ORIGINAL ARTICLE

Deepening big data sustainable value creation: insights using IPMA, NCA, and cIPMA

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Abstract

The impact of big data analytics capabilities (BDACs) on firms' sustainable performance (SP) is exerted through a set of underlying mechanisms that operate as a "black box." Previous research, from the perspective of IT-enabled capabilities, demonstrated that a serial mediation of supply chain management capabilities (SCMCs) and circular economy practices (CEPs) is required to improve SP from BDACs. However, further insight regarding the role of BDACs in the processes of SP creation can be provided by deploying complementary analytics techniques, namely importance-performance map analysis (IPMA), necessary condition analysis (NCA), and combined importance-performance map analysis (cIPMA). This paper applies these techniques to a sample of 210 Spanish companies with the potential for circularity and environmental impact. The results show that BDACs exert a positive total effect toward achieving SP. However, companies still have the potential to improve and benefit from these capabilities. In addition, BDACs are a necessary condition (must-have factor) for all dependent variables in the model, including SP. In this case, high levels of BDACs are required to achieve excellence in SP, justifying organizational initiatives that prioritize the improvement of BDACs to achieve SP goals.

Keywords Big data analytics capabilities · Circular economy practices · Supply chain management capabilities · Sustainable performance · IT-enabled capabilities perspective · Importance-performance map analysis (IPMA) · Necessary condition analysis (NCA) · Combined importance-performance map analysis (cIPMA)

Introduction

Achieving sustainable development is now a key priority pursued by governments and international institutions (Andersson et al. 2022). Businesses play an essential role in moving toward a sustainable future. As testimony to this, the United Nations (UN) launched the Global Compact (https://unglobalcompact.org/), the largest international initiative that seeks to engage companies from all over the world, along with governments and civil society, in the commitment to the Sustainable Development Goals (SDGs) as part of its 2030 Agenda (United Nations 2015). The SDGs challenge businesses to evaluate strategic and operational decisions to leverage economic, social, and environmental sustainability opportunities (Jiménez et al. 2021). Indeed, while the SDGs implicitly focus on global change, individual firms must incorporate sustainability into their strategy to ensure viability (Yadav et al. 2022).

Addressing the fundamental uncertainty and complexity of sustainability challenges requires innovative methods that help make decisions based on the diverse dynamics of multiple stakeholders and scenarios (Berrone et al. 2023). Such techniques require leveraging the high volume and velocity of information assets (i.e., big data) through organizing for insight, increasing data storage and processing, and using improved methods to achieve actual impact

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across disciplines (Abrantes and Ostergaard 2022). The expanded use of big data in infrastructure, analytics, and services has contributed to sustainable development by helping navigate this environment and measuring progress toward SDGs (Hassani et al. 2021). Digital transformation through emerging technologies can lead to methods and approaches that provide improved solutions to societal issues that drive strategy and create value for both the business and society (Pappas et al. 2023).

Studies have consistently demonstrated the impact of big data analytics (BDA), including marketing analytics, on creating business value. However, how it affects the sustainability aspects of this value still needs to be explored (El-Haddadeh et al. 2021). Although research is abundant on the impact of BDA on economic performance, its environmental and social considerations, as well as the holistic view of sustainable performance under a triple-bottom-line form, are lacking and require further investigation (Behl et al. 2022; Cetindamar et al. 2022; Zhu and Yang 2021). Additionally, there is a lack of theories to explain the underlying mechanisms through which using BDA to extract, integrate, and optimize large-scale data contributes to firm performance and the conditions under which this occurs (Olabode et al. 2022). Specifically, there is an urgent need for empirical studies that reveal how organizations can effectively capture the value of BDA (Persaud and Zare 2023).

To shed light on these issues, an emerging branch of information systems research, the information technology-enabled capabilities perspective, advocates that information technology (IT) can facilitate other organizational capabilities that improve organizational performance (Liu et al. 2020). In short, this perspective argues that a hierarchy of organizational capabilities exists in which higher-order capabilities require technological capabilities to enable them (Felipe et al. 2020). BDA capabilities (BDACs), which are defined as IT capabilities designed for efficient and effective management and exploitation of big data (Cetindamar et al. 2022), can be conceived as one of these enabling capabilities. Consistent with the postulates defended by the perspective of IT-enabled capabilities, an emerging research line posits that integration and coordination of BDACs within other organizational capabilities in the fields of supply chain management (supply chain management capabilities – SCMCs) and circular economy (circular economy practices – CEPs) leverage them in such a way as to impact economic, environmental, and social performance positively (Riggs et al. 2023; Yu et al. 2022). SCMCs facilitate integrating and coordinating internal and external resources within the supply chain and collaboration among elements beyond the organization's boundaries (Kalubanga and Gudergan 2022). Meanwhile, CEPs comprise corporate activities that promote the optimal use of resources through reusing, recycling, reducing, and remanufacturing, among others, as opposed to a traditional linear production and consumption model (Le et al. 2023).

However, this potential benefit of big data contrasts with research showing that big data investment plans are in decline, with firms still attempting to understand the necessary conditions for big data to improve outcomes (Ghasemaghaei 2020). It is relevant to note that while previous literature has evaluated the mediating role of SCMCs and CEPs in specific BDA value-creation processes (Piprani et al. 2023; Sahoo et al. 2023), an alternative approach, which has not been sufficiently exploited by previous literature on big data sustainable value creation, is the evaluation of existing underperformance of companies in these areas, meaning there is a potential for improving sustainable results through their influence. This information can be provided by importance-performance map analysis (IPMA) (Ringle and Sarstedt 2016), which has only recently begun to be used in marketing research (Damberg et al. 2024).

Notably, our study seeks to answer the following research question:

RQ1: Is there room for improvement in the level of big data analytics capabilities reached by companies to positively impact their sustainable performance?

Additionally, all previous literature has focused on studying the impact of different capabilities on performance in terms of additive logic, explaining the outcome through sets of variables that are sufficient but not explicitly necessary for influencing the outcome of interest (Richter and Hauff 2022). This paper proposes that the application of a necessity logic can offer fresh insights into the phenomena under investigation by examining whether the existence or non-existence of a concept (or a particular level of it) ensures the manifestation or non-manifestation of the outcome (Bokrantz and Dul 2023). For this purpose, the novel technique of necessary condition analysis (NCA) will be applied (Dul 2020). This methodology will expand the previous knowledge on the effects of BDACs on the variables considered, which has traditionally been addressed from their positive or negative impacts on them. Specifically, we aim to answer the following research question:

RQ2: Are big data analytics capabilities a necessary condition (must-have factor) for sustainable performance of firms and specific antecedents of sustainable performance, such as circular economy practices and supply chain management capabilities?

Both questions are pertinent to present BDA research on the IT business value-creation field and will offer valuable contributions to the associated state of the art. First, this study will provide significant theoretical and empirical

insights into BDA mechanisms to create sustainable value using novel research approaches. Thus, this article examines the perspective of IT-enabled capabilities from a causal approach of necessity rather than sufficiency (Dul 2024). It provides an in-depth understanding of the must-have organizational factors related to big data or facilitated by them that lead to sustainable outcomes. As a result, this paper is among the first to put forward and contrast necessary condition hypotheses, thereby aiding the development of theoretical support for future cases and expanding the practical application of NCA for prospective users. Additionally, this article combines the use of IPMA and NCA in applying the cIPMA (Hauff et al. 2024) approach, representing a pioneering implementation of this technique. Finally, stressing the call for companies to understand the urge for data-driven decisions to respond to highly dynamic markets (Petrescu and Krishen 2023), this study provides practical guidance to managers seeking to improve the effectiveness of their big data investments and increase their positive impact on sustainable performance.

To this end, the present article proceeds as follows. Following the introduction, the article presents a detailed analysis of the theoretical background that underlies our research, encompassing the foundational theoretical and conceptual frameworks, the conceptual model, and the formulation of necessary condition hypotheses. Then, the methodological approach of the research is outlined, highlighting the three techniques utilized: IPMA, NCA, and cIPMA. The following section presents the results, while their subsequent discussion, theoretical and practical implications, limitations, and future research opportunities are exposed in the final part of our paper.

