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Leveraging green innovation from big data analytics: Examining the role of resource orchestration and green dynamic capabilities

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Abstract

PURPOSE: *The notion of big data analytics (BDA) has received increased attention from both researchers and managers. Keeping in view the significance of BDA, the current research aims to examine the role of BDA capability to leverage firm green innovation (GI). Drawing from the dynamic capability view, current study suggests that BDA capability prompts green dynamic capabilities (DCs), enabling organizations to attain GI successfully. Particularly, present study proposes that BDA analytics prompt GI directly as well as through green DCs. Moreover, this study also draws from complementarity perspective and proposes that resource orchestration capability (ROC) is likely to enhance the effectiveness of green DCs in eliciting GI. Thus, the objectives of the current study are threefold; first, it aims to unveil the role of BDA capability in prompting GI; second, it examines the mediating role of green DCs for the relationship between BDA capability and GI; and third, this research examines the moderating effect of ROC to examine if it strengthens the effects of green DCs.* ***METHODOLOGY:*** *This study involves testing hypotheses using primary data collected by using the method of survey questionnaire. The data were collected from 291 Pakistani organizations. Pakistan is an emerging economy where businesses are responsible for substantial amounts of carbon di-oxide and greenhouse gasses (GHG) emissions. Therefore, Pakistani organizations serve as a suitable context for the study. The respondent organizations were from both the manufacturing and service sectors. PLS-SEM was employed as an analytical approach for testing the hypotheses. Construct validity and reliability were confirmed prior to hypotheses testing.* ***FINDINGS:*** *Results demonstrate that BDA capability positively affects GI (β=0.33, $p<0.01$), indicating that organizations with strong BDA capabilities involve in GI activities. Likewise, results indicate a positive relationship between BDA capability and green DCs (β=0.35, $p<0.01$) and between green DCs and GI (β=0.50, $p<0.01$). Results also indicate that green DCs play a mediating role between BDA capability and firm GI (β=0.18, $p<0.01$). This indicates that BDA capability is an imperative capability of organization that promotes green DCs and fosters GI. Finally, findings indicate that ROC strengthens the effectiveness of green DCs in prompting GI (β=0.14, $p<0.01$).* ***IMPLICATIONS:*** *Findings imply that organizations that prioritizing green innovations (GI) should invest more in developing BDA capabilities. These actions may involve acquiring and analyzing large volumes of data associated with sustainability, which can provide insights and support decision-making processes. By leveraging BDA capability, managers can uncover insights and patterns that can help them make informed decisions, recognize areas for improvement, and devise innovative solutions to align organizational strategic objectives with sustainability goals.* ***ORIGINALITY AND VALUE:*** *This study contributes to the literature by offering an integrated framework based on BDA and DCs to seek solutions to economic concerns while ensuring the sustainability value of the business activities. The findings also imply that businesses should focus on developing ROC, and integrating them with green DCs to further enhance GI initiatives.*

Keywords: *big data analytics capability, green innovation, green dynamic capabilities, resource orchestration, PLS-SEM*

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INTRODUCTION

Over the past few years, big-data analytics' significance has gained growing attention (Jiang et al., 2024; Su et al., 2022). Big data are enormous, diverse sets of data having numerous kinds and quantities of information; they need peculiar infrastructure, resources, and platforms (e.g., big data analytics) to process and generate valuable results (Gupta & George, 2016). Big data analytics (BDA) explicates a general approach for processing, managing, and analyzing the volume, variety, velocity, veracity, and value of large data sets to generate superior solutions and innovative ideas for competitive advantage (Mikalef et al., 2020; Wamba et al., 2015). By using BDA, organizations can make sense of large amounts of data to generate better-informed decisions, gain valuable insights, and reconfigure their strategies (Brewis et al., 2023). BDA enables organizations to extract valuable information from various data sources (e.g., customer feedback, market trends, and competitor activities) to develop data-driven and evidence-based strategies (Garmaki et al., 2023; Su et al., 2022). Therefore, BDA capability has the capacity to transmute business activities and recognize challenges and opportunities of these activities so that the information can be used to formulate strategies and policies to achieve strategic goals (Su et al., 2022). The capacity to integrate BDA effectively helps organizations to achieve organizational goals, gain sustainable competitive advantage, and deliver values to stakeholders (Al-Khatib, 2022; Chen & Liang, 2023) because by incorporating BDA across decision-making, businesses can improve their agility and responsiveness to changes in the external environment. However, creating a balance between the BDA resources remains a challenge for the organizations to undertake environmentally friendly business activities through green innovation (i.e., innovations in products and processes that can direct the organizations to achieve competitive advantages ecologically) (Benzidia et al., 2024; Itani et al., 2024; Xin et al., 2023). Thus, the first objective of current study is to unveil the role BDA capability plays in prompting green innovation (GI).

It is suitable to argue that the organizations aimed at achieving green GI from BDA capability need to develop new and/or reconfigure existing capabilities, which could transform the impact of BDA towards GI more proficiently. This proposition is based upon the extant literature that recognizes the significance of firm capabilities and resources in attaining superior performance, innovation, efficiency, and competitive advantage by (re)constructing dynamic capabilities (e.g., Mikalef et al., 2020; Sing & El-Kassar, 2019), which are successively generated by combining and organizing several capabilities, and are difficult to imitate by the competitors (Leemann & Kanbach, 2022). In the present study, we argue that green dynamic capabilities (DCs) will likely offer an underlying mechanism for BDA capability (besides direct nexus) to promote GI. Green DCs denote the unique competence of the organizational ability of sensing, seizing, and reconfiguring internal and external resources, including technological and green processes, to meet the changes in the business environment and to develop new organizational strategic decisions (Eisenhardt & Martin, 2000; Zahra et al., 2022). Furthermore, the development of DCs helps organizations to align internal and external resources to foster performance and promote sustainability (Ahmad et al., 2024; Li et al., 2024; Zhu et al., 2023). However, it is imperative to comprehend how green DCs prompt sustainable and eco-friendly performance. Hence, the second objective is to examine the mediating effect of green DCs on the relationship between BDA capability and GI.

