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Towards a business analytics capability for the circular economy

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ABSTRACT

Digital technologies are growing in importance for accelerating firms' circular economy transition. However, so far, the focus has primarily been on the technical aspects of implementing these technologies with limited research on the organizational resources and capabilities required for successfully leveraging digital technologies for circular economy. To address this gap, this paper explores the business analytics resources firms should develop and how these should be orchestrated towards a firm-wide capability. The paper proposes a conceptual model highlighting eight business analytics resources that, in combination, build a business analytics capability for the circular economy and how this relates to firms' circular economy implementation, resource orchestration capability, and competitive performance. The model is based on the results of a thematic analysis of 15 semi-structured expert interviews with key positions in industry. Our approach is informed by and further develops, the theory of the resource-based view and the resource orchestration view. Based on the results, we develop a deeper understanding of the importance of taking a holistic approach to business analytics when leveraging data and analytics towards a more efficient and effective digital-enabled circular economy, the smart circular economy.

Introduction

Sustainability has been an issue subject to extensive research and discussion ever since the Brundtland report in 1987 (Commission on Environment and Development, 1987). Following this, the concept of circular economy (CE) has gained attention by policymakers, researchers, and organizations alike as a way to promote sustainable development (Geissdoerfer et al., 2017; Ghisellini et al., 2016). The CE envisions a global economy in which value-creation is decoupled from the consumption of finite resources by leveraging a range of productivity and efficiency-enhancing as well as restorative strategies to keeping products, components, and materials in use for longer (Blomsma and Tennant, 2020; EMF, 2015a, 2015b). In other words, the CE promotes two ideas at the heart of sustainable development: economic development combined with reducing the environmental burden of economic activity. As a result, the CE is rapidly gathering momentum as a way of boosting economies, while addressing mounting resource-related challenges, creating jobs, spurring innovation, and generating substantial environmental benefits (European Commission, 2020a, 2020b; Stahel, 2010). However, so far, the adoption of CE principles in the industry has been modest (Circle Economy, 2020; Haas et al., 2015; Planing, 2015; Sousa-Zomer et al., 2018).

Simultaneously, the rapid innovations of digital technologies have raised data and analytics to the top of corporate agendas along with claims that '*data is the new oil*' that is to be refined to extract unprecedented value (Brown et al., 2011; McAfee et al., 2012). Hence, the capacity to gather, process, structure, and use data in decision-making, known as business analytics (BA), is increasingly seen as a source of competitive advantage (Mortenson et al., 2015; Provost and Fawcett, 2013). Correspondingly, we see a growing interest from organizations in leveraging BA for an accelerated transition towards the CE (Antikainen et al., 2018b; Bressanelli et al., 2018a; EMF, 2016, 2019; Kristoffersen et al., 2020; Nobre and Tavares, 2017; Pagoropoulos et al., 2017). BA can support firms' CE transition in various ways. For one, BA can be used to optimize circular strategies such as reverse logistics, energy consumption, and maintenance (Bressanelli et al., 2018b; Lenka et al., 2017; Rymaszewska et al., 2017). Second, BA may serve to identify and address structural waste, such as underused product capacity or waste-to-resource matching in industrial symbiosis systems (Bin et al., 2015; Low et al., 2018). Third, BA may support the innovation process of

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future circular strategies through simulating impacts of life cycle scenarios or identifying possible life cycle extending activities (Lieder et al., 2020). In this capacity, BA can be used to identify novel business opportunities and alternative sources of competitive advantage.

Currently, however, most studies connecting the fields of BA and CE are in a nascent stage and offer mostly anecdotal evidence (Kristoffersen et al., 2020). Unsurprisingly, there is limited empirical work grounded on established management, information systems (IS), and CE theories (Lahti et al., 2018). A gap exists in understanding how to wield BA in a targeted way to support circular strategies operationally and find new CE opportunities. As a result, questions of whether, under what conditions, and how BA can improve firms' competitive performance through the enhanced leveraging of circular strategies, remains unanswered. However, to answer this, an instrument to empirically investigate BA's contribution towards CE must be developed. An important first step is to identify which distinctive BA resources[1] that, in combination, build a business analytics capability (BAC) for CE and the processes through which firms orchestrate and leverage them.

Notwithstanding the number of studies on BA capabilities for general business operation and supply chain management (Akter et al., 2016; Wang et al., 2016), these are all rooted in the linear economic model and way of thinking. Hence, they lack alignment with more holistic information management and sustainable principles core to the CE (Gupta et al., 2019). This applies both to strategic and operational activities such as reinventing and reconfiguring business models and value chains, reducing raw material sourcing and manufacturing impacts, and recirculating products and materials to additional use cycles. The CE sets greater demand for firms to collect, integrate, analyze, and share data across organizational boundaries, both upstream and downstream in the value chain. Consequently, adopting CE imposes different BA resources compared to previous BAC research. This lack of research and limited understanding severely hampers organizations' ability to transition to the CE, restructure organizational resources, and fully capitalize on their BA investments. Therefore, to obtain relevant theoretical and practical insights, for researchers and practitioners alike, it is essential to identify what the core artifacts of BA pertinent to CE are, and how they are structured, bundled, and leveraged within firms.

To address this gap, this study employs thematic analysis of a series of semi-structured interviews to identify the core organizational resources, or building blocks, of a BAC for CE (RQ1) and examines how firms orchestrate these resources into a firm-wide BAC for CE (RQ2). We build on a qualitative exploratory approach in order to isolate the key resources that comprise a BAC for CE, and to identify the mechanisms through which they are leveraged. The research questions addressed in this study are:

RQ1 What are the business analytics resources required for circular economy?

RQ2 How should firms structure, bundle, and leverage their business analytics resources into a business analytics capability for circular economy?

The rest of this work is detailed in the following sections. First, Section 2 provides background on the relation between CE, digital technologies, and BA together with theory on developing organizational capabilities. Section 3 explains the research methodology followed to analyze 15 semi-structured expert interviews. We then present the result of our analysis of emergent factors, conceptual model, and how firms manage their BA resources for CE Section 4. Our results uncover eight key organizational resources of a BAC, along with insights on how to deploy them. Finally, in Section 0 and 6, we provide a discussion of the findings along with limitations, avenues for future research, and conclusive remarks.

Background

Smart circular economy

Despite the growing interest from industry and academia alike, CE is still in its infancy, and a unified definition is missing (Kirchherr et al., 2017). In their analysis of 114 definitions, Kirchherr et al. (2017) provide the following meta-definition: "*A CE describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, and recycling […] materials in production/distribution and consumption processes, […], with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations*". As such, CE may be understood as an umbrella concept, in which various frames exist Blomsma and Brennan (2017), but that has as a common goal to replace current 'take--make-use-dispose' systems with systems addressing structural waste. Instrumental to this is the application of circular strategies, which provides new value creation opportunities and reduce value loss and destruction by narrowing, slowing, and closing material and energy flows Bocken and Short (2016). For instance, think of recycling materials instead of shipping them to landfill or incineration and reusing parts and products through repair, remanufacturing, sharing, or access-over-ownership models.

However, companies embracing a CE may be subject to several risks, such as a mismatch between fluctuating demand, supply, and value of used assets, causing uncertainties with cost and return on investment (de Sousa Jabbour et al., 2018). Consequently, to date, resources[2] are reused at marginal volumes. One of the fundamental causes to these issues is the missing information throughout the industrial life cycle Wilts and Berg (2018). From an IS point of view, the CE transition can be understood as a problem of information logistics. Digital technologies can support this by addressing key operational barriers in the loss of information that typically results in linear value chains, such as no insight into location, availability, or condition of assets (Su et al., 2013). Hence, effectively leveraging the abundant sources of data available throughout the industrial life cycle to fully connect material- and information flows may provide the step change needed for companies to go beyond incremental efficiency gains towards the CE. To this end, the emergence and increased uptake of digital technologies are highlighted as vital for CE implementation (Antikainen et al., 2018a; Bressanelli et al., 2018a; de Sousa Jabbour et al., 2018; EMF, 2019, 2016; Kristoffersen et al., 2019; Nobre and Tavares, 2017). In this context, the term *digital technologies* encompass various related concepts, such as the internet of things, big data, artificial intelligence, BA, cloud computing, cyber-physical systems, and blockchain. In this study, we limit our focus to BA due to its potential to leverage data for improved resource management and decision-making support across the different stages of the industrial life cycle.