Theoretical background

IT-enabled capabilities perspective and big data analytics value creation

Information technology plays a significant role in enabling organizational success in today's business environment. However, it is widely acknowledged that mere investment in IT infrastructure or the deployment of IT tools does not directly turn into a competitive advantage (Majhi et al. 2022). Instead, IT is leveraged through its impact on certain value-creating vehicles that lead to outperformance (Mikalef et al. 2021). To be more specific, IT capabilities, defined by Bharadwaj (2000) as the firm's ability to deploy IT that contributes to the development of corporate strategies and operations, will enable the creation or enhancement of other higher-order capabilities that genuinely make a difference in excellence (Mikalef and Pateli 2017). This theoretical approach is known as the IT-enabled capabilities

perspective, which is the pillar of numerous studies that analyze IT value-creation processes through the mediation of other organizational capabilities (Benitez et al. 2018a).

Concerning this approach, there remains a substantial lack of understanding of the underlying mechanisms through which investments in BDA result in organizational performance, despite the promise of their prospective usefulness in organizations (Elia et al. 2022). According to the triple-bottom-line conceptualization, this fact is particularly apparent in its potential contribution to sustainable performance. Therefore, an exciting field of research emerges to investigate the interconnections between big data and two relevant contemporary business concepts that can influence firms' sustainable performance: the circular economy (CE) and supply chain management (Persaud and Zare 2023).

To address this research gap, the IT-enabled capabilities perspective provides a suitable framework for identifying those organizational capabilities BDA can enable to produce desirable sustainable outcomes. In this vein, our recent work (Riggs et al. 2023) develops a research model that focuses on the effects on the sustainable performance of big data analytics capabilities (BDACs), which are IT-based organizational capabilities designed for efficient and effective management and exploitation of big data (Cetindamar et al. 2022) (Fig. 1). The results showed that the impact of BDACs on sustainable performance (SP) (under a triple-bottom-line model – that is, economic, social, and environmental results) is fully and sequentially mediated by two other organizational capabilities, namely supply chain management capabilities (SCMCs) and circular economy practices (CEPs).

However, that study aligns with most of the previous literature in the field, primarily dominated by additive logic to address causal relationships between variables (Richter and Hauff 2022). This logical approach posits that one or more variables can be sufficient, though not necessary, to affect an outcome. Moreover, these variables can offset each other, which raises a question that traditional additive logic cannot answer: Are BDACs indeed a necessary condition for achieving SP, or even for the two IT-enabled capabilities that have been proven to facilitate SP achievement (SCMCs and CEPs)?

Necessity theory: its application to big data analytics capabilities value-creation processes

Following Dul (2020, 2024), an 69 phenomena and providing valuable insights is necessity theory. This novel theoretical development is defined as "a theory that employs causal necessity logic for describing the causal relationships between all or a selection of the concepts of a theory" (Bokrantz and Dul 2023, p. 54). Therefore, this lens posits that the outcome strictly depends on predetermined conditions, which will not occur in their absence. This concept

Fig. 1 Conceptual model
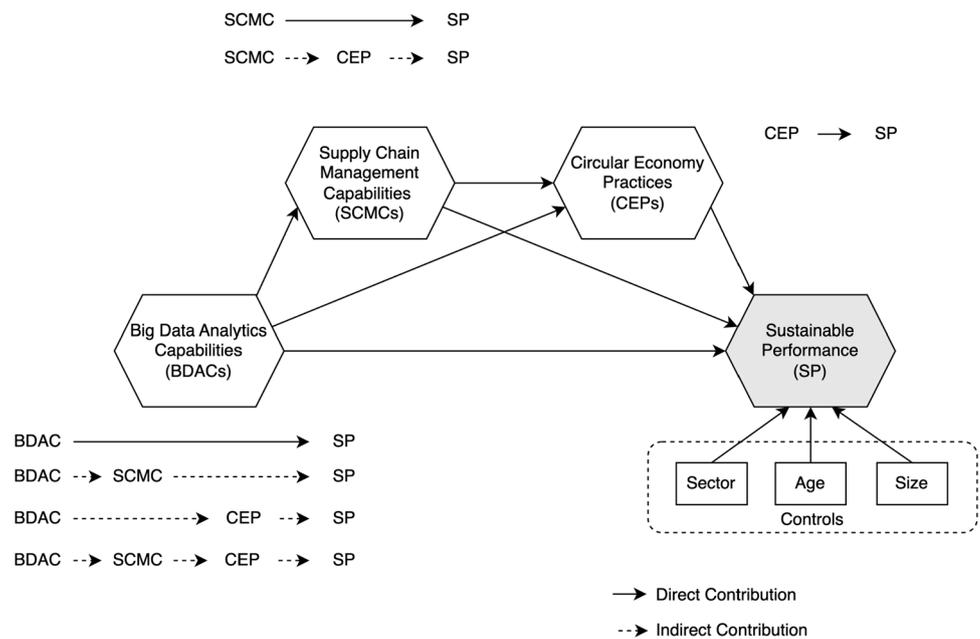
is conveyed through phrases such as "X is needed for Y (output)," "X is critical for Y," or "X is a requirement for Y," among others, denoting the presence of a crucial element for the desired result to occur or, conversely, a barrier to overcome (Dul et al. 2023).

On this basis, our work seeks to enhance the perspective of IT-enabled capabilities with novel insights by incorporating the causal necessity approach to this theoretical framework. First, to assess the current state of the art in research that formally addresses big data as a necessary condition from the necessity logic approach, a literature review was performed to identify existing articles that could establish a necessity for big data to obtain sustainable performance. A review of the Scopus database began by searching for all items that included necessity terms and big data, resulting in 296 documents (Table 1). When this list was limited to articles only, the results were reduced to 150. After a preliminary review of these articles, only eight addressed

big data as an antecedent in the relationships proposed in the articles. Of these eight, only five sources considered big data an antecedent to performance (Table 2). None of them referred to sustainable performance under a triple-bottom-line conceptualization. Novikov (2020) and Ylijoki and Porras (2019) were descriptive and did not include data analysis. Of the remaining three, only Talib et al. (2023) specifically analyzed big data as a necessary condition independent of the additive effects of any other antecedents. Table 2 summarizes the specific contribution that our paper makes to the previous works cited.

Therefore, the bibliographic search has confirmed the novelty of applying the necessity theory to the already well-established IT-enabled capabilities perspective. This helps to assess the necessary role that BDACs may play in their relationships with SP, CEPs, and SCMCs for a deeper comprehension of the underlying mechanisms of business value creation.

Table 1 Review of relevant articles

Process	Number of results
Scopus Search: (TITLE-ABS-KEY ("necessary condition") OR ((TITLE-ABS-KEY (necessary) AND (TITLE-ABS-KEY (sufficient) OR TITLE-ABS-KEY (insufficient)))) AND TITLE-ABS-KEY ("big data"))	296
Scopus Search: (TITLE-ABS-KEY ("necessary condition") OR ((TITLE-ABS-KEY (necessary) AND (TITLE-ABS-KEY (sufficient) OR TITLE-ABS-KEY (insufficient)))) AND TITLE-ABS-KEY ("big data")) AND (LIMIT-TO (DOCTYPE, "ar"))	150
Review Scopus results for target antecedent includes "big data"	8
Review "big data" results for target outcomes related to performance	5

Table 2 Articles linking big data and performance outcomes

Article	Theoretical framework	Target antecedent	Target outcome
Ghasemaghaei (2020)	Resource-based view	Big data utilization	Organizational performance
Hayajneh et al. (2022)	Resource orchestration theory	Business analytics capabilities	Innovative performance
Novikov (2020)	(No specific theory)	Big data as a liquid product	Profitability
Talib et al. (2023,)	Dynamics capabilities perspective	Big data analytics infrastructure Big data analytics management Big data analytics personnel	Decision-making performance
Ylijoki and Porras (2019)	Virtual value chain Data/Information/Knowledge/Wisdom IT value-creation theory		
This article	Necessity theory applied to IT-enabled capabilities perspective	Big data analytics capabilities	Sustainable performance

Conceptual framework and hypotheses development

Big data analytics capabilities

Compared to traditional analytics, big data analytics examines data in greater volume, at higher velocity, and from a greater variety of sources (McAfee and Brynjolfsson 2012). However, these voluminous data have no value per se for companies; instead, value comes from the quality and sophistication of the processes used to handle and analyze them (Ferraris et al. 2019). BDACs refer to specific information processing capabilities based on organizational culture, data management, and skills to synthesize voluminous raw data into a successful business strategy (Kiron et al. 2014). One of the most comprehensive definitions regarding BDACs that the existing literature on information systems has produced is that of Mikalef et al. (2018), who noted that BDACs are those organizational capabilities that leverage IT infrastructure, massive data management, and the skills of the staff involved, and that support the competitive operation of the company. In line with this definition, Akter et al. (2016) conceptualized the three critical dimensions of BDACs: BDA management, BDA infrastructure, and BDA talent.