The influence of green DCs on GI is likely to be contingent on contextual factors, e.g. resource orchestration. Although green DCs are important in transforming business activities by capturing and developing knowledge regarding products, markets, customers, and environment; resource orchestration is essential to assess and apply such knowledge by mitigating internal conflict and enhancing resource complementarities in the organization (Grimpe & Hussinger, 2014; Sirman et al., 2011). Recent studies have highlighted the role of resource orchestration in terms of an organization's internal capacity that structures, bundles, and leverages resources to transform knowledge to achieve innovation and competitiveness (e.g., Wang et al., 2020; Xin et al., 2023). We assert that ROC complements green DCs in transforming and applying knowledge towards building GI. The third objective of this research is to investigate the moderating role of ROC and asses if it strengthens the effects of green DCs in determining GI.

To fill the research gap, this study attempts to highlight *why* and *how* BDA capability influences GI. To answer *why*, this study argues that BDA capability is an important source of knowledge derived through processing, organizing, and analyzing huge amounts of data and that organizations use such knowledge to respond to external changes and market through innovations that also reap ecological benefits along with economic return (first objective). To answer *how* this study proposes that organizations use knowledge derived through BDA capability to develop green DCs to achieve GI effectively (second objective). In this way, we suggest green DCs as mediating mechanisms linking BDA capability and GI. Furthermore, the literature suggests that various contextual factors influence the extent to which firm-level antecedents predict outcomes. In this regard, we argue that ROC plays a contingent role in complementing the effect of green DCs in predicting GI (third objective). Figure 1 displays the proposed research model.

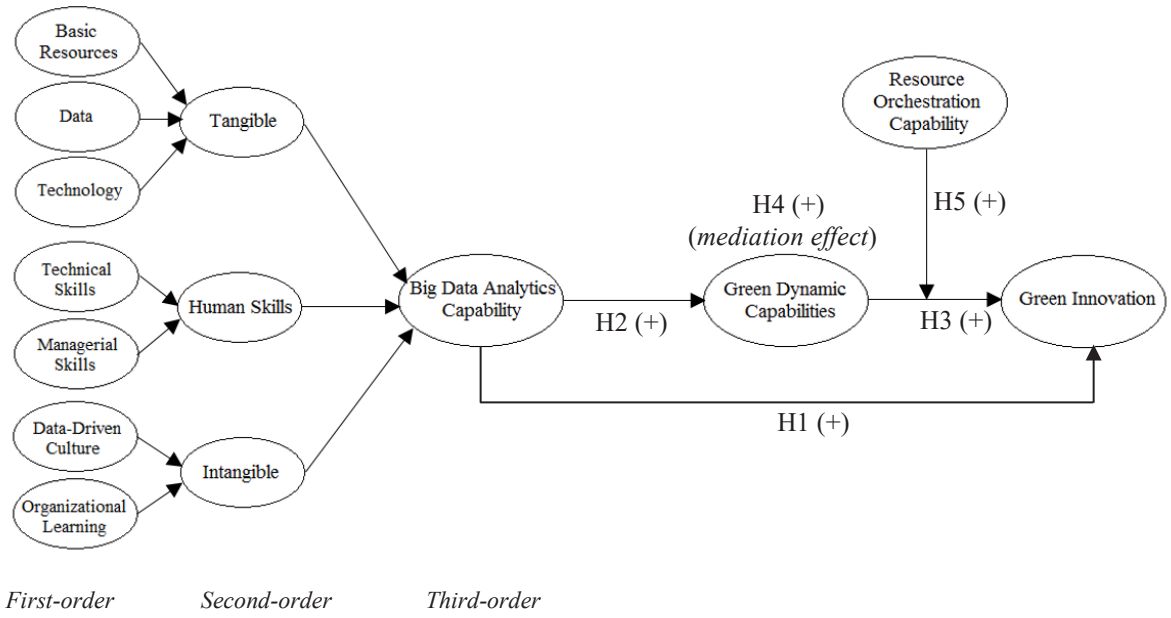


Figure 1. Proposed research model

LITERATURE REVIEW

Big data analytics capability

BDA capability refers to „ a firm's ability to assemble, integrate, and deploy its big data-specific resources" (Gupta & George, 2016, p. 1051). According to Gupta and George (2016), BDA capability is a third-order construct comprising human skills and tangible and intangible resources related to big data. These three pillars of BDA capability are second-order constructs and represent infrastructure, resources, technology, and skills essential for collecting, processing, and analyzing large volumes of data. Big-data related tangible resources encompass data, technology, and basic resources to implement BDA, whereas intangible resources focus on development of "data-driven culture" and "continuous organizational learning." These big-data-oriented resources provide necessary technology and basic resources to establish BDA infrastructure. However, human skills (i.e., technical and managerial skills) enable organizations to utilize these resources (Mikalef et al., 2020).