In other words, an increased drive towards digitalizing the CE could pave the way for a more efficient and effective CE, known as the *Smart CE* (Kristoffersen et al., 2020). Acknowledging the potential of a Smart CE, various sources have voiced the need for research into how organizations can leverage digital business practices for CE implementation and value creation (Chauhan et al., 2019; EMF, 2019, 2016; European Commission, 2020b; Okorie et al., 2018; Rosa et al., 2020). To address this, several theoretical frameworks connecting CE with digital strategies have been presented (Askoxylakis, 2018; Bianchini et al., 2018; Ingemarsdotter et al., 2019; Kristoffersen et al., 2020; Rosa et al., 2020; Ünal et al., 2018). However, no dominant framework has yet emerged, and only one provides detail on the underlying technical mechanisms needed for identifying BA resources (Kristoffersen et al., 2020). Thus, for

[1] Here, we refer to BA resources as a subset of organizational resources under the resource-based view theory.

[2] Here, we refer to physical resources such as materials, components, and products.

the purpose of this study, we draw on the *Smart CE framework* by Kristoffersen et al. (2020) for contextual alignment.

Resource-based view and resource orchestration

Building on the works by Wernerfelt (1984) and Amit and Schoemaker (1993), developing and sustaining a competitive advantage is fundamental to strategic management literature. To date, the resource-based view (RBV) is considered to be one of the most rigorous theories to explain firm performance through the resources they own and control Barney (2001). The theory has also been under considerable scholarly attention under the notion of IT capabilities Bharadwaj (2000). RBV proposes that a firm generates competitive advantage through the collection of tangible and intangible resources, specifically the ones that are valuable, rare, inimitable, and non-substitutable (known as VRIN) Barney (1991). Despite decades of empirical work and recent meta-analysis supporting the importance of these resources for competitive performance, scholars argue that the theory requires additional specification to explain differences amongst firms' outcomes (Crook et al., 2008; Kraaijenbrink et al., 2010; Sirmon et al., 2011). The core assumptions of VRIN also pose a challenge when applied to the context of BA, as the core resource, data, is often not rare, but an open and shared resource (Braganza et al., 2017).

Amit and Schoemaker (1993) define organizational resources as stocks of tradable and nonspecific assets in the firm, and capabilities as the firms specific and non-tradable ability to deploy such resources, through organizational processes, to affect a desired end. Hence, one can distinguish between the notion of resource-picking (identifying resources of strategic value) and capability-building (orchestrating these resources into useful assets) Makadok (2001). Much attention from IS research has been paid to the resource-picking aspects of firms' BAC, but less to capability-building (Mikalef et al., 2018). To this end, Sirmon et al. (2011) propose the resource orchestration view (ROV) to extend the understanding of RBV by explaining the role of managers for transforming resources into capabilities.

The research stream of ROV builds on RBV and dynamic capabilities through the complementary integration of the resource management framework by Sirmon et al. (2007) and the asset orchestration framework by Helfat et al. (2009). The integrated framework provides a more robust perspective of managers' specific role in the processes of structuring, bundling, and leveraging capabilities across differences in firm characteristics (i.e., scope, life cycle stage, and levels in the managerial hierarchy). Each process includes several sub-processes with varying relative importance depending on the firm's characteristics, suggesting variance in the type and importance of managerial actions in orchestrating the firm's resources (Sirmon et al., 2011) (see Table 2 for details). Despite limited studies on research orchestration and BAC, the framework has been applied to the role of IT resources, capabilities, and dynamic capabilities for innovation Ahuja and Chan (2017). Ahuja and Chan (2017) used the retrospective case study of Barclays 'digital eagles' program to examine the process of 'IT resource orchestration' to explain how the firm transformed its IT resources into IT capabilities and dynamic capabilities for increased innovation and firm performance. The motivation for choosing RBV and ROV as the theoretical groundings in this study is because the former presents a solid foundation whereupon all organizational resources can be identified, while the latter provides a lens to examine how these resources are managed and turned into capabilities to leverage circular strategies for increased competitive performance.

Business analytics capability

The term *intelligence* was first used by artificial intelligence researchers back in the 1950s, later spurring the concept of *business intelligence* in the 1990s closely followed by *business analytics* in the 2000s (Chen et al., 2012). While numerous definitions exist, BA is frequently referred to as the collection of technologies, methodologies, practices, and applications that enable the analysis of critical business data to make more sound and evidence-based business decisions (Chen et al., 2012; Seddon and Currie, 2017). Recently, the term big data analytics have emerged to describe the set of techniques and application in which the (big) data sets are too large and complex for traditional methods (Chen et al., 2012). For the purpose of this study, we treat BA and big data analytics as a unified term and draw on the systematic literature review by Mikalef et al. (2018). As highlighted in their review, many data characteristics exist; however, the attributes of *volume, velocity*, and *variety* are highlighted as key to underpinning the notion of BA (McAfee et al., 2012). Recent studies have extended this with characteristics such as veracity (Abbasi et al., 2016; Akter et al., 2016), *visualization* (Seddon and Currie, 2017), and *variability* (Seddon et al., 2017).

Nevertheless, effectively leveraging and transforming data into business value and actionable insights require companies to go beyond the technical aspects of data characteristics (Vidgen et al., 2017). Becoming a data-driven organization is a complex and multifaceted task requiring the transformation of multiple organizational resources with attention from several levels of managers. To address these challenges and provide guidelines for practitioners, scholars have introduced the concept of a *business analytics capability* to indicate an organizations' ability to leverage data for increased strategic and operational insight (Mikalef et al., 2018). Mikalef et al. (2018) define BAC as a firm's proficiency in capturing and analyzing data towards the generation of insights by effectively managing its data, technology, and talent.

Present BA research streams in IS have put considerable efforts into defining the building blocks, or resources, of a firm's BAC through the RBV. However, little is known about the orchestration process required to leverage these resources into a firm-wide capability (Mikalef et al., 2018). Specifically, a gap exists in explicitly addressing managers' roles and actions in effectively structuring, bundling, and leveraging firm resources through the ROV (Sirmon et al., 2011). Furthermore, efforts in BA research have primarily focused on the mechanisms through which it generates competitive performance while mostly disregarding the impact in areas of CE and sustainability. The review by Rialti et al. (2019) advocates for future research to explore the additional effects of BA capabilities apart from competitive performance. Despite interest in the role of BA for sustainable supply chain management, as seen in (Dubey et al., 2016; Hazen et al., 2016; Wang et al., 2016; Wu et al., 2017; Zhao et al., 2017) and circular supply chain management in (Gupta et al., 2019), there has been significantly less research on its role in leveraging a broader range of circular strategies. To date, most studies connecting the fields of BA and CE are in a nascent stage and offer only anecdotal evidence (Kristoffersen et al., 2020). Unsurprisingly, there are limited empirical work grounded on established management, IS, and CE theories (Lahti et al., 2018). Hence, it needs to be established, which factors of BA companies adopting CE should leverage, and how. For any data-driven business, this includes assembling, integrating, and deploying both tangible and intangible analytics-related organizational resources (Mikalef et al., 2018; Shuradze and Wagner, 2016).