Supply chain management capabilities

The functionality of supply chains hinges on numerous relationships among not only their direct players but also many other agents in their business ecosystem, which involve vulnerability to potential disruptions (Sharma et al. 2022). In current turbulent environments, firms and their supply chain members must adeptly address continuous shifts, employing a combination of knowledge and technological tools (Moryadee and Jitt-Aer 2020). Therefore, supply chain management implies collaboration, process integration, and information sharing among supply chain partners, thus, satisfying customers' needs by leveraging information and technology (Min et al. 2019). Following Wu et al. (2006), SCMCs are the firm's ability to exploit and assimilate internal and external resources, such as information that allows its supply chain operations. These authors also proposed four critical dimensions for SCMCs, which were as follows: information exchange between supply chain players, interfirm coordination, integration of activities both within and outside the limits of firms, and supply chain responsiveness to all types of environmental changes (Wu et al. 2006).

Circular economy practices

According to the Ellen MacArthur Foundation (2013), a circular economy (CE) is "an industrial system that is restorative or regenerative by intention and design" (p. 7). Therefore, a CE model means an economic system that replaces end-of-life concepts with reducing, reusing, recycling, and recovering materials to achieve sustainable development (Kirchherr et al. 2017). CE uses cyclical flows of materials, renewable energy sources, and sustainable development to maximize the service of materials and energy (Korhonen et al. 2018). The shift from linear production systems to circular ones requires the implementation of specific practices in business activities (Schroeder et al. 2019). Govindan and Hasanagic (2018) proposed six groups of internal CE practices (CEPs) for practically implementing circular business in companies, which are as follows: (i) governance initiatives, such as indicators systems for monitoring and measuring CE projects; (ii) economic initiatives, which are those activities seeking to obtain economic advantages from CE opportunities; (iii) cleaner production, or those processes that aim at achieving eco-efficient manufacturing; (iv) product development pursuing durable design or reuse; (v) top management support for CE implementation; and (vi) CE knowledge, which means a proactive CE education, both for companies' employees and community in general.

Sustainable performance

Sustainable performance is commonly understood to involve three simultaneous objectives: economic prosperity, environmental quality, and social equity (Kirchherr et al. 2017). Indeed, the literature is dominated by the so-called triple bottom-line conceptualization of sustainability (Purvis et al. 2019), which reflects business effects on profitability, nature, and people (Nursimloo et al. 2020). First, economic performance highlights the impacts of corporate activities on the economic system (Elkington 1997). Second, environmental performance refers to creating value related to the resilience of natural resources (van Buren et al. 2016). Sustainability minimizes the current environmental impact and takes a restorative and regenerative approach to address past damage (Ellen MacArthur Foundation 2013). Social performance considers elements related to the welfare of stakeholders, such as the health and safety of employees, the creation of employment opportunities for the surrounding community, education and training, and the reduction of risks to the general public (Das 2018; Paulraj 2011).

Conceptual model

Figure 1 illustrates the conceptual model from Riggs et al. (2023). Our findings showed that SCMCs and CEPs fully and sequentially mediated the relationship between BDACs and SP of the organization (Fig. 2).

The proposed conceptual model and its results serve as the basis of our study to assess the level of importance and the performance of each variable on sustainable

performance. Applying the importance-performance map analysis (Ringle and Sarstedt 2016), we examine if companies can enhance BDACs performance to achieve excellence in their SP.

Additionally, and according to Dul (2020), we will provide theoretical support in the following sections for proposing the necessary condition hypotheses (in this case, BDACs) as the needed precedent for the other dependent variables of our base research model (SCMCs, CEPs, and SP).

Finally, focusing on the final dependent variable, SP, combined importance-performance map analysis (Hauff et al. 2024) will help us prioritize initiatives to achieve a high level of performance in SP.

Big data analytics capabilities as a necessary condition for supply chain management capabilities

Supply chains operate in increasingly complex and uncertain environments, with frequent and unpredictable changing conditions, sometimes even disruptive (e.g., COVID-19 or recent international conflicts). This fact, coupled with the exponential growth and development of IT, has dramatically affected supply chain management, which has become increasingly challenging and demanding. Supply chains are becoming extensive and complex networks of participants, often located far from each other, that require physical and digital interactions between all chain links, including electronic equipment and devices, until reaching the final customer (Novikov 2020). Under these circumstances, BDA and its related capabilities become indispensable business tools

Fig. 2 Structural model results
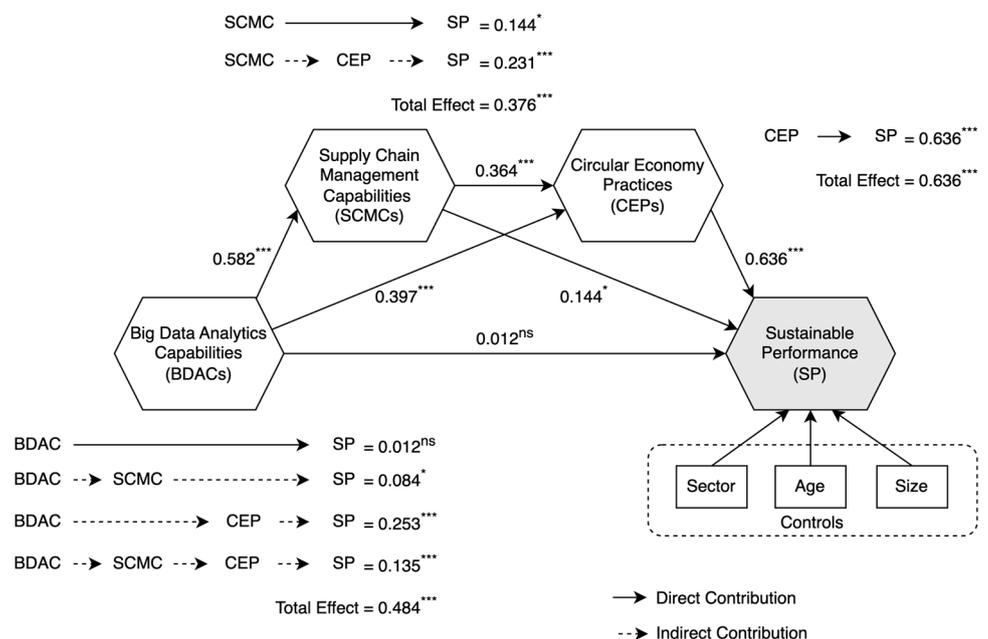
Note: * $p < 0.05$; *** $p < 0.001$; ns: non-significant

for supporting all agents who must adapt to these new modes of operation. Moreover, BDACs have improved flexibility, reliability, and resource optimization, which can be applied to supply chain management (Manikas et al. 2023).

Mandal's (2019) study revealed that corporate abilities to plan, coordinate, and control BDA serve as "critical enablers" (p. 297) of certain functions required for successful supply chain management in current turbulent business environments, such as supply chain preparedness, alertness, and agility. Similarly, a recent study by Piprani et al. (2023) argued that the application of BDACs will become indispensable for supply chain management if the company wants to influence its efficiency and competitiveness. In their research effort to identify the skills necessary for supply chain management professionals, Stek and Schiele (2021) remarked that big data analysis was found to be a key and required skill. Finally, resulting from an exhaustive systematic review of the literature on BDA and supply chain management, Lee and Mangalaraj (2022) concluded that "BDA plays a vital role in the functioning of supply chain management" (p. 24), highlighting the relevance of monitoring customers' preferences, supply chain resilience, and visibility.