Past studies showed that organizations use market information as a key source to meet the customers demands by introducing innovative products and processes (Demirel & Kesidou, 2019; Zahra, 2021). Research on BDA suggests that organizations using data-related capabilities have more propensity to gain competitive advantage and environmental performance because incorporation of BDA enables organizations to make sense of and capture critical insights from huge volumes of data (Behl, 2022; Garmaki et al., 2023; Jiang et al., 2024; Ranjan & Foropon, 2021). Empirical studies have revealed that BDA capability is a key factor to prompt dynamic and operational capabilities which help organizations to achieve superior performance outcomes (Mikalef et al., 2019). Moreover, Mariani and Wamba (2020) noticed that BDA offers insights into market trends, external changes, competition, and consumer behavior based on information extracted from the huge amount of data (Bartosik-Purgat & Ratajczak-Mrozek, 2018). Given the advancement of big data, organizations need to cultivate big data analytic capabilities with the aim of deriving significant insights to make sensible decisions (Brewis et al., 2023; El-Kassar & Singh, 2019). Keeping in view the significance of environmentalism, that is why, this study attempts to examine if BDA capability plays a crucial role in prompting green DC and green innovation.

Big data analytics capability and green innovation

Due to the growing concerns about ecology and environmental protection, organizations are inclined to transform products, services, and processes to ensure that business operations are less harmful to society and the environment (Hofmann & Jaeger-Erben, 2020; Paredes-Chacin et al., 2024; Zhu et al., 2023). Under this motivation, green innovation (GI) has become essential to business activities. It revolves around the idea of improving existing and/or offering new

products and processes that are more sustainable, eco-friendly, and protect the environment (Khanra et al., 2022; Takalo & Tooranloo, 2021). GI in processes gives the opportunity to save energy, prevent pollution, and recycle waste material, whereas offering green products helps capture increased market share. Extant studies indicate that green/eco-friendly products are gaining popularity across the atlas, and organizations are reaping financial benefits besides mere compliance with principles of environmentalism. For example, Yi et al. (2023), in a meta-analytical study, noted that green products lead to sales increase and enhance competitive performance. The „green" gives a direction in searching customers' concerns, seizing new market opportunities, and creating value for their customers by producing eco-friendly products. Indeed, green innovation is considered a strategic tool required for organizations that give the opportunity to fulfill customer demand without harming the environment (Dong et al., 2024; Xie et al., 2019).

Big data serves as a significant tool in enhancing a firm's efficiency in assessing new opportunities (Olabode et al., 2022). BDA capability is dynamic in nature as it fosters innovation by providing the organizations with innovative insights and actionable information. Valuable insights gained from BDA can help organizations to identify environmental problems and find innovative solutions to resolve such problems (Mikalef et al., 2018). Organizations can use BDA to identify trends and patterns of market changes, hence enabling to improve processes, reduce waste, and enhance energy efficiency to create economic value while ensuring environmental sustainability (Beier et al., 2022). Furthermore, BDA capability enables organizations to analyze consumer behavior and market preferences and gain insights into the demand for eco-friendly products, thereby promoting sustainable consumption through developing eco-friendly products and services (Chen et al., 2021). Furthermore, recent body of research has noticed that big-data analytics are important for fostering green practices, eco-innovation, and environmental performance. For example, Arici et al. (2023) found that BDA assists hospitality organizations in evaluating customers' feedback regarding green service quality and offers a roadmap to foster innovative green processes. Al-Khatib (2022) advocated that BDA capability enabled Jordanian firms to improve green supply chain performance by promoting GI. In addition, Chen and Liang (2021) and Dong et al. (2024) found that BDA capability strengths the effect of internal and external factors, which in turn facilitate the development of green solutions and innovation performance. Therefore, it is proposed that BDA capability is likely to promote GI.

H1: BDA capability has a positive relationship with GI.

Big data analytics and green dynamic capabilities

Green DC is defined as „ability of a company to exploit its existing resources and knowledge to renew and develop its green organizational capabilities to react to the dynamic market" (Chen & Chang, 2013, p. 109). Green DCs represent the firm's proficiency to identify, develop, and deploy resources and capabilities related to sustainable and environmentally friendly practices. These capabilities enable a firm to adapt and thrive in an ever-changing business landscape while addressing growing environmental concerns (Singh et al., 2022). As a result, green DCs create value for the organization by changing the ways of doing business with respect to changes in trends, competition, and the external environment (Chen & Chang, 2013; Yuan & Cao, 2022). Green DCs enable organizations to mitigate environmental risks and help them capitalize on emerging market opportunities related to sustainability, hence establishing a competitive advantage in the long run (Mazon et al., 2023). Studies have found the significance of traditional and green DCs in fostering competitive advantage, superior performance, firm green image, and goodwill (Singh et al., 2022; Yousaf, 2021; Zhu et al., 2023). We argue that BDA capability helps organizations prompt green DCs so that organizations could (re)shape how to create value and embed sustainable practices.

BDA offers organizations information about several aspects of business operations, such as external market trends, resource consumption, areas of excessive usage or waste, potential risks, and future demand, hence optimizing organizations' ability to monitor what is happening in terms of trends, opportunities, and threats related to green practices (Mikalef et al., 2019). Moreover, information through predictive analysis can be used to make informed decisions for utilizing and exploiting resources and opportunities to implement green initiatives (Bresciani et al., 2022; Zhu et al., 2023). Likewise, BDA helps organizations regularly update and revise their green practices based on feedback, learning, and improvements to achieve long-term sustainable outcomes (Su et al., 2022; Singh & El-Kassar, 2019). BDA capability, which encompasses the provision of valuable insights derived from diverse data sources across various business domains, is expected to prompt green DCs by letting the organizations aware of sustainability opportunities (sensing), taking action to capitalize on them (seizing), and continuously adapting to stay at the forefront (reconfiguring) of eco-friendly practices for overall business success. In this way, BDA capability prepares organizations to take proactive steps to tap into opportunities and

improve environmental performance (Saeed et al., 2023; Wamba et al., 2024). Resultantly, BDA facilitates organizations to continuously review and adjust existing systems, processes, and strategies in response to changing environmental contexts, i.e., reconfiguration of resources.