Research methodology

Research design

Given the emergent state of the field, we employed an exploratory qualitative study to develop the first instance of an instrument to empirically investigate BA's contribution towards CE. Specifically, a construct for measuring firms' CE-specific BAC and a conceptual model with propositions for the mechanisms through which this capability improves competitive performance in terms of paths and mediating roles of CE implementation and resource orchestration capability. Utilizing the RBV and the ROV as the grounding theoretical frameworks, we employed a literature review in combination with semi-structured interviews (see Fig. 1 for the steps involved). Provided no previous

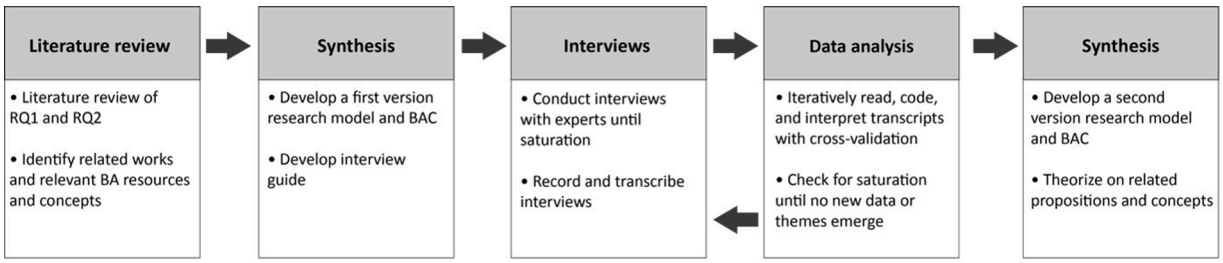

Fig. 1. Research steps.

measures of BAC for CE exist, it was necessary to conduct an exploratory qualitative study before any confirmatory quantitative studies can proceed. This was done in order to explore key concepts and their associations to ensure that no important concepts were omitted from further studies. It is also argued by several method studies that exploratory research should precede confirmatory quantitative studies, in order to explore the construct space and the intricacies of the concept being examined (Sarker et al., 2013).

We started by conducting a literature review with a focus on the critical aspects and organizational resources of a CE-specific BAC. The purpose of the review was to identify the main underlying concepts from related research streams in both BAC theory and CE theory. Based on this, we developed the first version of a theoretically guided conceptual model and BAC for CE (see Fig. 2 and Table 3 for the final versions). Following the literature review, a gap remained in identifying the dimensions of a BAC for CE and understanding how firms orchestrate these resources into capabilities. To address this, we employed a series of semi-structured interviews, following the guidelines of Bogner et al. (2009) and Patton (1990), with experts from key positions in industry. In this context, experts are defined as someone with privileged knowledge about the topic of interest (Bogner et al., 2009). The interviews were supported by an interview guide developed on the basis of the literature review and in accordance with the recommendations of Myers and Newman (2007). Semi-structured interviews represent an effective way to elicit rich data (Alshenqeeti, 2014; Kvale and Brinkmann, 2009), understand why some resources are more important than others, and under which conditions they are used for capability-building activities. The benefit of this approach, in contrast with structured interviews or quantitative approaches, is that it allows for thematic analysis and the discovery of new perspectives and relationships between topics that were previously not conceptualized Savin-Baden and Howell-Major (2013). This enabled, after the interviews, updating the initial constructs, definitions, and relationships in the conceptual model and through this the core organizational resources or building blocks of BACs. In particular, it allowed us to explore and refine the key concept of this study, the BAC for CE.

Data collection

Data were collected over a period of two months, from November 2019 to December 2019. Interviews lasted between 50–120 min and covered a total of 15 organizations (see Table 1 for details of respondents). The interviews followed a conversational style, opening with a general discussion about the company, CE, and BA before proceeding to more detailed questions on BA resources. Interviews were the primary source of data, in which the respondents' thoughts, opinions, and beliefs together with personal, firm, and industry experiences were captured. When necessary, clarifications and mining questions were used to encourage more detailed and accurate responses. All interviews were recorded and later transcribed according to the defined themes, as seen in Table 2 and Table 3.

Following the rationale of Sirmon et al. (2011) to develop a more robust theoretical perspective along with a wide representation of circular strategies, we employed purposeful sampling with snowballing to target experts from firms across variance in breadth (scope of the firm) and life cycle (stage of maturity), resulting in a total of 74 potential respondents. The extensive and diverse industry experience of the respondents allowed for several key strategies and decision areas of the CE to be represented.

Data analysis

The data analysis was performed through an iterative process of reading, coding, and interpreting the transcriptions Myers and Newman (2007). We employed cross-interview analysis along with the visual mapping strategy and the continuous comparison strategy (Eisenhardt, 1989; Patton, 2014). Firstly, following the open coding scheme by Yin (2017), concepts and factors were identified based on the theoretical

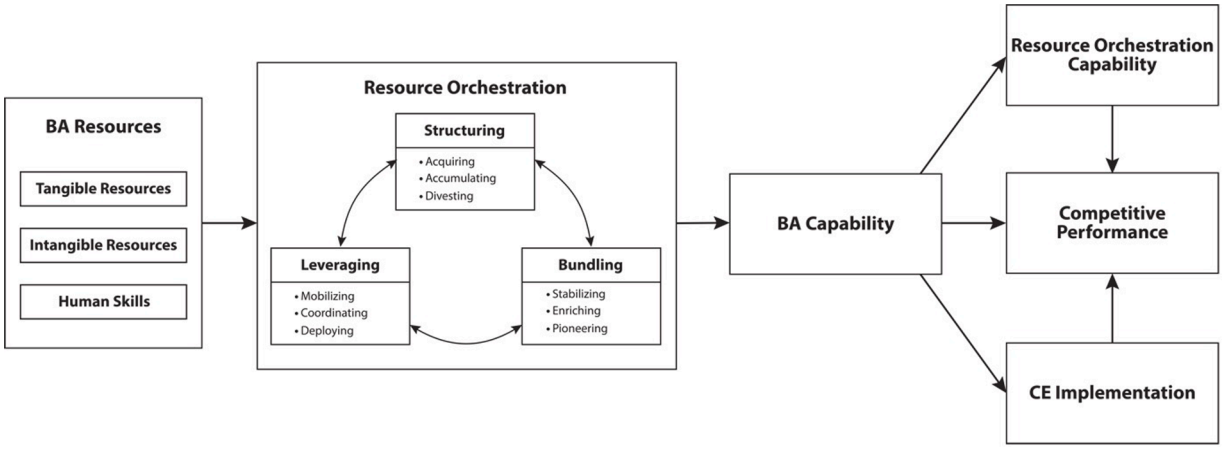

Fig. 2. Conceptual Model.

Table 1
Details of respondents.

Respondent	Role	Business area	Employees	Experience	Education
R1	Data scientist	Deep sea shipping (spot market)	3500	5 years	PhD
R2	CEO	IT services (product management)	12	13 years	MSc
R3	Director	IT services (blockchain protocol)	104	19 years	MSc
R4	CEO	Consultancy (IT and sustainability)	1	37 years	PhD
R5	Director	IT services (waste management)	4	24 years	BSc
R6	Director	IT services (advanced analytics)	40	15 years	MSc
R7	Manager	Renewables and environment	4000	14 years	BSc
R8	Director	IT services and infrastructure	150 000	23 years	PhD
R9	Executive	Consultancy (IT and CE)	30	23 years	MSc
R10	CEO	Consultancy (Sustainability and urban development)	1	22 years	MSc
R11	Manager	IT services (waste management)	23	15 years	BSc
R12	CEO	IT services (waste management)	6	23 years	BSc
R13	Service designer	IT services	150	12 years	MSc
R14	Executive	Civil engineering	21	31 years	MSc
R15	Executive	Retail	100 000	17 years	MSc

Table 2
Thematic support for the theoretical framework.