However, we could ask if there could be other organizational capabilities that exert the same effect or that could substitute for BDACs. To justify the impossibility, we use the arguments provided by Rolf et al. (2023). They proposed that companies incorporate real-time supply chain planning, coordination, execution, and control to prevent costly operational disruptions and ensure the timely delivery of goods and services to customers. This implies that these management principles can only be implemented if accurate real-time data are accessible to all relevant stakeholders, allowing them to identify shortcomings, simplify procedures, and mitigate risk. On top of this, Pratt et al. (2023) emphasized two critical factors for managers to rely on BDACs to support their supply chain decision systems: (1) the urgent need for more sophisticated IT tools to coordinate operations and communication among partners and (2) the significant amount of data generated both internally and externally within a supply chain that cannot be handled with conventional IT tools. We can propose the following hypothesis after all the above exposed theoretical support.

H1: Big data analytics capabilities are a necessary condition for the development of supply chain management capabilities.

Big data analytics capabilities as a necessary condition for circular economy practices

The circular economy system seeks to decouple economic profitability from excessive consumption of resources and degradation of nature. Therefore, it advocates the complete elimination of waste or its recovery as valuable raw materials or by-products and prolonging the product's useful life. The academic study of the relationship between the two proposed variables, BDACs and CEPs, is still developing, resulting in an inherent scarcity of theoretical references. However, early studies have highlighted the need to use BDACs to fully capitalize on the potential of CE models, with the success of circularity dependent on the availability of complex and innovative tools that allow the acquisition, sharing, and analysis of large volumes of data (Chiappetta Jabbour et al. 2019). In this sense, BDACs serve as a critical facilitator for the deployment of CEPs by enabling partners to implement the required communication and collaboration through exchanging and sharing a large amount of data (Kamble et al. 2021).

BDACs produce insights into manufacturing and consumption processes that can hardly be obtained by traditional data analysis, thus, facilitating their design or reengineering in pursuit of circular efficiency (Dubey et al. 2019). In addition to this, BDACs are necessary to collect and analyze data related to the various stages of the product life cycle to achieve the product optimization required by CEPs (Khan et al. 2022). Other studies have stated that BDACs become facilitators for adopting CEPs to the extent that only these capabilities can support management decisions by reducing the risk involved in such complex operational systems (Gupta et al. 2019). Finally, if we question potential alternative paths, Phoon et al. (2022) claim that simply relying on experience, judgment, and existing designs will be insufficient to implement a circular economy fully. Along these lines, Pieroni et al. (2019) indicated that significant changes are required in all companies' conventional operations and organizational features to reach circularity. We posit that the instruments needed to facilitate navigation in these disruptive changes are BDACs. Thus, we formulate the following hypothesis:

H2: Big data analytics capabilities are a necessary condition for the implementation of circular economy practices.

Big data analytics capabilities as a necessary condition for sustainable performance

Finally, our study evaluates the role of BDACs as a necessary condition to achieve SP in organizations, as represented by the triple bottom line of previously described economic, environmental, and social dimensions. A study conducted by Ylijoki and Porras (2019) highlighted that companies "must have big data capabilities to produce impactful results" (p. 1093) on organizational performance (to which the authors refer in principally economic terms). However, they acknowledged that the effect might fail due to other influencing elements, resulting in the deployment

of BDACs being only necessary yet insufficient. Similarly, the work of Talib et al. (2023) represents one of the few studies that address necessary condition analysis (NCA), specifically focusing on decision-making performance in public organizations. Their findings emphasized the necessity of BDACs (namely, BDA infrastructure, management, and personnel) to facilitate effective managerial decisions to achieve notable performance. In the referred study, BDA management capabilities become the most crucial dimension for this goal.

Similarly, Ghasemaghaei (2020) stated that "the capability to process and utilize big data is considered a firm's critical resource" (p. 398). These capabilities to analyze large-scale data and use their results for business purposes will enable achieving desirable performance. Consistent with these postulates are the results from Hayajneh et al. (2022), who conducted research by surveying 450 professionals and managers from large Saudi Arabian companies. The findings explicitly showed that to secure competitiveness for companies, respondents recognized the need for their workforce to acquire capabilities in BDA. More specifically, the authors suggested that these capabilities are required to achieve innovative performance. Most theoretical support referred to a performance concept, meaning business or organizational results, without referring to their sustainability dimensions. This issue was finally addressed by Chiappetta Jabbour et al. (2019), who advocated the critical role of large-scale data and related IT capabilities as fundamental resources to create value for stakeholders, generate competitive advantages, and transition to more environmentally respectful operations. As for this description, this impact was not limited to the economic field but extends to companies' social and environmental performance. Finally, and as we have done when supporting previous hypotheses, we will question whether other elements can replace BDACs for this purpose. To this end, we use the resounding arguments of Novikov (2020), explaining that data have become an invaluable and unique resource in today's economy due to the growing dependence of economic systems on massive data collection and analysis. The author contended that the transformation required to ensure successful performance for companies operating in the current global environment involves exploiting big data to gain valuable insights regarding customers, suppliers, partners, and the external environment. As expressed in his conclusions, "the role of the Big Data is to be a liquid product, a prerequisite for improving the profitability of organizations through personalized customer service and predictive analytics" (Novikov 2020, p. 762). According to all the theoretical support above summarized, we posit the following hypothesis:

H3: Big data analytics capabilities are a necessary condition for sustainable performance in companies.

Methodology

Sample

This study limited its sample to the critical value chains identified in the Circular Economy Action Plan (European Commission Directorate-General for Communication 2020) and prioritized within that report's policy framework. Limiting the sample to sectors with a significant presence in Spain and companies with at least fifty employees, the initial population consisted of 3,572 companies. Using a random stratified sampling procedure, we produced a representative sample of companies based on dimensional parameters and industry.

Data were collected from September 2021 until October 2021, initiated by telephone contact followed by a questionnaire. For each company included, a single top-level manager completed the questionnaire and then used it for analysis at the organizational level. A total of 210 completed questionnaires were collected and processed in this way. Table 3 provides the demographic composition of the final sample.

Measures

This study used validated scales for all variables. All constructs were measured using a 7-point Likert scale, except for control variables. Eight indicators measured BDACs applying the scale developed by Raut et al. (2021). For SCMCs, the scale from Wu et al. (2006) was used, which consisted of four dimensions: information exchange, coordination, integration, and responsiveness. The CEPs were measured using the scale developed by Riggs et al. (2023)

Table 3 Demographic data of the respondents

	Frequency	Percentage (%)
Current position		
Director of environmental sustainability/CSR	17	8
Quality manager	127	60
Operations/production manager	28	13
Supply chain manager	1	0
General manager	10	5
Other	27	13
Total	210	
Firm size		
50 to 249	179	85
250 to 1000	28	13
More than 1,000	3	1
Total	210	

based on the systematic review of Govindan and Hasanagic's (2018) article, which grouped these practices into six dimensions that form a higher-order construct. These dimensions include governance initiatives, economic initiatives, cleaner production, product development, management support, and knowledge. We measured the sustainable performance variable using the scale proposed by Çankaya and Sezen (2019). This multidimensional construct included three dimensions: economic, environmental, and social performance. The four primary constructs of our study were modeled as composites (Henseler 2021). The items and dimensions of the scales can be found in the Annex. Finally, the study also controlled for firm size, industry sector, and age.

Data analysis

This study applied three analytic techniques to answer our research questions. From the results obtained with partial least-squares structural equation modeling (PLS-SEM) (Ciavolino et al. 2022), we carried out an importance-performance map analysis (IPMA) (Ringle and Sarstedt 2016). Additionally, PLS-SEM-generated construct scores were used as input for the necessary condition analysis (NCA) (Richter et al. 2020). Next, we performed a combined importance-performance map analysis (cIPMA) (Hauff et al. 2024). We used SmartPLS software (version 4.0.9.6) (Ringle et al. 2022) and the necessary condition analysis package with R (version 3.3.3) (Dul 2023a).