H2: BDA capability has a positive relationship with green DCs.

Green dynamic capabilities and green innovation

Green innovation offers economic and environmental benefits by reducing greenhouse gas emissions (GHG), industrial waste, resource usage, and energy consumption and protecting the environment (Khanra et al., 2022; Singh et al., 2022). In this regard, extant literature suggests many antecedents that provide a significant contribution in developing and supporting GI. The present study proposes green DC as a key predictor of GI. Originating from RB-V, the dynamic-capability perspective advocates that DCs allow organizations to continuously adapt and innovate in response to changes in market trends, technological advancements, and evolving customer preferences (Teece & Pisano, 2003). With sensing, seizing, and reconfiguring at its heart, DCs facilitate organizations to effectively identify and seize new opportunities while enabling organization to successfully respond to potential threats and challenges in the business operating environment (Baia & Ferreira, 2024). Drawing from a dynamic-capability perspective, it is submitted that green DCs are expected to facilitate organizations to identify gaps, opportunities, and areas where sustainable actions are needed (Bornay-Barrachina et al., 2023; Alshanty & Emeagwali, 2019). For example, sensing enables organizations to monitor environmental and market trends, and recognize societal needs and challenges related to sustainability. By understanding the environmental needs along with customer demands and regulatory changes, organizations can gain valuable insights necessary for initiating GIs (Teece, 2018).

Similarly, green DCs facilitate resources allocation, goals setting, and establishment of strategic partnerships to address the identified gaps and/or market demands; ensuring that potential sustainable opportunities are not overlooked (Bogers et al., 2019). As a result, green DCs, through seizing, help organizations take proactive measures in developing and implementing green initiatives. Finally, the reconfiguring element of green DCs assists organizations in transforming their resources, existing business processes, and systems to accommodate GI (Conboy et al., 2020; Teece, 2018). These green initiatives involve many actions, including changes in production methods, energy usage, waste management, and product design. Hence, green DCs are expected to align an organization's activities with its commitment to green practices and ensure that innovation is well applied and integrated into products and core operations of the organization.

H3: Green DC has a positive link with GI.

Mediation effect of green dynamic capabilities

Green DCs are expected to serve as a mediating mechanism and link BDA capability with GI. Besides direct influence of BDA capability on GI, green dynamic capabilities are expected to mediate how BDA capability prompts green innovation through green capabilities. As argued earlier, BDA capability can influence green DCs by fostering sensing, seizing, and reconfiguring (Teece, 2018). BDA capability helps organizations collect, process, and analyze large volumes of data from various sources in real-time or near real-time (Mikalef et al., 2020). This enables organizations to sense changes, identify trends, and recognize patterns and anomalies in the data, which are not readily obvious through traditional methods. The ability to sense such information helps organizations make more informed decisions and take timely actions (Yousaf, 2021).

Contrary to that, organizations less proficient in sensing external changes are less likely to prepare and adapt to change and competition. BDA capability also allows organizations to seize strategic opportunities and competitive edge by identifying actionable insights from the data. Moreover, these actionable insights help organizations reconfigure and transform resource bases, processes, and business operations (Yuan & Cao, 2022). Green DCs, in turn, lead towards changes in existing and/or offering of new products, processes, and practices that are sustainable and eco-friendly, hence promoting green innovation (Yuan & Cao, 2022; Zhu et al., 2023). This implies that organizations' inability to tap into opportunities, mitigate risk, and respond to challenges may lead to operational and financial setbacks. In simple words, BDA capability is an important factor that determines green dynamic capabilities, which in turn promote GI. In this way, it is expected that green DCs serve as a mediating mechanism for the association between BDA capability and GI.

H4: Green DCs play mediating role between BDA capability and GI.

Resource orchestration capability as moderator

Resource orchestration capability (ROC) refers to a firm's ability to „structure the resource portfolio, bundling the resources to build capabilities, and leveraging those capabilities to create and maintain value for customers and owners" (Sirmon et al., 2007, p. 273). Rooted in the resource-based view (RBV), ROC indicates how effectively organizations combine, allocate, and deploy resources to achieve strategic goals. ROC comprises three elements: structuring, bundling, and leveraging (Sirmon et al., 2011; Sirmon et al., 2007). Structuring represents an organization's actions to acquire, accumulate, and divest resources. Bundling emphasizes building capabilities by improving and extending existing capabilities and developing new competencies and/or, finally, leveraging focuses on mobilizing resources to create value.

This research proposes that ROC may strengthen the nexus between green DCs and GI. Drawing from complementarity perspective (Adegbasen, 2009; Harrison et al., 2001; Song et al., 2005), we propose that ROC works together with green DCs to have a synergistic effect and increases the effectiveness of green DCs in eliciting green innovation. Since green DCs involve the continuous development and adaptation of innovative practices to address environmental challenges, resource orchestration capability allows for the integration, coordination, and efficient utilization of diverse resources (Sirmon et al., 2007), such as human, financial, and technological, to support green innovation initiatives. It also helps to coordinate and align the activities of different operational units within an organization toward green innovation goals. With ROC, organizations can effectively combine, allocate, and deploy pool of resources (Peterson et al., 2023; Wang et al., 2020) which allows for continuous development and adaptation of innovative practices to address environmental challenges.