Concept	Source
Business analytics resources	
- *Business analytics resources* are stocks of tradable and nonspecific BA assets in the firm that can be divided into tangible (e.g., financial and physical resources), intangible (e.g., organizational culture and organizational learning), and human skills (e.g., employees' knowledge and skills) types.	(Mikalef et al., 2018)
Business analytics capability	
- *Business analytics capability* is the ability of a firm to mobilize and deploy BA resources effectively, utilize BA resources, and align BA planning with firm strategy to gain competitive advantage and improve firm performance.	(Garmaki et al., 2016)
Resource orchestration	
- *Structuring* is the process of acquiring, accumulating, and divesting resources to form the firm's resource portfolio.	(Sirmon et al., 2011)
- *Bundling* is the process of integrating these resources to form capabilities; it includes stabilizing, enriching, and pioneering activities.	(Sirmon et al., 2011)
- *Leveraging* is the process of exploiting the firm's capabilities and take advantage of specific market opportunities; it includes mobilizing, coordinating, and deploying these capabilities to create value. Resource orchestration capability	(Sirmon et al., 2011)
- *Resource orchestration capability* is the ability of a firm to effectively structure, bundle, and leverage the resource portfolio towards firm performance.	(Choi et al., 2020; Sirmon et al., 2011; Wang et al., 2020)
CE implementation	
- *CE implementation* is the degree to which a firm effectively leverage circular strategies for value creation and capture as relevant for the perspective of the firm.	(Bocken et al., 2016; Khan et al., 2020)
Competitive performance	
- *Competitive performance* is the degree to which a firm has superior performance relative to its competition in areas of operations excellence, customer relationship, and revenue growth.	(Rai et al., 2006)

underpinnings established from the literature review, as identified in Table 2. On this ground, we identified a large number of codes ranging from practices, tools, challenges, strategies, resources, enablers, and barriers. This allowed us to cluster the data according to themes using a tabular structure and grouping the data into high-level categories and analyze for internal homogeneity (coherence and consistency) and external heterogeneity (distinctive and representative with a clear connection to the research questions) (Miles et al., 1994). Through the application of visual maps and continuous comparison, the data were iteratively compared to the theoretical lens and existing literature to improve the conceptual model until saturation by no further data being added or new themes and concepts emerging Eisenhardt (1989). Satisfactory saturation was achieved after 15 interviews. To strengthen the credibility and validity of our findings, we cross-validated the analysis result between the authors and employed triangulation of sources, including secondary data such as firm websites and industry reports Tracy (2010).

Findings

Overall, our results corroborate the findings of related qualitative studies, such as the importance of holistic information processing and sharing for BA-enabled CE supply chains by Gupta et al. (2019). The role of BA is highlighted by all respondents as critical to the success of their organization's CE transition. The general consensus was that CE sets greater, and more holistic, demands for a firm's BAC. Consequently, several respondents argue that a broader definition of BA should be developed to reflect the triple bottom line (economic, environmental, and social value) of the CE, as was mentioned for instance by R10:

"There has to be a broader definition of analytics. Because right now, it is just based on financial analysis and profit return for shareholders and loose analysis without a lot of understanding of social and environmental impact. It is very important that BA is used more holistically. It cannot just be a single bottom line. BA has to include social and ecological value or impact."

Based on the results of the interviews, the initial constructs of BA resources from literature were adjusted, refined, and further developed to reflect the theories and practices of CE, as can be seen in Table 3. Following this, we visualized the results in five tables to summarize the evidence for each theoretical construct, improve the testability of the theory, and strengthen the bridge between the qualitative evidence and the conceptual model Eisenhardt and Graebner (2007). First, an overview is given in Table 4 of the BA resources respondents have implemented for CE. Following this, Table 5, Table 6, and Table 7 provide detail for each resource with subthemes, sample quotes, and key takeaways. Finally, Table 8 presents the results for resource orchestration, CE implementation, and competitive performance.

Business analytics capability

Considerable discussion concerned the issue of a separate BAC for the CE. While several parallels were drawn to preexisting BA resources, the respondents were unison in their response that effectively transitioning to the CE required new BA resources. In summary, eight BA resources were identified that, in combination, build a BAC for CE. In Table 4 the importance of each resource is noted, black circles (●) indicate that the resource was mentioned as an important aspect and/or implemented in the organization's strategy of using BA for CE, whereas half circles (◑)

Table 3
Definition of BA resources for CE.

Resource	Adjustments made	Adapted from literature (s)
Tangible		
- ***Data***: Organizations utilizing BA for CE need to capture both internal and external data from multiple sources, independently of structures and on a continuous basis. Further, aspects concerning data such as quality, sources, availability, and methods for curating needs handling.	Adjusted the content of the definition to comply with CE.	(Arunachalam et al., 2018; Gupta and George, 2016; Hedberg et al., 2019; Janssen et al., 2017; Kwon et al., 2014; Mikalef et al., 2017)
- ***Technology***: Novel digital technologies are necessary for handling the large volume, diversity, and speed of data accumulated throughout circular value chains. The complexity of these value chains increases the need for firms to deploy advanced data generation, integration, analysis, and sharing infrastructures.	Adjusted the content of the definition to comply with CE.	(Arunachalam et al., 2018; Gupta and George, 2016; Gupta et al., 2019; Hedberg et al., 2019; Mikalef et al., 2017)
- ***Basic resources***: Refers to an organization's investment of time and funds. This includes financial resources as direct investments in the support of these technologies and working hours allocated to experimentation with utilizing the potential of BA.	None.	(Gupta and George, 2016; Mikalef et al., 2017; Wamba et al., 2017)
Intangible		
- ***Data-driven culture***: Describes the extent to which organizational members are committed to BA and make decisions based on insight derived from data.	None.	(Arunachalam et al., 2018; Dubey et al., 2019; Gupta and George, 2016; Mikalef et al., 2019)
- ***Circular-oriented innovation culture***: Describes the extent to which CE goals, principles, and strategies are integrated into technical and market-based innovations to create value by enabling sustainable management of resources throughout the design of processes, products/services, and business models.	Identified the resource and developed the definition from relevant research.	(Brown et al., 2019; Gupta et al., 2019; Munodawafa and Johl, 2019; Pauliuk, 2018; Prieto-Sandoval et al., 2019; The British Standards Institution, 2017)
- ***Openness and co-creation***: Describes the extent to which organizational members are mutually open about decisions and activities that affect the society/economy/environment and willing to communicate these in a clear, accurate, timely, honest, and complete manner to enhance formal and/or informal arrangements internally and externally to create mutual value.	Identified the resource and developed the definition from relevant research.	(Gupta et al., 2019; Hedberg et al., 2019; Pauliuk, 2018; The British Standards Institution, 2017)
Human Skills		
- ***Systems thinking skills***: Refers to the competencies of employees to take a holistic approach for understanding larger contexts over longer periods of time, looking at connections and patterns of how individual decisions and activities impact environmental, economic, and social issues beyond the immediate first-tier scope.	Identified the resource and adjusted the definition from relevant research.	(Bocken et al., 2019; Gupta et al., 2019; Pauliuk, 2018; The British Standards Institution, 2017; Webster, 2013)
- ***Data science skills***: Refers to the competencies of employees to formulate and implement machine learning problems, utilizing data analytics skills such as statistics, computing, and knowledge about correlation and causation.	Identified the resource and adjusted the definition from relevant research.	(Dhar, 2013; Dubey et al., 2019; Gupta and George, 2016; Power, 2016)

and blank circles (○) indicates that it was only somewhat or not implemented. The absence of a circle signals a lack of insight by the respondent or relevance for the company. For instance, the tangible resources of R4 and R10 were both left empty as they represent a one-person consultancy firm.

Tangible resources

Generally, the type of tangible BA resources required for CE is similar to that of standard BA capabilities and the categories of data, technology, and basic resources presented by Gupta and George (2016). However, the respondents highlight that the increased lifespan of products, new business models, and the complexity of circular value chains sets different requirements for these tangible resources. For instance, R7 cites that increasing the lifespan of their products required additional life cycle data and more advanced analytics to estimate the products' remaining useful life. In addition, R3, R5, and R6 note that CE business models have a longer time period for their return of investment (ROI) and increased demand for upfront investment. Further, R3 explained that circular value chains are often more complex and involve multiple stakeholders, increasing the importance of having a holistic data collection and integration infrastructure in order to maintain a single-source-of-truth.