Results

Importance-performance map analysis (IPMA)

To answer our first research question, "Is there room for improvement in the level of big data analytics capabilities reached by companies to positively impact their sustainable performance?" we applied IPMA (Ringle and Sarstedt 2016). This technique aims to identify antecedent variables with a high impact on a target construct (in our case, SP) but also with the potential for improvement. To this end, IPMA uses the total effect of a predecessor construct (direct plus indirect) to indicate its importance in shaping the target construct. The predecessor performance is estimated using its average rescaled latent variable scores. IPMA describes areas of greater importance to a target construct, even though the construct performs poorly, suggesting significant areas to improve (Nitzl and Chin 2017). In this case, BDACs are essential for explaining SP, achieving a more significant impact than SCMCs but lagging CEPs. A one-unit increase in BDACs performance increases SP performance by 0.48. Since the performance of BDACs is 61.58% of its potential, there is still room for improvement (Fig. 3).
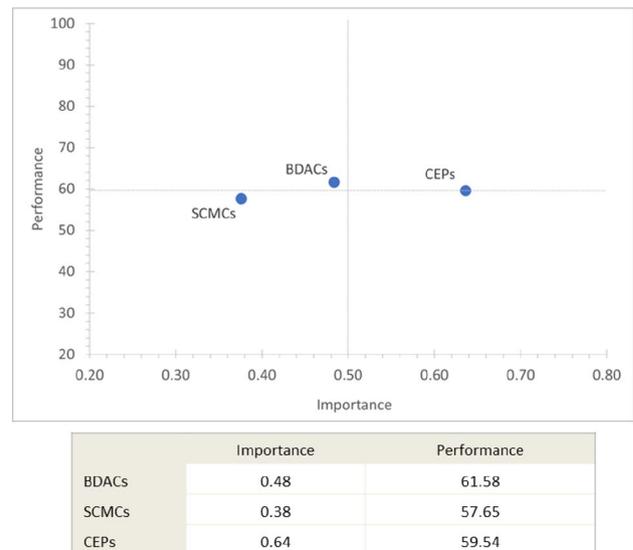

	Importance	Performance
BDACs	0.48	61.58
SCMCs	0.38	57.65
CEPs	0.64	59.54

Fig. 3 Importance-performance map analysis for the target construct sustainable performance (SP)

Necessary condition analysis (NCA)

The joint use of PLS-SEM and NCA allows one to determine the should-have factors that produce the best possible outcome under a sufficiency logic and those that are critical for an outcome following a necessity logic (Richter et al. 2020). PLS-SEM helps to decide which variables provide the best possible outcome (i.e., should-have factors), even though they may not be required. NCA helps determine which antecedents are essential for a dependent construct (i.e., must-have factors) to specify the necessary conditions to attain a particular outcome. For this reason, our study uses NCA to answer the second research question: "Are big data analytics capabilities a necessary condition (must-have factor) for sustainable performance of firms and certain antecedents of sustainable performance, such as circular economy practices and supply chain management capabilities?".

NCA starts with analyzing scatter plots between two variables to identify the presence of empty spaces, which could indicate the presence of a necessary condition (Dul 2020). Figure 4 provides the scatter plots for each dependent variable in our model (SCMCs, CEPs, and SP) regarding BDACs. The ceiling lines are located above the data, representing the level of condition required for a specific outcome level. The NCA ceiling lines separate the area without observations from the area with observations. Two methods exist to establish ceiling lines (Dul 2023b). On the one hand, the ceiling envelopment–free disposal hull (CE-FDH) is a stepwise linear line recommended for discrete data or when the border is irregular. On the other hand, the ceiling regression-disposal hull (CR-FDH) is a trend line through the CE-FDH line calculated by a linear regression using the upper left
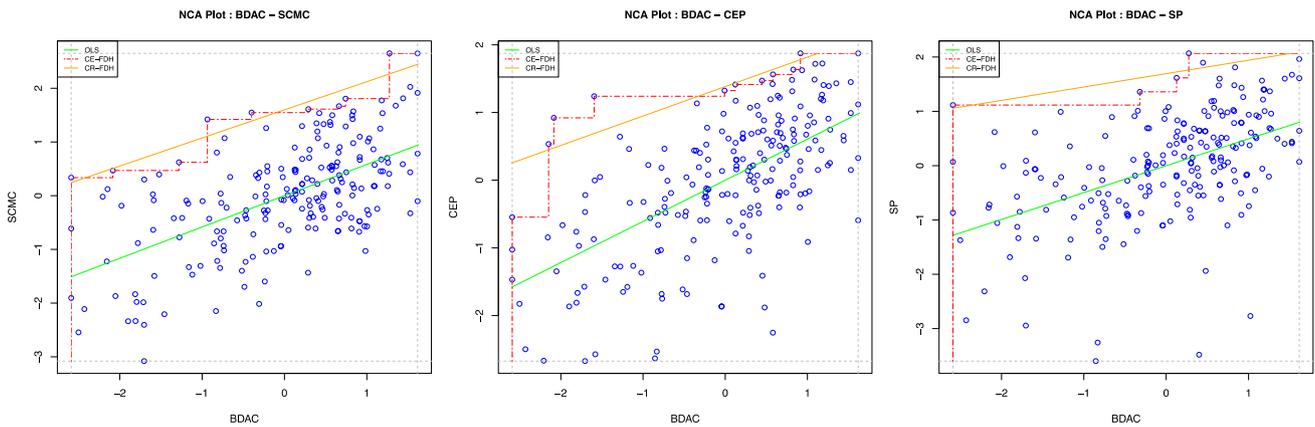
Fig. 4 Necessary condition analysis scatter plots

points of the CE-FDH line. The regression approach is recommended when the pattern of observations near the ceiling line is approximately linear. We focus on the CE-FDH ceiling lines because the pattern of observations near the ceiling line is irregular. The empty spaces in the upper left corners of the scatter plots show that BDACs may be necessary conditions for SCMCs, CEPs, and SP, respectively.

NCA estimates two parameters to determine whether there is empirical evidence for a necessity hypothesis (Dul 2020). The first is the necessity effect size d, the key indicator. It is calculated by dividing the empty space (the ceiling zone) by the total area that includes observations. Dul (2016) established $0 < d < 0.1$ as a small effect, $0.1 \leq d < 0.3$ as a

medium effect, $0.3 \leq d < 0.5$ as a large effect, and $d \geq 0.5$ as a substantial effect. Dul et al. (2023) recommended the threshold of $d \geq 0.1$ to support a necessity hypothesis. The second parameter is the statistical significance of the necessity effect size (d) generated by a permutation test.

According to the NCA results (Table 4) using a permutation test of 10,000 resamples, the BDACs construct is a necessary ($d \geq 0.1$) and significant ($p \leq 0.05$) variable for SCMCs ($d = 0.247^{***}$; H1 supported), CEPs ($d = 0.157^{***}$; H2 supported), and SP ($d = 0.107^{*}$; H3 supported). Therefore, BDACs are a must-have factor with medium effects, although their relevance is more pronounced for SCMCs than CEPs and SP. Therefore,

Table 4 PLS-SEM and NCA for dependent constructs

Construct	SCMCs				
	PLS-SEM			NCA	
	Direct effect	Indirect effect	Total effect	CE-FDH effect sizes (d)	Support
BDACs	0.582***		0.582***	0.247***	H1: Yes
Construct	**CEPs**				
	PLS-SEM			NCA	
	Direct effect	Indirect effect	Total effect	CE-FDH effect sizes (d)	Support
BDACs	0.397***	0.212***	0.609***	0.157***	H2: Yes
SCMCs	0.364***		0.364***	0.243***	
Construct	**SP**				
	PLS-SEM			NCA	
	Direct effect	Indirect effect	Total effect	CE-FDH effect sizes (d)	Support
BDACs	0.012 ns	0.472***	0.484***	0.107*	H3: Yes
SCMCs	0.144*	0.232***	0.376***	0.212***	
CEPs	0.636***		0.636***	0.206***	

$*p < 0.05$; $***p < 0.001$; ns: non-significant

we find support for the three hypotheses we have posited. In addition, although they are not the main object of our study, we can also observe how SCMCs and CEPs become necessary conditions for the constructs of which they are antecedents.