Furthermore, ROC is likely to enable organizational learning and adaptation in the context of green innovation. ROC facilitates organizations to identify and acquire new resources, enhance employee learning and skills development, and adapt to changing environmental requirements (Kristoffersen et al., 2021). This improves a firm's ability to continuously innovate and create environmentally-friendly products and processes. Hence, Resource orchestration capability enables the efficient allocation, integration, and coordination of diverse resources, and innovative solutions enabling the organization to amplify the effect of sensing, seizing, and reconfiguring abilities to develop sustainable, innovative solutions (see Andersen, 2023; Mao et al., 2024). In sum, green DCs, when combined with ROC, increase an organization's effectiveness in fostering green innovation.

H5: ROC moderates the relationship between green DCs and GI in such a way that the relationship is strong at a high level of resource orchestration.

RESEARCH METHODOLOGY

Sample and data collection

The present research involves testing hypotheses using primary data collected by using the survey questionnaire. We collected data from service and manufacturing sector organizations working in Pakistan. Pakistan is an emerging economy where businesses are responsible for substantial amounts of carbon di-oxide and greenhouse gasses (GHG) emissions. According to the European Commission, Pakistan falls among polluted countries (low air quality index), and its economy is responsible for 1.02% of global GHG emissions (Crippa et al., 2023). Furthermore, as an emerging economy, businesses are embedding ICT solutions and big-data tools for improving economic, operational, and sustainability performance. Therefore, Pakistan represents a suitable study context.

Following the guidelines from extant studies (e.g., Del Vecchio et al., 2018; Maroufkhani et al., 2023), we targeted only medium-sized and large firms. In this regard, we used a criterion of a minimum of fifty employees working in the organization as firm size, hence to exclude small and micro firms. We used this criterion because it is expected that small and micro firms have strict financial constraints that lead them to outsource big data-related sources instead of investing in developing big data infrastructure within the organization. However, medium and large organizations are more capable of possessing their own data resources and infrastructure (Kim et al., 2022; McAfee & Brynjolfsson, 2017). Secondly, we set a minimum of six years as a criterion of firm age to select the sample because, for innovations, Li and Liu (2014) advocated that new organizations are more prone to innovations and newness, and it takes at least four years for a start-

up to get into routine. Therefore, there is a greater likelihood of nascent organizations inclined towards sustainable and eco-innovations. Hence, to reduce the potential influence of newness toward green innovation, we targeted organizations that had been working for at least six years at the time of data collection.

The unit of analysis is organization; key respondents were top-level managerial employees, and one response was collected from each organization. Top-level managerial employees possess a broad perspective as they oversee the entire organization and have a holistic view of its operations. Hence, in the context of BDA and innovation capabilities, top-level managers possess the necessary information and can provide more accurate information regarding study constructs. We used convenience sampling and one of the authors approached the respondents using professional and personal linkages. The data were collected from 291 organizations from the following industries: textile (41), pharmaceutical (34), general electric and electronics (27), agribusiness (19), food and beverages (29), advertising (4), education (6), chemical (21), travel and tourism (31), leather (20), banking and financial (23), and FMCG (36).

Construct measurement

BDA capability was operationalized as a third-order latent construct, and the measurement scale was adapted from Mikalef et al. (2019). BDA capability has three dimensions: human skills and tangible and intangible resources. These three dimensions represent second-order latent constructs. Human skills comprise two first-order constructs with six items each (managerial skills, technical skills), and tangible resources comprise three first-order constructs (basic resources – 2-items, data – 3-items, technology – 5-items). Intangible resources comprise two first-order latent constructs with five items each (data-driven culture, organizational learning). A 7-item scale was adopted to measure green DCs (Chen & Chang, 2013). GI is operationalized as eco-friendly innovations in products, processes, and managerial activities. An 8-item scale was adapted from Chiou et al. (2011) to measure green innovation. To measure resource orchestration capability, a three-item scale was adapted from Wang et al. (2020). We controlled the effects of firm age and size.

RESULTS

Validity, reliability, and correlation analysis

Prior to hypotheses testing, we examined the validity as well as reliability of the constructs. We employed a PLS-SEM approach and used WarpPLS 7.0 (Kock, 2018) to perform confirmatory factor analysis (CFA) for construct validity. PLS-SEM has been preferred over covariance-based SEM (CB-SEM) because it considers measurement errors when aggregating latent indicators to calculate latent variables, unlike CB-SEM, which does not consider these errors. According to Henseler et al. (2015), neglecting measurement errors is likely to lead to bias as they serve as additional indicators. Additionally, PLS-SEM increases theoretical parsimony because it eliminates complexity when estimating hierarchical models by making flexible assumptions (Kock, 2018). Finally, BDA capability comprises formative indicators, which are limited in analysis by CB-SEM, while PLS-SEM allows the incorporation of both reflective and formative indicators (Sarstedt et al., 2021). The results in Table 1 show factor loadings, AVEs, and full-collinearity VIF. The values of factor loadings and AVEs ensure convergent validity as the values cross the threshold to accept the values, i.e., 0.5 (Hair et al. 2014). This ensures convergent validity. However, Kock (2015) advocated that full-collinearity VIF is an effective test in the context of PLS-SEM to address the issue of common method bias. A value of full-collinearity VIF less than 5 indicates that common method bias is not a significant issue.