Data

Data itself was frequently cited as a key building block and its importance acknowledged by most all respondents (see Table 4 for details). From the analysis, we were able to identify three themes: single-source-of-truth, data quality and availability, and metadata preservation (see Table 5 for details). In general, the type of data needed to enable the CE was mentioned to be sector- and use case-specific. Nevertheless, having a standardized format for collecting location, availability, and condition data of products and materials throughout the supply chain, their life cycle, and across ownership transfers would be critical, as detailed by R2:

"The kind of data you need for the CE has information about the product

Table 4
Overview of outcomes on BA resources for CE.

Resources	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Tangible															
- Data	●	●	●		●	●	●	●	◑		●	◑	●	●	●
- Technology	●	●	●		●	●	●	●	◑		●	◑			◑
- Basic resources	◑	●	◑		●	●	●	●	●		●	◑			●
Intangible															
- Data-driven culture	●	●	●	●	●	●	●	●	◑	●	●	●	○	●	●
- Circular-oriented innovation culture	○	●	◑	●	●	◑	●	○	●	●	◑	○	◑	◑	◑
- Openness and co-creation	◑	●	●	◑	●	◑	●	●	●	●	●	●	●	●	●
Human Skills															
- Systems thinking skills	○	●	◑	◑	●	◑	●	●	●	●	◑	●	●	◑	◑
- Data science skills	●	●	●	●	○	●	◑	●		●	●		◑	●	○

Note: ○, Not implemented; ◑, Partly implemented; ●, Implemented

(what are the components, where are you buying and sourcing from, what are the materials, and so on).”

However, R2 notes that although collecting data is a mandatory step and enables everything else, it does not translate directly into value. R8 concur and note that:

“Data is an obvious important resource, not only for commercial aspects but for sustainability and CE in general. It is important that we collect data in order to operate these processes and concepts more efficiently.”

For the data to be useful, it needs to be trusted, for which respondents stressed the importance of data quality. Several solutions were presented on how to mitigate this challenge, such as R1, with their data quality framework of using ‘analytics on analytics’ to monitor the data with quantitative terms, catching problems, and visualizing the situation so that they can react swiftly. R4 also advised for collecting data as close to the source as possible to ensure it has not been tampered with. Further, R6 and R13 experienced that employing metadata preservation and visualization technologies were important to understand the context of the data and to ‘tell a story’ that people can trust.

Technology

Digital technologies and infrastructures were, by most all respondents, subject to large investments and focus. Overall, eight respondents reported to have implemented a satisfactory level of technologies, whilst three were partly satisfied with their current implementation level (see Table 4 for details). From the analysis, we were able to identify three themes: automated data collection, data integration and interoperability, and advanced analytics (see Table 5 for details).

Particularly, the respondents noted that the added complexity of CE value chains increased the need for automated data collection and integration. In general, the CE requires a shift from only looking at data from first-tier suppliers but also to second and third-tier suppliers. If this data is correctly managed and combined with advanced analytics, it can, for instance, prove vital for understanding and simulating alternative sourcing plans with details on how a change in material affects the whole supply chain. Furthermore, multiple respondents mentioned that circular strategies, specifically the ones involving services, were challenging to operate without advanced analytics software and high-resolution data with enough metadata to segment individual users and products. For instance, R5 shared their success in integrating gamification mechanisms in pay-as-you-throw business models for waste management:

“We have data with high resolution of each customer; this enables us to support different digital user experiences and communication strategies as well as add gamification and different tools of behavioral economics. We can make metadata from an individual customer’s recycling behavior available and, for instance, benchmark against the mean of the neighborhood to create behavioral incentives.”

However, R1, R5, R6, and R7 note that it is difficult to enable such advanced uses of analytics without having control of the basic technologies. R5 cite that one of their biggest challenge in implementing this solution was integrating all data points, vendor systems, and proprietary standards in a common cloud-based platform. R4 concur and note that:

“The challenge is to create infrastructures that are generic and static enough that you can support it with continuous update and new functionality without having to disrupt a large number of peer-to-peer nodes.”

In addition, R4 noted that it was important to include tools that better support the design of desirable systems dynamics of CE, such as STELLA (a systems thinking modelling package).

Basic resources

Financial resources were seen as imperative by most all respondents for the success of BA efforts for CE, with adequate funds reported for eight respondents and partly for three (see Table 4). From the analysis, we were able to identify three themes: non-value indicator, new costing models, and uncertain ROI and impact of lag effects (see Table 5 for details). Several respondents had experienced challenges with obtaining adequate funding for their efforts. Most all experiences could be traced back to a lack of top management buy-in due to the novelty of CE business models, lack of CE performance metrics, unclear ROI, and lag effects of circular strategies. Often, the lack of investment from top management could be linked to low systems thinking skills, resulting in a single bottom line where environmental and social value were not regarded as business success. R3 note:

“Top management buy-in is important; the challenge here is that they ask for ROI, which you often cannot provide upfront. Because the way you can get to a ROI is when you have indeed reshaped the business model by having brought all critical partners in the ecosystem together and shaping a scenario. It is a different approach; it is not plug-in solutions where you can come up with very clear indicators of success and monetary returns and ROI.”

Exacerbating this, the lack of key performance indicators (KPIs) to measure the progress towards CE was highlighted as a challenge. Meager improvements had been made by the respondents on this issue, and most based their calculations on crude approximations of resource optimizations, such as material intensity and amount of waste produced. However, the non-value indicator proposed by R4, when combined with automated pricing mechanisms and data collection, may prove fruitful as a pressure mechanism to incentivize companies to start sharing more data.

Intangible resources

The respondents mentioned that the CE sets greater demand for firms to collect, integrate, analyze, and share data across organizational boundaries, both upstream and downstream in the value chain. In terms of intangible resources, the general consensus was that this increases the

Table 5
Tangible resources subthemes, sample quotes, and takeaways.

Themes	Quotes	Key takeaways
Data		
Single-source-of-truth	R1: *"[…] consolidate all this information. We are working on having this in what we call a "single-point-of-truth" where anybody can access the data one is looking for, like lube oil consumption, fuel consumption, invoice, cost, savings, regulatory questions, health of an engine and onwards. And it is well presented, updated, and you can trust it."*	Data integration and availability is important for the data to be used and trusted.
Data quality and availability	R8: *"The biggest problem is in the quality of the underlying data. The tools and techniques are solid, so I think the biggest challenge is the availability and quality of data."*	Providing quality data is a bigger challenge than providing tools that use the data.
Metadata preservation	R6: *"You can easily get access to the data from different systems, but the system is created for different purposes than what we will use the data for. So, you often lose the context and the understanding of how data were created. The solution is metadata preservation."*	The lack of interoperability and preservation of metadata degrade the data quality.
Technology		
Automated data collection	R4: *"Automated process for moving data from one actor to another in the supply chain. […] you have an automated approach for the core data for input products that carries the KPIs, and […] you transfer what you could call the automated life cycle analysis result."*	Automating the collection of data throughout the supply chain could enable better life cycle analyses.
Data integration and interoperability	R9: *"It is critical to have data integration and sharing infrastructure, and it becomes more important when adopting a CE and it must happen throughout a product's lifecycle and the value chain in order for us as a society and economy to really realize the opportunities of circularity."*	Adopting CE requires more holistic data integration and sharing infrastructures.
Advanced analytics	R6: *"Without analytics, data is just data. What we want to extract is information, or even better, information for decision-making support. You need analytics to get the meaning out of the data and the context to tell a story so you can understand what to do."*	Analytics is critical for data to be interpreted, provide insights, and used.
Basic Resources		
Non-value indicator	R4: *"One vital KPI is the non-value indicator. What I mean is that is the lack of an indicator is an indicator in itself. If you see a product and if you have several sever information gaps in the product, that is an indication that you maybe should not trust it."*	The proportion of missing data is a valuable indication of integrity.
New costing models	R10: *"The total cost accounting model needs to be a critical foundation to any kind of digital tool or technology that can help really quickly analyze the impacts of producing something to the investor."*	The full lifecycle impact of a solution should be accounted for.
Uncertain ROI and impact of lag effects	R5: *"The investment in data collection infrastructure is expensive and uncertain, essentially to go from one paradigm to another, there is a lot of dark matter. The interesting thing is that you first discover the actual value of the data, long after it was collected. It is first when you have the data that you can see the pattern. This puts up a challenge for the leaders and with investment."*	Lag effects and uncertain ROI make investments difficult and require a shift in mindset.

importance of trust, transparency, and collaborative relationships along with the need for organizations to foster both a data-driven and circular-oriented innovative culture to encourage change. Despite the importance of the aforementioned tangible resources, the respondents experienced a greater challenge with changing their work processes and organizational culture accordingly. Although many respondents illustrated great knowledge of the CE and a high degree of digital maturity within their organization, the intangible resources as culture, trust, and collaboration remained an issue.