As shown in Table 5, a bottleneck table represents the ceiling line for each necessary condition in a detailed tabular form (Dul 2020). The shaded columns of the table list various levels of outcome. The columns to the right of each shaded column display the required levels of the associated conditions. This means that achieving higher levels of an output construct requires higher levels of the corresponding condition variables. In our study, the levels are expressed as a percentage of the range. For example, Table 5 shows that a necessary condition must be met to achieve a level of SCMCs of 60%: BDACs must be at least 12.01%. In the case of CEPs, BDACs would need to reach at least 10.51% to obtain a value of 50% in CEPs. For SP, it is observed that BDACs are a necessary condition for achieving excellence. To exceed 80% in SP, we must accomplish a BDACs value of 64.60%.

Combining the results generated by PLS-SEM and NCA (Table 4), we can observe that BDACs are a significant antecedent and necessary condition for SCMCs, CEPs, and SP. In the latter case, BDACs would only be a significant antecedent variable if we consider their total effect since all their influence on SP is conducted indirectly, that is, through SCMCs and CEPs. Therefore, BDACs are a necessary (must-have factor) and sufficient (should-have factor) condition for SCMCs, CEPs, and SP (in this case, considering its total effect). Thus, an increase in BDACs will increase the three dependent variables. However, results will only be delivered if particular levels of BDACs are reached (see Table 5).

Combined importance-performance map analysis (cIPMA)

After running IPMA and NCA analyses, this study follows the guidelines that Hauff et al. (2024) proposed to integrate both results into a combined importance-performance map analysis (cIPMA). This will allow us to prioritize actions that improve the target construct SP.

Based on the conceptual model (Fig. 1), we center on SP as the focal variable of our analysis. We then establish the desired level for that target construct. As such, this study aims to evaluate the conditions necessary to exceed a performance level of more than 80% in the SP variable. To accomplish this, we create a new bottleneck CE-FDH table (Table 6) that displays the percentage and number of cases that have not attained the required antecedent construct levels for the corresponding SP levels.

In the next step, we start from the previously conducted IPMA (Fig. 3) and include the antecedent variables as bubbles in the new cIPMA (Fig. 5). In this chart, the size of the bubbles indicates the percentage of cases that remain below the antecedent constructs' levels required to achieve the desired SP outcome above 80%. From a necessity perspective, a larger bubble indicates that the researcher should pay more attention to that antecedent variable.

According to previous findings, CEPs are observed to be very important and perform well. Even so, improvement of this variable still needs to be prioritized since 49.5% of the cases have not yet reached the level required to reach an SP level above 80%. Also to be considered is that BDACs also present a high importance and a good level of performance. However, it is also observed that 45.7% of the cases do not reach the level required to achieve the desired level in SP. Therefore, failing to prioritize BDACs in these cases would imply that the investment in the other antecedent variables would not bear the

**Table 5** Bottleneck CE-FDH table (percentages)

Outcome	Condition	Outcome	Conditions		Outcome	Conditions		
SCMCs (%)	BDACs	**CEPs** (%)	BDACs	SCMCs	**SP** (%)	BDACs	SCMCs	CEPs
0	NN	0	NN	9.34	0	NN	NN	NN
10	NN	10	NN	9.34	10	NN	NN	NN
20	NN	20	NN	11.80	20	NN	9.34	0.11
30	NN	30	NN	11.80	30	NN	9.34	2.20
40	NN	40	NN	11.80	40	NN	11.80	9.24
50	NN	50	10.51	18.57	50	NN	11.80	9.24
60	12.01	60	10.51	18.57	60	NN	11.80	9.24
70	39.32	70	10.51	35.78	70	NN	33.86	36.22
80	52.09	80	23.68	42.63	80	NN	43.08	36.22
90	91.89	90	72.21	46.59	90	64.60	48.02	61.82
100	91.89	100	83.33	72.89	100	68.09	59.38	61.82

NN not necessary

Table 6 Bottleneck CE-FDH table for sustainable performance (SP)

Outcome	Conditions					
	Percentage (and number) of cases that do not reach the necessary levels required for SP					
SP (%)	BDACs		SCMCs		CEPs	
0	0	(0)	0	(0)	0	(0)
10	0	(0)	0	(0)	0	(0)
20	0	(0)	0.5	(1)	0.5	(1)
30	0	(0)	0.5	(1)	1.4	(3)
40	0	(0)	1.0	(2)	2.9	(6)
50	0	(0)	1.0	(2)	2.9	(6)
60	0	(0)	1.0	(2)	2.9	(6)
70	0	(0)	12.4	(26)	16.2	(34)
80	0	(0)	22.9	(48)	16.2	(34)
90	45.7	(96)	32.9	(69)	49.5	(104)
100	51.0	(107)	61.9	(130)	49.5	(104)
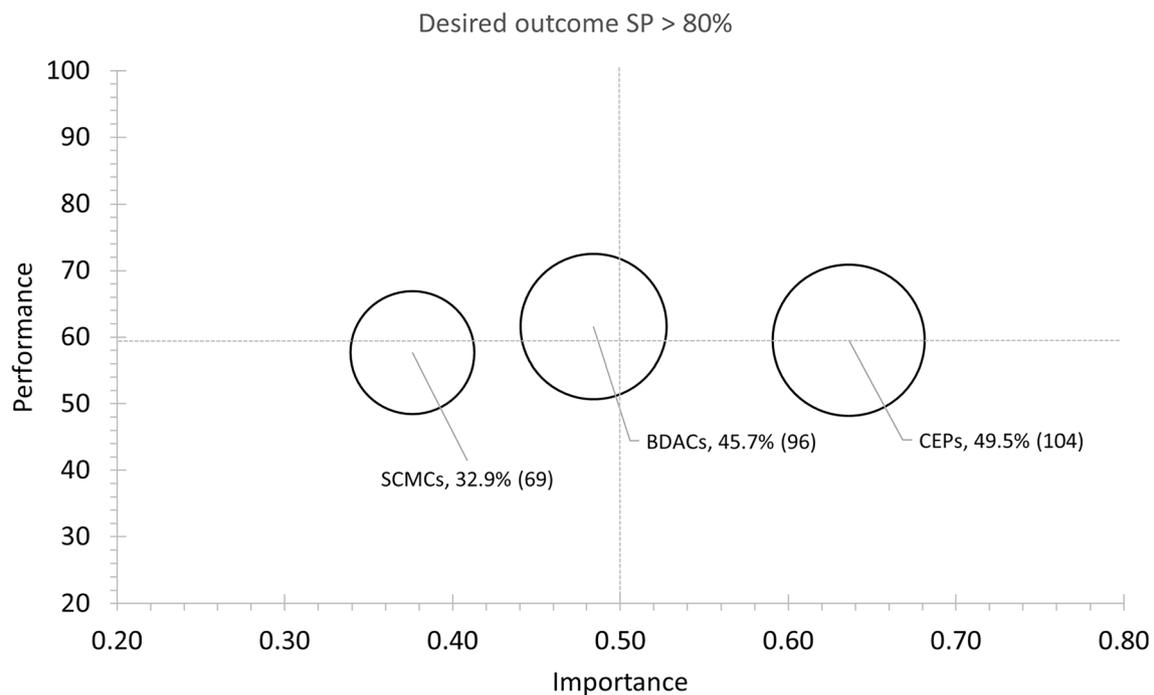
Fig. 5 Combined importance-performance map analysis (cIPMA) of the target construct sustainable performance (SP). Note: The percentage figure indicates the portion of cases that do not reach the required necessary level (> 80%) for sustainable performance (SP). The number of cases that do not reach the required level is shown in parentheses

expected fruits unless the bottleneck corresponding to BDACs is resolved. Finally, although SCMCs have a lower importance and a suitable performance, their improvement should not be discounted, as almost 33% of cases do not reach the required level. Overlooking the enhancement of SCMSs would limit the effectiveness of the other variables in improving SP.

Discussion and implications

We began our study by asking whether companies still had room for improvement in the performance of their big data analytics capabilities to enhance their sustainable performance. Our findings indicate that companies still

have room to invest and advance in BDACs. In addition, we found that a significant percentage of companies have not yet reached a level of performance in their BDACs that would allow them to achieve excellence in their SP. For this reason, it is essential to prioritize actions aimed at achieving high levels in BDACs if excellence in SP is to be achieved.

