Mimetic pressure
NP	Normative pressure
CP	Coercive pressure
DCT	Dynamic capabilities theory
TBL	Triple bottom line

TABLE A2 Constructs, their sources, and items.

Construct (source)	Items
Exploitation orientation strategy (EPO) (Tamayo-Torres et al., 2014)	EPO1: Our firm develops activities of which a lot of experience has been accumulated by the stakeholder or person concerned EPO2: Our firm develops activities that serve existing (internal) customers with existing services/products EPO3: Our firm develop activities of which it is clear to us how to conduct them EPO4: Our firm develops activities primarily focused on achieving short-term goals EPO5: Our firm develops activities that we can properly conduct by using our existing knowledge EPO6: Our firm develops activities that clearly fit into existing company policies
Exploration orientation strategy (ERO) (Tamayo-Torres et al., 2014)	ERO1: Our activities search for new possibilities with respect to products/services, processes, or markets ERO2: Our activities aim to evaluate diverse options with respect to products/services, processes, or markets ERO3: Our activities focus on strong renewal of products/services or processes ERO4: Our activities require you to learn new skills or knowledge
Degree for I4.0 implementation (DII) (Bag, Gupta, & Kumar, 2021)	DII1: All our plants located across different geographical regions have the capability to apply Industry 4.0 front-end technologies and base technologies DII2: All divisions in our organization have the capability to apply Industry 4.0 front-end technologies and base technologies DII3: Our firm has the capability to apply Industry 4.0 front-end technologies and base technologies at the functional level
Adoption of circular economy practices (CEP) (Zeng et al., 2017)	CEP1: Our firm has the ability to provide circular economy-friendly products to suppliers for sustainable consumption and production CEP2: Our firm helps existing suppliers establish rules and regulations related to circular economy principles for sustainable consumption and production CEP3: Our firm cooperates with suppliers to technically reduce the environmental, social, and economic impact toward sustainable consumption and production
Sustainable Development Goals (SDG) (Leal Filho et al., 2021)	SDG1: How would you rate the degree of awareness about the SDG12 on your firm/company? SDG2: How would you characterize the current focus on the SDG12 as part of the firm/company operations? SDG3: How would you characterize the current firm focus on the SDG12 as part of the following areas of action: Research, training, and extension (3rd mission) SDG4: How would you rate the institutional focus currently given to the implementation of SDG12?
I4.0 delivery system (IDS) (Bag, Gupta, & Kumar, 2021)	IDS1: Top management support in the Industry 4.0 project is high IDS2: Top management shows a lot of interest in the Industry 4.0 project IDS3: Time and resources are invested in training manpower for using Industry 4.0 techniques IDS4: Internal users are provided with proper on-the-job training to apply industry 4.0 systems IDS5: Experienced and capable project managers are in charge of the Industry 4.0 project team IDS6: The Industry 4.0 implementation schedule is logical and realistic IDS7: Collaboration between research institutes and universities for Industry 4.0 projects will be useful for developing social relationships
Mimetic pressure (MP) (Wang et al., 2019)	MP1: Our main competitors who have adopted supply chain management practices have greatly benefitted MP2: Our main competitors who have adopted supply chain management practices are favorably perceived by others within the same industry MP3: Our main competitors who have adopted supply chain management practices are favorably perceived by the customers
Normative pressure (NP) (Wang et al., 2019)	NP1: The extent to which our firm's customers have adopted sustainable supply chain management practices NP2: The extent to which suppliers of our firm have adopted supply chain management practices NP3: The extent to which professional bodies have influenced our organization for sustainable supply chain management
Coercive pressure (CP) (Wang et al., 2019)	CP1: State government requires our firm for sustainable supply chain management CP2: The industry association requires our firm for sustainable supply chain management CP3: Our firm's main customers that matter to us believe that our firm should work toward sustainable supply chain management

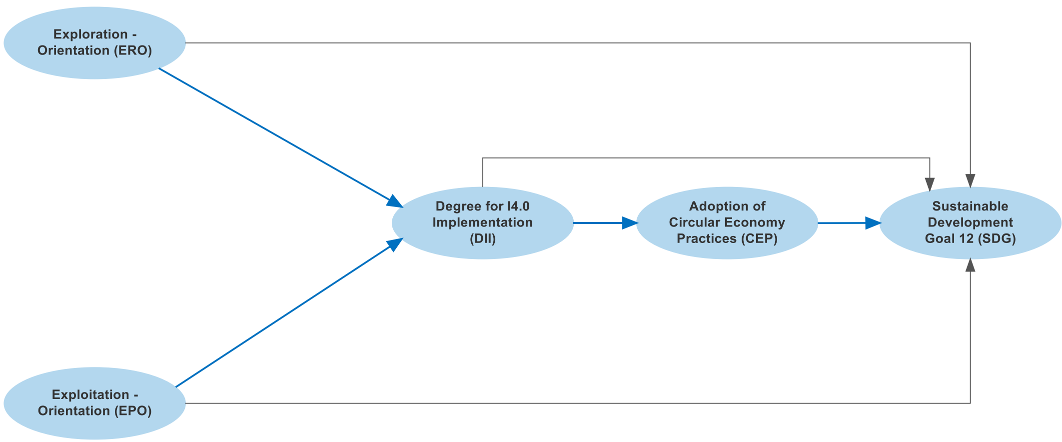
(Continues)