Data-driven culture

Fostering a data-driven culture was seen as fundamental nearly all respondents for the success of BA efforts for CE, with 13 respondents reporting considerable efforts, as can be seen in Table 4. From the analysis, we were able to identify two themes: feedback loops and value-driven (see Table 6 for details). Although many respondents cited to have implemented advanced analytics in several of their company's projects, the vast majority reportedly struggled to effectively incorporate the extracted information in decision-making, as was mentioned for instance by R6:

"We have a tendency to take fast decisions, often on gut feeling. We are less experienced with being true to the organization's strategy, visions, and to work systematically with data. At the same time, we have a high degree of digitalization in general […], but our culture is a challenge, possibly one of the biggest."

R5 concur and note the importance of addressing both the technical and non-technical elements of becoming data-driven:

"The most important dimensions here is to create data-driven businesses and make decisions based on data. For this, you need sufficient data quality, and you have to change the culture in many organizations. One needs to address both the technical and cultural challenge of becoming data-driven."

Circular-oriented innovation culture

Concerning culture, there was a lot of discussion by the respondents on the potential of CE to heighten the data-driven culture to a value-driven culture. From the analysis, we were able to identify three themes: catalyst for change, open innovation, and CE as a source of innovation (see Table 6 for details). Overall, six respondents reported CE as important for innovation and had implemented measures to adopt a supportive culture whilst an additional six were only partly convinced

Table 6
Intangible resources subthemes, sample quotes, and takeaways.

Themes	Quotes	Key takeaways
Data-driven culture		
Feedback loops	R8: *"We are very much concerned with what we call feedback loops, we are interested in gathering signals on how our customers are using our technology to give feedback to the next generation of the product. We also do the same for our employees to figure out what works and what does not, where can we improve how our processes are working. We think of all this as feedback loops where we gather data, process, and analyze it to figure out how we can improve. We are very aware of this and how we control it."*	Using customer and employee feedback data to drive strategic decision-making improves organizational learning.
Value-driven	R10: *"I do see a more sophisticated use of data within the culture of organizations, but I do not think it will ever supplant value-driven culture from leadership. The mission and value of the organization should override the data-driven culture or make specific use of that data for a purpose."*	Pairing the data-driven culture with value-driven leadership is critical.
Circular-oriented innovation culture		
Catalyst for change	R7: *"Our CE vision is clear, both at a top strategy level and for individuals. It required a re-branding process, not by changing logo or anything, but changing our expression and communication. […] We have also made recruitments. The new people are employed based on our new expression and vision, which in itself has a catalyzing effect. The CE is a catalyst for change."*	Incorporating a CE vision throughout the firm is effective for stimulating change and making recruitments.
Open innovation	R3: *"A lot of our innovation lies on the edge of each vertical, it is when you cross each vertical that you get the potential. You need to cultivate a culture of open innovation, which is quite transformative for some organizations, but you could argue it is a cultural approach to see how you build value for the company with surrounding stakeholders."*	Crossing verticals and including multiple stakeholders trigger innovation.
CE as a source of innovation	R11: *"In our organization, our people definitely understand what the CE means and the opportunities it brings. It is definitely an innovation opportunity because, for instance, you are looking for different materials that is changing the line of production and business in the company."*	The CE brings new value propositions that spark innovation.
Openness and co-creation		
Data sharing	R5: *"One of the core challenges with the CE, is to be able to share and distribute data internally and externally. Most companies are not able to effectively share data internally and are reluctant to share data externally and with the environment. If one is to succeed within CE, you have to open up these models, but in a way that safeguards the actors in the supply chain."*	The CE requires more and new models for data sharing that safeguards the actors.
Removing silos and internal alignment	R10: *"It absolutely requires tremendous more collaboration internally and externally. The majority of companies are very siloed in their management regimes, and there is so much deficiency because of that and not a lot of understanding of synergies between different departments, people do not see the patterns or the interconnectedness or interdependencies. Lose sight of those and we lose value. I think assessing the organizational structure is really critical to identify where that collaboration leads to more value."*	Removing silos and encouraging more internal collaboration reduce deficiencies and the increase value potential.
Collaborative relationships	R3: *"What is underneath the CE is that you have to work in cooperative modus. Thus, orchestrating this ecosystem and collaborating becomes a vital success factor. This seems to be contradicting the competition mindset, but there is something about it. You have a digital enablement, but as an organization, you have to complement this through co-creation methodologies and facilitation."*	Collaborating and co-creating across firms are vital success criteria for the CE.

(see Table 4 for details). In contrast, three respondents mentioned that the CE did not drive their culture or innovation processes as a result of either counteractive compliance rules or regulation, low market readiness, or low CE concept maturity, as for instance mentioned by R12:

"I do not think the CE concept has enough of a foothold to directly influence how we operate. It will only be indirect, it is clear that a lot of the things we wish to do is connected to the sustainable development goals and what the customer want to do, but it does not drive us directly."

However, if incorporated, the value-driven vision of the CE can provide better purpose to digitalization efforts of the organization, leveraged through data-driven insights and decisions. For instance, R13 note that by, firstly, regarding CE as a source of innovation, one can turn circular strategies into hypotheses which in turn are used as questions for data collection and analysis:

"We have been trying to work within hypothesis-driven development. Essentially, you have a decision and a direction you want to go, let us turn this vision into a hypothesis and let us test it. This has been a very useful method. […] So instead of starting with what data do we have, start with what do you actually want to know. Essentially, figure out what are the key questions your company needs answers to now, and then whether we have the data for those answers and only look at that, not everything else."

Table 7
Human skills resources subthemes, sample quotes, and takeaways.

Themes	Quotes	Key takeaways
Systems thinking skills		
New criteria for success	R3: *"That is one thing we see, that those that are too short-termist asking for ROI, clear black numbers before taking action will probably end up disrupted in some industries. […] You need to open up the company and go beyond just ROI for shareholders and bring in new indicators of success."*	Expanding the criteria and horizon for business success is important to remain competitive.
System dynamics	R4: *"They will need to utilize these additional tools, mainly the system dynamics to understanding their own processes because BA without yourself understanding what your organization is, the processes are and the consequences to different actions are, is useless. So, you have to build up a foundation of system dynamics thinking where you understand your own business."*	The capacity to utilize system dynamics tools is helpful in understanding the organizations processes, impacts, and role within the system.
Shifting mental models	R10: *"The big thing here is that the CE is a big mental model shift to how one should work through the world. That is the big tipping point; you have to have the right mental model, framework and governance before you can apply it effectively."*	Shifting the mental model to include a systems view of the organization is critical in order to facilitate the CE effectively.
Data science skills		
Tacit knowledge management	R5: *"The challenge is to combine the human inputs with what is machine-readable data. We have done this by systematically collecting this operational insights and fed this as background data for the algorithm to make better decisions. This is an example of the human-machine interface where you systematize the tacit knowledge of humans."*	Translating and combining tacit human knowledge with machine-readable data is crucial for developing analytics for decision-making support.
Data visualization	R10: *"It is crucial with data science and data visualization and interpretation of large quantity of data, not big data, but like edge data."*	Mastering data visualizations skills are essential in order to interpret large data sets and core to data science.
Setting goodness requirements	R1: *"Good stable requirements are difficult and require people to know what they want and getting exactly that. For the goodness requirement, we do not have a good solution. If you don't know what you want, asking you to write what you want is like looking for bacon in an empty fridge. If you don't have good requirements it is a long and difficult process."*	Domain knowledge and analytics and business understanding are important in order to set appropriate requirements for algorithm development.
Explainability	R8: *"Well, I think our leaders are quite good in using these tools and techniques. In general, I think they are good at communicating the outputs and understand the nuances in the data produced by analytics."*	Understanding the nuances of analytics is important in order to effectively communicate its outputs.