Considering our conceptual model, we have also found that BDACs are a must-have factor or necessary condition to achieve both SP and its antecedent variables, i.e., SCMCs and CEPs. All three hypotheses based on a necessity logic have been supported.

Next, we will discuss the theoretical and practical contributions that can be derived from the results of this study.

Theoretical contributions

This article illustrates a novel approach by integrating PLS-SEM analysis with IPMA, NCA, and cIPMA in a research model that examines the mechanisms through which SCMCs and CEPs mediate the influence of BDACs on SP. Our study provides some implications for the theory. Through a solid methodological approach that includes techniques such as IPMA, NCA, and cIPMA, our investigation contributes to theoretical advancements by elucidating the underlying mechanisms through which BDA contributes to generating business value. This research represents a pioneering effort to apply necessity theory to the perspective of IT-enabled capabilities, employing a causal necessity logic to dissect how the variables in the conceptual model interconnect and affect the SP of companies, providing valuable insights for those companies seeking to improve their economic, environmental, and social impact. Previous studies have mainly used additive logic to assess the influence of BDA on SP. However, they have neglected to explore the requisite conditions and scope for improving BDACs.

First, our study concludes that prioritizing BDACs is critical for companies seeking excellence in SP, as proven by the support of Hypothesis 3. These capabilities enable organizations to collect, analyze, and use data effectively to make decisions that drive sustainability throughout business operations. The structural dimension of BDACs contributes significantly to propelling the improvement in SP. A robust technological foundation, which falls under the infrastructure dimension, is essential for efficiently handling and processing large volumes of data. When analyzing large datasets, companies can identify patterns and purchasing behaviors that enable them to target specific market segments with personalized messages and offers, allowing them to customize their products to meet individual consumer needs. This enables organizations to extract meaningful information and make informed decisions, ultimately enhancing overall performance (Garmaki et al. 2016). Specifically, BDACs,

through marketing analytics tools, leverage consumer behavior data that enable sustainable production practices, such as minimizing emissions, optimizing production costs, and avoiding waste, which leads to benefits for consumers and the company (Baig et al. 2023).

Additionally, SCMCs and CEPs act as critical mediators in the relationship between BDACs and SP, highlighting the need to integrate these dimensions into business strategies. Integrating BDACs with SCMCs and CEPs allows companies to align marketing decisions more closely with sustainability values and promote products and services that positively impact the environment and society. This work responds to the demands of Magnano et al. (2024) in a recent literature review, which calls for research into the organizational capabilities that facilitate CEPs and SPs, as well as the role that specific technologies play in these relationships. As Hypotheses 1 and 2 have confirmed, our article contributes to existing research by revealing that BDACs are a key antecedent and must-have factor for both mediating variables in their relationship with SP. Adopting BDACs to achieve SP is a complex link and requires complementary resources to help organizations achieve their full potential (Benitez et al. 2018). Firstly, the emergence of BDACs represents a novel technological advancement that empowers supply chains to handle large amounts of data (Chen et al. 2015). BDACs help companies track and analyze voluminous data related to the supply chain, allowing them to identify areas of inefficiency and opportunities to optimize resource use. This implies the ability to monitor and optimize processes, identify areas for improvement, anticipate potential problems, and make decisions based on real-time information. Subsequent studies suggest that BDACs improve supply chain agility and adaptability (Fosso Wamba et al. 2020). The development of robust BDACs is required to improve the effectiveness of supply chain management, as Jha et al. (2020) highlighted. Through monitoring and analysis of real-time data, companies can identify potential issues and implement corrective actions before they disrupt product availability. This proactive approach directly influences marketing strategies by ensuring a reliable and efficient supply chain. These capabilities enable organizations to take advantage of the vast potential of big data, resulting in innovation and a greater competitive advantage within their supply chain operations (Tan et al. 2015). With a deeper understanding of the supply chain and a more transparent comprehension of demand and purchasing patterns, businesses can improve the customer experience by ensuring product availability, providing more accurate delivery times, and offering more efficient customer service. Secondly, incorporating advanced BDACs is critical in implementing CEPs. In the context of CE, BDACs, through marketing analytics activities, allow the identification of opportunities to anticipate customers' changing needs and preferences that may influence the

design of future circular products. This statement is consistent with the recommendation from Dam et al. (2019) to leverage BDA to promote collaboration and co-creation of products and services with suppliers and customers. By identifying historical patterns and correlations in the data, companies can make informed decisions on adapting their marketing strategies to maximize impact.

Furthermore, BDACs aid in the intelligent selection of environmentally friendly raw materials for production and reduce defects and wastage (Bag and Pretorius 2022). In this line, de Souza et al. (2021) explain that certain BDACs enable the development of marketing strategies in the retail sector that optimize pricing, purchasing, sales, and operations management, leading to the implementation of CEPs aimed at reducing food waste. In conclusion, without these BDACs, efficient and sustainable supply chain management and CE would be hindered (Tipu and Fantazy 2023), as the necessary tools to address challenges proactively and effectively would be lacking. Agreeing with this position, scholars such as Kristoffersen et al. (2021) and Bag et al. (2021) underscore the importance of these capabilities in elevating resource orchestration and fostering a sustainable competitive advantage.

NCA analysis shows how BDACs are a necessary condition to achieve satisfactory levels of SCMCs, CEPs, and SP. These results support the idea of the necessity logic approach. In particular, bottleneck analysis suggests that BDACs are required to achieve moderate levels of SCMCs and CEPs, which can only be achieved in the presence of BDACs. From the perspective of necessity logic, BDACs are required to achieve adequate levels due to the strict dependence on predetermined conditions (Dul et al. 2023). Necessity logic posits that certain elements are critical and required for a desired outcome to occur. In the context of sustainability, it is argued that the capabilities of big data are a necessary condition because they are essential for informed and strategic decision making in supply chain management and CE (Talib et al. 2023).

The bottleneck analysis also shows that two necessary conditions are required to achieve even low SP levels: SCMCs and CEPs must be at a primary low degree. However, achieving excellence in SP demands BDACs at a medium–high level. Combining the results generated by PLS-SEM and NCA, it can be observed that BDACs are a significant antecedent and a necessary condition for SCMCs and CEPs (must-have factor). Nevertheless, it should be emphasized that ranges of BDACs above moderate levels are required to achieve exceptional SP results.

Finally, our study has facilitated the identification that companies still have room for improvement in utilizing BDACs to achieve optimal SP; thus, not prioritizing the development of these capabilities may affect the positive impact of SCMCs and CEPs on SP. Since BDACs are

necessary to achieve excellence in SP, it is emphasized to continue developing and strengthening these capabilities. The IPMA results indicate that BDACs can still influence SP improvement and should be driven by management as they are essential performance enablers (Akter et al. 2016). Thus, it shows that the score of BDACs is close to the mean value in terms of importance in its total effect on SP, even above the role played by the SCMCs variable but below the influence generated by CEPs. Building on this using the cIPMA technique, we observe in our sample that many companies (45.7%) have not yet reached the required level of BDACs to achieve SP performance above 80%. This means that improving BDACs should become a priority for these companies. Unless this bottleneck is overcome, investment in the other variables will not lead to excellence in SP. Moreover, the PLS-SEM results indicate that BDACs do not directly affect SP significantly. However, they have a significant total effect as the influence on SP is indirect. These results are consistent with previous studies that found that the relationship between BDACs and SP was not significant and that the implementation of CEPs and SCMCs mediates this relationship (Cheng et al. 2021; Kristoffersen et al. 2021; Riggs et al. 2023). Furthermore, this study supports the theoretical proposition posited by the perspective of IT-enabled organizational capabilities, suggesting that IT resources and capabilities are necessary to enable other organizational capabilities, ultimately affecting performance (Li et al. 2023). This research contributes to expanding the emerging body of literature that employs this perspective to explain and contrast the potential mediating capabilities that lead to creating value from big data (Li et al. 2023; Sáenz et al. 2022).