Table 1. Results of confirmatory factor analysis for construct validity

Construct	Indicator	Loading	AVEs	Full collinearity VIFs
Data	DT01	0.870	0.791	2.035
	DT02	0.909		
	DT03	0.889		
Technology	TEC01	0.912	0.832	3.728
	TEC02	0.901		
	TEC03	0.922		
	TEC04	0.918		
	TEC05	0.908		

Construct	Indicator	Loading	AVEs	Full collinearity VIFs
Basic Resources	BR01	0.950	0.902	2.352
	BR02	0.949		
Technical Skills	TS01	0.893	0.811	4.254
	TS02	0.918		
	TS03	0.918		
	TS04	0.886		
	TS05	0.898		
	TS06	0.891		
Managerial Skills	MS01	0.858	0.776	2.576
	MS02	0.870		
	MS03	0.880		
	MS04	0.899		
	MS05	0.903		
	MS06	0.873		
"Data-driven-Culture"	DD-1	0.825	0.708	2.131
	DD-2	0.867		
	DD-3	0.839		
	DD-4	0.850		
	DD-5	0.824		
Organizational Learning	OL01	0.758	0.567	1.319
	OL02	0.789		
	OL03	0.782		
	OL04	0.702		
	OL05	0.732		
Tangible [a]	Data	0.838	0.748	3.071
	"Technology"	0.913		
	"Basic Resources"	0.842		
Human [a]	"Technical Skills"	0.931	0.867	3.347
	"Managerial Skills"	0.930		
Intangible [a]	"Data-driven-Culture"	0.847	0.718	1.707
	"Organizational Learning"	0.845		
BDA Capability [b]	Tangible	0.902	0.771	1.382
	Human	0.928		
	Intangible	0.799		
"Green Dynamic Capabilities"	GDC-1	0.749	0.580	1.740
	GDC-2	0.840		
	GDC-3	0.713		
	GDC-4	0.698		
	GDC-5	0.842		
	GDC-6	0.752		
	GDC-7	0.724		
"Resource Orchestration Capability"	ROC-1	0.796	0.678	1.180
	ROC-2	0.866		
	ROC-3	0.806		
"Green Innovation"	GI-1	0.815	0.580	2.071
	GI-2	0.635		
	GI-3	0.657		
	GI-4	0.762		
	GI-5	0.764		
	GI-6	0.796		
	GI-7	0.813		
	GI-8	0.823		

Note: All values of factor loadings are significant at $p<0.001$, [a] second-order latent construct, [b] third-order latent construct.

To examine discriminant validity, we used both Fornell and Larcker's (1981) approach and ratios of HTMT (Henseler et al., 2015). According to Fornell and Larcker (1981), discriminant validity among constructs exists if the square roots of AVEs are less than the respective correlation coefficients (see Table 3). Table 2 provides hetero-trait-mono-trait (HTMT) ratio values, which also support discriminant validity. These results support the presence of discriminant validity.

Moreover, values of construct reliability are displayed in Table 3 since the values of composite reliability and Cronbach's Alpha exceed the threshold value, i.e., 0.7 (Hair et al., 2014); therefore, data supported construct reliability.

Table 2. HTMT ratios for discriminant validity

Construct	1	2	3	4	5	6	7	8	9
1. Data	--								
2. Technology	0.740								
3. Basic Resources	0.580	0.639							
4. Technical-Skills	0.668	0.524	0.787						
5. Managerial-Skills	0.623	0.702	0.621	0.574					
6. Data-driven-Culture	0.592	0.687	0.551	0.663	0.669				
7. Organizational Learning	0.247	0.339	0.243	0.391	0.396	0.511			
8. Green Dynamic Capabilities	0.279	0.376	0.279	0.287	0.308	0.340	0.263		
9. Green Innovation	0.717	0.454	0.364	0.423	0.431	0.467	0.342	0.573	
10. Resource Orchestration Capability	0.093	0.056	0.146	0.124	0.057	0.069	0.124	0.180	0.247

Note: All values are significant at p<0.001; good if values <0.90, best if <0.85.

Once construct validity and reliability were established, we performed correlation analysis to seek mutual relationships between study constructs. Table 3 displays coefficients of correlation and indicates that all individual dimensions of BDA capability have a positive correlation with GI with green DCs as well. These results also show a positive correlation between green DCs and GI.

Table 3. Construct reliability and correlation coefficients along with square roots of AVEs

Constructs	1	2	3	4	5	6	7	8	9	10
1. Data	**0.889**									
2. Technology	0.671	**0.912**								
3. Basic Resources	0.512	0.682	**0.950**							
4. Technical Skills	0.609	0.787	0.725	**0.901**						
5. Managerial Skills	0.562	0.664	0.569	0.734	**0.881**					
6. Data-Driven-Culture	0.521	0.633	0.496	0.617	0.617	**0.841**				
7. Organizational Learning	0.204	0.297	0.207	0.344	0.345	0.437	**0.753**			
8. Green Dynamic Capabilities	0.244	0.342	0.246	0.264	0.282	0.302	0.221	**0.762**		
9. Green Innovation	0.389	0.425	0.335	0.398	0.400	0.420	0.295	0.506	**0.761**	
10. Resource Orchestration Capability	0.051	0.035	0118	0.090	0.024	0.021	0.052	0.094	0.204	**0.823**
"Composite Reliability"	0.919	0.961	0.949	0.963	0.954	0.924	0.867	0.906	0.916	0.863
"Cronbach's Alpha"	0.868	0.950	0.892	0.953	0.942	0.897	0.809	0.878	0.895	0.762

Note: Correlation coefficients with values less than 0.11 are statistically insignificant. "The square roots of AVEs are shown on a diagonal.