Table 8
Key quotes for resource orchestration capability, CE implementation, and competitive performance.

Themes	Quotes	Key takeaways
Resource orchestration capability		
Structuring	R5: *"You need to expand the overall skillset within the organization in order to recruit and address a series of new challenges, and they have to collaborate more interdisciplinary. You need to be both a human and technical leader and have the ability to project future technology trends and hit at the right time, because the cost of investing in legacy systems is very high, but also the cost of being too early is very high. So, you need to be able to target when the technology is sufficiently mature whilst not incurring technical debt."*	Addressing the challenges of BA and CE requires procuring new talent and resources at the right time to ensure competitiveness whilst not incurring technical debt.
Bundling	R5: *"The investment in data collection infrastructure is expensive and uncertain, essentially to go from one paradigm to another, there is a lot of dark matter. One thing to consider is that there's already been produced a lot of data, but that in an analytics context can be used in a different manner, essentially the repurposing of data. The interesting thing is that you first discover the actual value of the data, long after it was collected."*	Before acquiring new data resources, an assessment should be made if existing data sets within the firm can be bundled or enriched to fit the need.
Leveraging	R13: *"Having access to data and the facts have been a very helpful tool to answer the question of 'why are we actually doing this?' Just saying 'it is good for the world and times are changing' can be quite abstract, but with BA we can make it more concrete and how it can actually create value for the company."*	BA makes CE efforts more concrete and easier to understand, increasing strategic value and market opportunities.
CE implementation		
Net positive impact	R9: *"They understand from both a positive benefit standpoint as well from a negative cost, either financial, reputational, indirect or social. They realize the importance of these impacts."*	The wider effects of CE have a positive impact on business operation.
Brand reputation and differentiation	R10: *"CE brings corporations an advantage. It gives clarity for the community or customers you are engaging with or the government that you have an authentic commitment beyond business as usual. You are a different thinker*	CE increases customer and stakeholder relationships.

(*continued on next page*)

Table 8 (*continued*)

Themes	Quotes	Key takeaways
	if you are engaging with the CE."	
Competitive performance		
Improving planning	R1: *"Where we can create a competitive advantage is by improving planning, and we will do this through BA by improving transparency. […] essentially making better and more informed decisions. Knowing where you are, knowing where it hurts. The thing I would downplay a bit is BA's ability to predict. Being able to plan ahead, that is a competitive advantage."*	BA provides an enhanced ability to predict and plan ahead, improving firms' operations excellence.
Recruiting and retaining talent	R6: *"I think it is all about getting hold of and keeping the best individuals and be true to their own values. Today, it is a stronger demand by employees to identify oneself with the company and have good corporate values and their contribution to society. The focus should not be to only make money, because this does not motivate people. There is often a mutual gain that the organization gets to keep their employees (which again gives profitability over time). Finding this intersection will be very beneficial."*	CE strengthen firms' corporate vision and improves their ability to recruit and retain talent, promoting operations excellence.
Increased diversification and reduced risks, inefficiencies, and cost	R10: *"If you do it intelligently, it also saves you money and adds more value to what you are building or creating. It also brings a unique procurement ecosystem and partnership arrangements with other corporations."*	CE enables the reduction of risks and costs through diversification whilst providing new value propositions promoting firms' revenue growth.

Openness and co-creation

An MIT Sloan Management Review by Ransbotham and Kiron (2017) highlights that companies that share data and collaborate more intensively tend to be more innovative. Similarly, nearly all respondents reported having implemented measures to become more open as a firm and improve co-creation by increasing trust, transparency, and collaboration (as can be seen in Table 4). From the analysis, we were able to identify three themes: data sharing, removing silos and internal alignment, and collaborative relationships (see Table 6). Further, many respondents saw a close relationship between being data-driven and their ability to innovate for the CE. While CE requires an overall redesign of products, processes, and business models, it also demands companies to rethink their value chains and the degree to which stakeholders are involved. The respondents recognized that no single company could transition to the CE alone and pointed to the need for increased data sharing, collaboration, transparency, and trust internally and externally. Several respondents noted that external collaboration and co-creation was more difficult due to a lack of transparency and trust in the value chain, re-emphasizing the need for a single-source-of-truth and good data quality throughout. However, R2 mentioned that due to the novelty and lack of awareness of CE and sustainability, internal collaboration was, in fact, more challenging than external:

"Collaboration within one company is more important and to some degree even more challenging than collaboration between companies. It is easier for two sustainability directors of two different companies to collaborate than it is for a sustainability director to collaborate with a compliance director for example."

Table 9
Quality evaluation.

Criteria for quality	Methods and tactics used
Worthy topic	Utilizing BA for CE is an important topic of timely concern with significant relevance to research, industry, and policy.
Rich rigor	The study used rigorous theoretical frameworks (RBV and ROV) to ground the research.
Sincerity	The study is transparent about the methods used and tactics used to arrive at identified themes and concepts. The authors are reflective about their subjective values, biases and inclinations.
Credibility	The research is marked by concrete details and examples of how the data has been interpreted in the analysis. Triangulation of sources and cross-validation between the authors is employed.
Resonance	Based on thick descriptions of the themes identified with several graphical and tabular representations, transferability of findings is achieved.
Significant contribution	The research provides significant contributions of both academic and practical use. Propositions for future studies is provided and testing of the proposed conceptual model is possible.
Ethical	Appropriate ethical considerations were made throughout the interview process to ensure respondents about their anonymity and data protection rights.
Meaningful coherence	The study employs appropriate methodologies to reach its stated goals in the research questions and provides meaningful connections to extant literature and calls for action.

Human skills

Closely related to intangible resources, human skills were credited as being a crucial factor by most all the respondents in this study, but difficult to acquire. Effectively leveraging BA with circular strategies reportedly requires a different skillset for humans to master both the technical aspects of BA together with the system dynamics of CE through systems thinking skills. Thus, central to improvements of both tangible and intangible resources are managers with systems thinking skills and analytics acumen, as was mentioned by R9:

"Human skills are very important in terms of building those relationships within a value chain that has to be in place in order to able the flow of data necessary to close loops and design products differently. On the management and executive side, that is very much critical, because the idea of redesigning products' lifecycle to be circular is not something that can happen in one department of the firm. It is very much a large-scale effort that requires teams from design, procurement, EHS, waste management, etc. Where you need to have a management buy-in to be able to bring those internal teams together and show this is a priority as well as working on the outside on the value chain side with upstream suppliers as well as downstream customers."

When examining the human skills required for leveraging BA for CE, two primary resources were identified. The first was systems thinking skills, mainly encompassing a shift in managers' mental models in order to set new criteria of success and utilize tools for system dynamics. The second were data science skills, encompassing the requirements of technical-oriented roles for developing analytics models and more business-oriented roles to communicate requirements and the results of these models.