TABLE A2 (Continued)

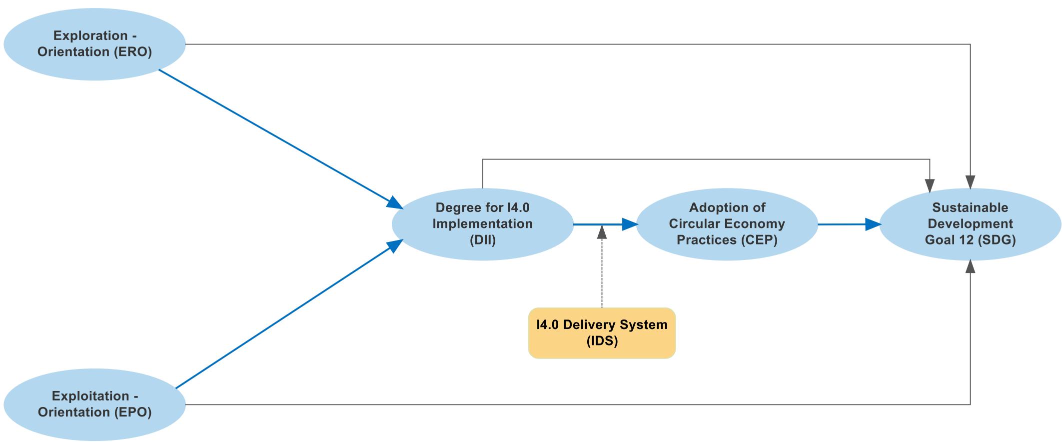
Construct (source)	Items
	CP4: Our firm's main suppliers that matter to us believe that our firm should work toward sustainable supply chain management
	CP5: Our firm may not retain important customers who do not believe in sustainable practices.
	CP6: Our firm's main suppliers may not support us if our firm does not work toward sustainable supply chain management

TABLE A3 Sample characteristics.

Industry	N	%	Size of company	N	%
Pharmaceutical	76	15.84	Small and medium	310	64.58
Electronics	64	13.33	Large	170	35.42
Steel	58	12.08	**Total**	**480**	**100**
Automotive	56	11.66	**Respondents profile**	**N**	**%**
Construction	54	11.25	Supervisors	162	33.75
Metal	30	6.25	Executives	135	28.12
Energy	29	6.05	Senior managers/managers	130	27.09
Chemicals	25	5.20	Area heads/vice president/ president	30	6.26
Software and technology	25	5.20	Director/CEO/CMO	16	3.33
Paper and cellulose	24	5.00	Owner	7	1.45
Petrochemicals	15	3.12	**Total**	**480**	**100**
Consumer goods	14	2.93	**Age of organization**	**N**	**%**
Others	10	2.09	3–6 years	145	30.20
Total	**480**	**100**	7–10 years	154	32.09
			11–14 year	105	21.88
			More than 15 years	76	15.83
			Total	**480**	**100**



(a)



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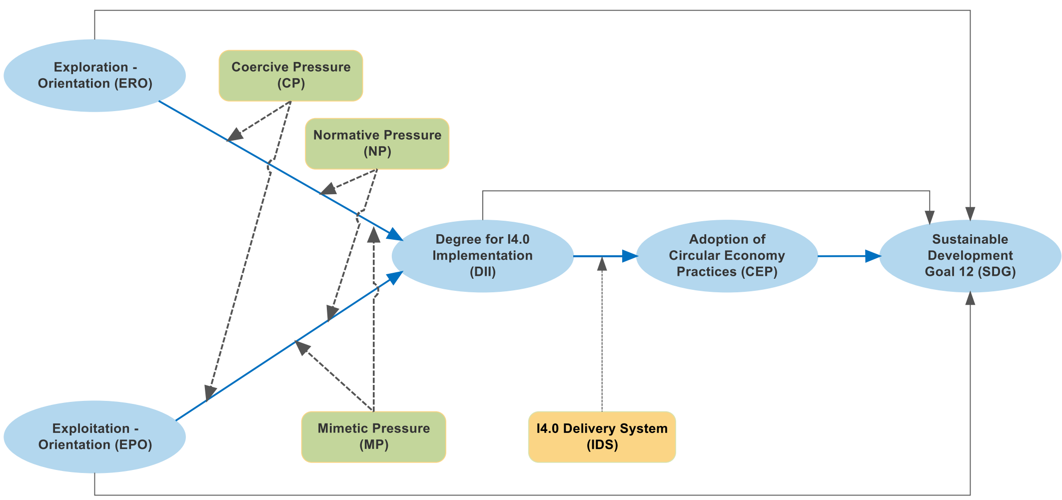

(c)

FIGURE A1 Nested mediation for (a) serial mediation through DII and CEP (Model 6), (b) moderated serial mediation through DII and CEP (Model 91), and (c) moderated serial mediation through DII and CEP (Model 83).