Practical implications

The findings of the present study have practical implications. Managers must be aware that more than implementing BDACs is necessary to achieve positive SP—it must be linked to CEPs and SCMCs. In this context, our results have confirmed Hypothesis 3, which validates that BDACs are an essential element but insufficient to improve SP. Meanwhile, the presence of BDACs is necessary, and their connection and alignment with the principles and goals of CE and supply chain management are considered crucial to achieving optimal levels of SP. As confirmed by Hypotheses 1 and 2, our results ensure that BDACs are also necessary for developing CEPs and SCMCs, enablers of SP. Therefore, our study can serve as a valuable guide to help managers consider investing in BDACs due to their importance in improving adaptability and flexibility in the supply chain in terms of information sharing, coordination, integration, and responsiveness, allowing companies to cope with the complexities and uncertainties of the supply chain. BDACs

help identify bottlenecks and areas for improvement in the supply chain. By monitoring and analyzing real-time data, companies can proactively detect potential issues and take corrective actions before they negatively affect product availability. This directly affects marketing strategies by ensuring an efficient and reliable supply chain.

Moreover, adopting CEPs must be supported using BDACs due to the importance of acquiring, processing, and using large volumes of information and knowledge; hence, the value of big data analytics to enable the ambitious reengineering processes and complex operational systems necessary to transition to a circular economy model. The ability to transform large datasets into valuable information enhances the effectiveness of CEPs, providing a more precise and sustainable approach to resource management and minimization of environmental impacts. BDACs are based on data availability, enabling companies to integrate processes and share resources, extend the product's shelf life, and promote the reuse and recycling of materials, allowing companies to achieve their economic, environmental, and social objectives. Through marketing analytics based on extensive datasets concerning consumer behavior, preferences, and market trends, companies can obtain valuable information on how to design products that are more sustainable and aligned with the principles of CE. For example, they can identify alternative materials that are easier to recycle or develop modular products that can be easily disassembled and repaired.

Finally, our findings indicate that high levels of BDACs performance are required to achieve excellence in SP. BDACs help companies identify areas of inefficiency and waste in their operations. BDACs enable companies to collect and analyze data on their stakeholders' opinions, preferences, and needs, including customers, employees, local communities, and interest groups. This helps them better understand the expectations of these groups and make decisions that promote corporate social responsibility and equity. Focusing on marketing analytics, companies can also identify emerging sustainability trends, such as shifts in consumer preferences toward more eco-friendly products or environmental concerns in certain regions. This enables companies to adapt their marketing strategies to capitalize on these trends and meet market demands. Because there is still room for improvement in the performance that companies can achieve in this variable, and many companies have not yet reached a level in BDACs high enough to guarantee a performance above 80% in SP, this leads us to recommend that companies place priority on their efforts and investments in this variable.

Limitations and future research

The study was limited in several ways. For one thing, it has relied on participant perceptions of their organization's situation regarding the survey elements. This introduces the risk that subjective impressions of respondents do not necessarily reflect objective reality. In addition, the study has examined only the variables and constructs in one country and used unique qualifiers. For example, the sample was selected based on inclusion within sectors identified by the European Commission as having the potential to benefit from a circular economy model. Therefore, the study should be replicated using different demographic and geographic criteria.

Future studies on the necessity of BDACs for sustainable performance could further investigate variables outside of SCMCs and CEPs as alternative necessities for sustainable performance. Current concerns about environmental uncertainty and existing research could indicate that environmental stability is necessary to justify investments in SCMCs and CEPs implementations. Additionally, analyses could consider the necessity of SCMCs and CEPs for sustainable performance independent of BDACs. Lastly, a longitudinal comparison of the results could indicate whether the necessity of these elements depends on the organization's maturity.

Appendix

Construct/*Dimension*/Indicator

Big data analytics capabilities. Source: Raut et al. (2021)

Our organization is capable of parallel computing to address voluminous data

Real-time assess of data and information has helped our organization in better decision making

Our information systems are capable to handle semi-structured and unstructured data

Truthfulness and accuracy of data has helped our organization

Data driven intelligence has made decision making more effective

Our organization has good infrastructure and facilities to support analytics

Interchange ability of services (cloud, mobile, and analytics) plays key role

Analytics personnel are proficient with programming, data management, new tools etc

Supply chain management capabilities (HOC). Source: Wu et al. (2006)

Information exchange

My firm exchanges more information with our partners than our competitors do with their partners

Information flows more freely between my firm and our partners than between our competitors and their partners

My firm benefits more from information exchange with our partners than do our competitors from their partners

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Construct/*Dimension*/Indicator

Our information exchange with our partners is superior to the information exchanged by our competitors with their partners

Coordination

My firm is more efficient in coordination activities with our partners than are our competitors with theirs

My firm conducts transaction follow-up activities more efficiently with our partners than do our competitors with theirs

My firm spends less time coordinating transactions with our partners than our competitors with theirs

My firm has reduced coordinating costs more than our competitors

My firm can conduct the coordination activities at less cost than our competitors

Integration

My firm develops strategic plans in collaboration with our partners

My firm collaborates actively in forecasting and planning with our partners

My firm projects and plans future demand collaboratively with our partners

Collaboration in demand forecasting and planning with our partners is something we always do in my firm

My firm always forecasts and plans activities collaboratively with our partners

Responsiveness

Compared to our competitors, our supply chain responds more quickly and effectively to changing customer and supplier needs

Compared to our competitors, our supply chain responds more quickly and effectively to changing competitor strategies

Compared to our competitors, our supply chain develops and markets new products more quickly and effectively

In most markets, our supply chain is competing effectively

The relationship with our partners has increased our supply chain responsiveness to market changes through collaboration

Circular economy practices (HOC). Source: Riggs et al. (2023)

Governance initiatives

Our organization has developed a set of performance indicators in order to evaluate our recycling, reuse and remanufacture initiatives in supply chain

Our organization has increased the number of employees in circular economy positions

Economic initiatives

Our organization favors economic growth opportunities that have minimal environmental impact

The price of our products includes costs associated with reuse, recycle and remanufacturing

Cleaner production

Our organization has experienced increased eco-efficiency in production through the use of reduce, reuse, recycle, recover, redesign, and remanufacture

Our organizational purchasing processes consider sustainability factors in addition to price

Our organization experiments with new strategies in supply chain to constantly improve our circular economy efforts

Our firm collaborates with other organizations in order to make it possible to reuse/recycle/remanufacture

Construct/*Dimension*/Indicator

Our organization classifies the materials as either those candidates for reuse/recycle/remanufacture, or those that can be safely returned to the environment

Our organization reviews logistical routes and modes for constant improvement in terms of sustainability

Our organization utilizes equipment specifically designed to produce output that can be remanufactured

Our organization has implemented measurable data gathering systems to measure the environment performance in regards of the initiatives by implementing circular economy in supply chain

Product development

Our organization's products are designed as durable products for multiple cycles of use and for disassembly and reuse

Management support

Top managers of our organization actively endorse the circular economy efforts in supply chain

Knowledge

Our organization supports education and awareness programs that support recycling, remanufacturing and reuse among actors in our supply chain

Our organization implements formal training programs that educate our workforce about circular economy concepts and benefits in the supply chain

Our organization demonstrates visionary thinking and technical creativity to implement circular economy in supply chain

Sustainable performance (HOC). Source: Çankaya and Sezen (2019)

Economic performance

Decrease in cost of materials purchased

Decrease in cost of energy consumption

Decrease in fee for waste discharge

Improvement in earnings per share

Improvement in return on investment

Sales growth

Profits growth

Social performance

Improvement in customer satisfaction

Improvement in its image in the eyes of its customers

Improvement in investments on social projects (education, culture, sports)

Improvement in relations with community stakeholders, e.g., nongovernmental organizations (NGOs) and community activists

Improved awareness and protection of the claims and rights of people in community served

Improvement in employee training and education

Improvement in occupational health and safety of employees

Improvement in overall stakeholder welfare or betterment

Environmental performance

Improvement of an enterprise's environmental situation

Reduction in waste (water and/or solid)

Reduction in air emission

Decrease of consumption for hazardous/harmful/toxic materials

Decrease of frequency for environmental accidents

HOC higher-order construct

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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