Hypotheses testing

To test the hypotheses, we performed an analysis by employing PLS-SEM in WarpPLS 7.0 (Kock, 2018). To perform the analysis, we combined the dimensions of BDA capability and used them as formative indicators to make BDA capability a third-order latent construct. Similarly, we used composite scores of all three dimensions of green DCs to measure green DCs as a second-order latent construct. Table 4 shows PLS-SEM results as well as model-fit indices.

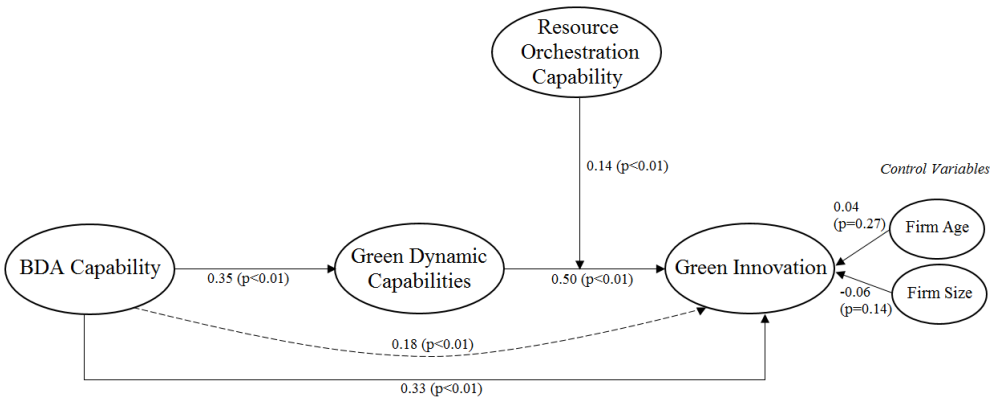
Table 4: PLS-SEM results for hypotheses testing and model-fit indices

Path	Estimate (β)	Effect size (f^2)	Remarks
BDA→GI	0.33	0.174	H1 Supported
BDA→GDCs	0.35	0.122	H2 Supported
GDCs→GI	0.50	0.332	H3 Supported
BDA→GDCs→GI	0.18	0.092	H4 Supported
ROC*GDCs→GI	0.14	0.031	H5 Supported
Firm size→GI	-0.06	0.011	
Firm age→GI	0.04	0.006	
"Model-Fit Indices"			***Value***
"Average path coefficient (APC)" *Acceptable if p<0.05*			0.212, p<0.001
"Average R-squared (ARS)" *Acceptable if p<0.05*			0.336, p<0.001
"Average adjusted R-squared (AARS)" *Acceptable if p<0.05*			0.328, p<0.001
"Average block VIF (AVIF)" *Acceptable if<=5, ideally<=3.3*"			1.078
"Average full collinearity VIF (AFVIF)" *Acceptable if<=5, ideally<=3.3*			1.339
"Tenenhaus GoF (GoF)" *Small>=0.1, medium>=0.25, large>=0.36*"			0.526
"Sympson's paradox ratio (SPR)" *Acceptable if>=0.7, ideally=1*			0.857
"R-squared contribution ratio (RSCR)" *Acceptable if>=0.9, ideally=1*			0.991
"Nonlinear bivariate causality direction ratio (NLBCDR)" *Acceptable if>=0.7"*			0.929

Note: BDA=big data analytics capability; GDCs=green dynamic capabilities; GI=green innovation; ROC=resource orchestration capability.

Results presented in Table 4 indicate that BDA capability has a positive relationship with GI (β=0.33, p<0.01), implying that BDA capability elicits green innovations. Hence, these results support hypothesis 1. Likewise, results also show that BDA capability positively impacts green DCs (β=0.35, p<0.01), hence providing support for hypothesis 2. For hypothesis 3, data also provided support as results indicate a positive and significant path coefficient from green DCs to green innovation (β=0.50, p<0.01).

Hypothesis 4 states that BDA capability influences green DCs, fostering GI performance. Results presented in Table 4 also support mediation, implying that green DCs mediate the relationship between BDA capability and GI (β=0.18, p<0.01). Finally, hypothesis 5 states resource orchestration's moderating effect on the relationship between green DCs and GI. The results provide empirical support for hypothesis 6, which implies that resource orchestration capability complements green DCs to increase their effectiveness in eliciting GI (β=0.14, p<0.01). Figure 2 illustrates the results of PLS-SEM.



Note: *Dotted line depicts mediating effect.*

Figure 2. Graphical illustration of PLS-SEM results

DISCUSSIONS, IMPLICATIONS, AND LIMITATIONS

As the attention towards sustainability is growing continuously, this study attempted to investigate how green innovation can be leveraged from BDA capability, which is also gaining increased consideration due to the ‚era of data.' The value of green innovation has been recognized in recent research. Studies focusing on the economic value of green innovation recognized that these innovations are costly but payback in the form of improved financial performance in the long run. Knowing the significance and need for green innovation, this study used the BDA perspective to suggest that BDA capability could serve as an important element in fostering green innovation. These findings are comparable and in line with recent findings of Ahmad et al. (2024), Saeed et al. (2023), and Wamba et al. (2024), which highlight the significance of BDA in determining organizational outcomes, including innovation. In addition, the aforementioned relationship can be better understood by highlighting how BDA capability improves green innovation and suggested green DCs as an underlying mechanism. The findings are striking when many studies talk about the transformative value of BDA. Particularly, findings suggest that BDA capability enables organizations to collect, organize, process effectively, and analyze big data sources to identify and understand market trends, demand, production, resources, customers, and media, which helps organizations identify opportunities and gaps for green initiatives. Findings also suggest that BDA capability makes organizations more proficient in sensing ‚what is happening,' seizing potential opportunities and transforming resources to create value to support sustainability. These findings are consistent with the studies of Brewis et al. (2023), Itani et al. (2024), and Li et al. (2024), which found that BDA capabilities play a key role in fostering dynamic and operational capabilities to reap operational as well as financial benefits.

In addition, the results highlight the potential role of ROC in developing green innovation. RB-V advocates the significance of firm resources, capabilities, and competencies in creating value and gaining competitive advantages. However, organizations need to understand which resources or combinations of resources are imperative and how they should be utilized to achieve sustainability. Particularly, when one resource and/or capability is combined with another, they complement each other and bring a synergistic effect. The findings of this research show that ROC plays an important role as moderator and increases the effectiveness of green DCs in eliciting GI. It is important to note that the findings of Kristoffersen et al. (2021) and Mao et al. (2024) also support the notion that the orchestration of assets and resources is likely to have synergistic effects.

Theoretical implications

Our research provides important theoretical and practical implications. For theoretical implications and contributions, this research offers an integrated framework based on big-data and DCs to link BDA with innovation to seek solutions for environmental concerns while ensuring the economic value of the business activities. By suggesting a direct effect of BDA capability on GI, it adds to the existing literature regarding role of digital capabilities in promoting sustainability practices. Second, drawing from RB-V, BDA capability denotes an organization's skills and tangible and intangible resources to tap into big data resources to develop capabilities to create value. With increased competition and uncertainty, organizations have to continuously align and transform their capabilities to tackle risks and benefit from opportunities. In this regard, this study suggests a theoretical understanding of how organizations utilize BDA capability to develop, align, and transform their green DCs in the quest for sustainability. Third, our research provides a significant contribution to the literature by using a complementarity perspective. It explains that when one capability is integrated with another capability, they are expected to have a synergistic effect, which is bigger than the sum of individual effects. Since an organization is perceived to be a system comprising various departments, units, assets, and resources, these components and/or capabilities need to be coordinated and worked on in isolation to ensure that organizations achieve their goals. Further, exploiting resources and capabilities in the right combination and coordination may amplify their effectiveness in achieving business objectives. In this regard, our framework suggests that when combined with green DCs, resource orchestration capability catalyzes the development and implementation of green initiatives.

Practical and managerial implications

For practical implications, the findings suggest that organizations aiming to foster green innovation should invest in developing BDA capabilities. This may involve acquiring and analyzing large volumes of data related to sustainability, which can provide insights and support decision-making processes. Since investing in BDA could be costly, especially

for small enterprises, managers can outsource and/or benefit from either cloud-based solution (e.g., Microsoft Azure HDInsight) or block chain-based solutions for big data analytics (e.g., Bluzelle, Ocean Protocol). Second, managers should also focus on building green DCs, which involve identifying and exploiting opportunities for sustainable innovation. This may be achieved by establishing cross-functional teams, nurturing a culture of environmental consciousness, and continuously learning and adapting to environmental changes. Third, this study highlights resource orchestration's importance in driving green innovation. Resource orchestration should be seen as a critical managerial task. Managers should invest in understanding and leveraging the sources of an organization and capabilities to maximize their effect on green innovation. Fourth, managers should strive to align organizational resources and capabilities to amplify their effectiveness in predicting and promoting sustainable outcomes. This can be done by developing effective coordination mechanisms, encouraging collaboration and knowledge-sharing, and allocating resources strategically. In a nutshell, managers should recognize the benefits of BDA in deriving sustainable practices. By leveraging BDA capability, managers can uncover insights and patterns that enable them to make informed decisions, identify areas for improvement, and develop innovative solutions that align with sustainability goals.

Limitations and future research

Besides offering important implications, this research also has limitations. First, the present study investigates the role of BDA capability in prompting GI. There is the possibility that BDA could be more beneficial in other forms of innovation and innovation capabilities. Future studies may develop and examine a comprehensive framework to evaluate the effectiveness of BDA in different forms of innovation (e.g., incremental, radical, exploratory). Second, the mediating mechanism we used is green DCs. However, future studies may attempt to explore other mechanisms (e.g., knowledge management, agility) to unveil the missing link between DBA and green innovation. Third, this study theorized resource orchestration capability as the complementary source. However, it is possible that ‚too good of a good thing' may not be useful in some circumstances, even if it can bring harm or substitute the key predictor. Considering this, future studies may examine the curvilinear nature of relationships among this study's variables. Last but not least, this study was undertaken in the context of a collectivist culture, which may restrict our comprehension regarding the implications of BDA capability for green innovation for organizations operating in communities with individualistic norms. Future studies may take a cross-cultural context to compare and comprehend the potential of BDA in deriving organizational outcomes.

CONCLUSION

The present study aimed to examine the role of BDA capability in leveraging GI directly and through the development of green DCs. Findings show that BDA capability positively influences both GI and green DCs. Moreover, green DCs are also linked with GI and mediate the effect of BDA capability on GI. The present research also investigated the moderating effect of resources orchestration. We argued that organizations' ability to structure, bundle, and leverage resources is likely to complement organizations' other strategic areas and capabilities to achieve amplified outcomes. Findings illustrate that green DCs, when combined with ROC, have a stronger effect in prompting green innovation. The findings of this study suggest that managers should recognize the potential benefits of BDA in deriving sustainable practices. By leveraging BDA capability, managers can uncover insights and patterns that enable them to make informed decisions, identify areas for improvement, and develop innovative solutions that align with sustainability goals.

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Conflicts of interest

The authors declare no conflict of interest.

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