Systems thinking skills

Fourteen respondents cited efforts in developing systems thinking

skills within their organization. However, only eight respondents reported that their managers showcased a satisfactory level of this skill, as can be seen in Table 4. The remaining respondents mentioned that most managers were not looking at the broader system that their organizations were operating in. Instead, many managers were rather focusing on smaller pieces of the system and optimizing them. From a CE perspective, this is often noted as focusing on efficiency rather than effectiveness and is often an outcome from working in silos. From the analysis, we were able to identify three themes: new criteria for success, system dynamics, and shifting mental models (see Table 7 for details). Together, these themes corroborate the general consensus of the respondents of the importance of systems thinking for CE implementation. R9 explains this by comparing the skill of systems thinking to the human vision:

"If you take the idea of your vision analogy, if you are looking at a linear product and only worry about price, performance, and esthetics. You are taking a very narrow front view. If you are trying to look at the unintended consequences and the hidden impacts and opportunities of a CE, you have to bring in your peripheral vision too."

Despite many respondents reporting a high level of systems thinking within their organization, actions were often still missing, suggestion knowledge of the CE and its implication is not enough as R2 note:

"Knowledge of it is not as important that acknowledgment that it is a central part of their job description. That is a bit of a problem."

Data science skills

Possessing, or having access to, analytics development talent is fundamental for organizations' capacity to realize the opportunities of BA. Overall, most all respondents cited having sufficient talent and skill within their organization, as can be seen in Table 4. From the analysis, we were able to identify four themes of: tacit knowledge management, data visualization, setting goodness requirements, and explainability (see Table 7 for details). With data science being a multidisciplinary field, often requiring extensive domain knowledge, managing tacit human knowledge together with machine learning algorithms was mentioned as particularly important. For instance, R7 explains how they combine hardware and reliability knowledge with machine learning skills to implement predictive maintenance:

"We see a need to shift more towards predictive maintenance. We are quite reliant on hardware and there will be parts that degrade and break. […] to be able to predict when a part might break so we can service it in advance has great value for us and our customers. […] we use all our domain knowledge and data on machine learning to get this up and running."

Furthermore, R5 highlight that it is crucial for data scientists to remember that you need an overall vision and to put the data into a context since it is not given that the most important insights are present in the dataset you are given:

"For those that are developing the algorithms, it requires a level of proactive thinking. It is important that leaders develop these individuals sufficiently and communicate this further."

Furthermore, as CE proposes a new paradigm for value generation and business model design, it sets greater demand for innovation and data on how these new products and services are operated. This increases the general demand for analytics acumen and particularly individuals mastering both the complex business landscape of CE and the technical challenges imposed by analytics, as for instance mentioned by R6:

"The combination of business and technical skills is difficult. It is also hard to find technologists that know business well. […] the leaders of tomorrow will need better knowledge of analytics and need the ability to understand how to use it. It is more a tool to ask good questions rather than finding the right answers. It is a new way of thinking."

However, only eight respondents experienced that their managers effectively communicated both the requirements for developing analytics and the outputs generated from the analysis, as can be seen in Table 4. R1 mentioned that their managers did not see the direct benefits of analytics and did not have a suitable educational background to become efficient at it.

Leveraging business analytics for circular economy

Resource orchestration capability

According to RBV, resources that possess VRIN attributes (as the ones detailed above) tend to provide better opportunities for competitive performance (Eisenhardt and Martin, 2000; Mata et al., 1995). However, our findings corroborate previous studies arguing that merely possessing such resources without leveraging them is counterproductive for the firm Ahuja and Chan (2017). To this end, ROV argues that resources have to be structured, bundled, and leveraged in order to create new capabilities and enable them to generate business value (Wright et al., 2012). Once these capabilities have been internalized, they are difficult for competitors to imitate.

Overall, we observed a great discourse amongst the respondents on the importance of leveraging firms' BA for CE and competitive gains. In particular, managers were highlighted as crucial to the potential success, or failure, of developments under tangible resources and human skills, such as culture development and employee training. Given the variance in breadth and life cycle of the firms' covered (e.g., from waste management start-ups as R12 to large multinational IT service corporations as R8), the respondents experienced a difference in the approach and willingness of management to both adopt circular strategies and prioritize corresponding BA investments. This can be understood by drawing on the life cycle logic of the ROV which states that the start-up stage requires a greater degree of resource-structuring behavior to support the firm's business model when compared to firms in the mature stage (Miller and Friesen, 1984; Sirmon et al., 2011). Correspondingly, a mature firm's resources may exert a greater influence on its external environment (Smith et al., 1985). Despite variance in organizations' operating environment and development trajectory, the underlying capability development mechanism was conducive to the process of structuring, bundling, and leveraging, as detailed in ROV. However, the granularity of our data did not allow for the respective sub-processes to be fully identified, for instance, such as stabilizing, enriching, and pioneering for bundling.

Structuring

Corroborating the results of Wright et al. (2012), the selection and structuring of BA resources was seen as an important prerequisite for building a firm-wide BAC. Overall, the respondents reported numerous related activities, from identifying resources of strategic importance and making investments related to them (e.g., sensor data and data science talent) to creating new organizational structures and business models (e.g., horizontal departments and product-service systems). Despite receiving great attention to the importance of CE, some respondents cited several challenges related to the lack of top management support and willingness to acquire new resources. This was, for instance, the case for R3, where it could be traced back to lacking systems thinking skills of the managers, which in turn resulted in missing structuring behavior within the firm.

In contrast, R7 cited that both their top and lower management experienced great systems thinking skills and had recently started repositioning their firm towards a Smart CE. Correspondingly, the firm had made substantial investments into accumulating new digital technologies, recruited a new horizontal department of 10 CE experts, and divested in hardware-specific knowledge. However, despite their efforts, they still experienced challenges with effectively leveraging their new strategy at large, suggesting more focus should be put towards bundling their newly sought resources with existing ones to form new capabilities. R7 note:

"One internal challenge we have is connected to our history as a hardware producer. We have produced hardware with a great deal of customer

customization. This has given us great customer experience and appreciation, but now when we not only have software on the hardware itself but in the cloud, then all this hardware customization works against you. We have a large task to streamline our portfolio."

Bundling

Overall, the process of effectively bundling resources into capabilities was frequently reflected in the firms' governance practices, and choice of IT archetypes. Most respondents cited their current archetype and operation as functional silos where each unit handled its own resource allocation. However, this archetype was seen as somewhat incompatible with the lateral nature of circular strategies, and several efforts were suggested to remove unnecessary silos and align around common KPIs, as mentioned by R1:

"The main challenge we have is to align internally around KPIs. […] sometimes we speak the same language and want the same things, sometimes we want the opposite things. Internally this is a major challenge because you try to strike a balance as you have to make someone else's KPI worse and yours better, and this is not good. […] you need to have an honest discussion to make the best outcome. […] it is management setting the direction and then a clear communication process taking into account the local flavor that irons out any disagreements or problems that might stand in the way."

Further, closely related to the intangible resource of trust, transparency, and collaborative relationships are the general consensus of the need to operate within an ecosystem in order to realize the value of CE. From the ROV, this can be seen as enriching internal capabilities with external capabilities to offer bundled services as a partnership between the firm and its suppliers, partners, and even competitors Ahuja and Chan (2017). Similar logic can be found in the literature on net-enabled business innovation cycles and value co-creation (Lenka et al., 2017; Zahra and George, 2002). Hence, bundling capabilities may result in increased customer value and provides more flexibility and options to the resources and capabilities offered by the firm, thereby making the overall value chain more robust against the competition, as for instance mentioned by R3:

"To be competitive in the future, you need to be part of this ecosystem or proactively shape your ecosystem. So, you shift from being value chain driven to value web or ecosystem based. The better you are at shaping or orchestrating your ecosystem to serve your purpose, the better you will be fit for the new environment. That is probably how companies that are not acting now will be disrupted because they are still functioning in a value chain approach, whilst what they really should be doing is repositioning themselves towards an ecosystem."

Leveraging

All the respondents were conscious that once the BA resources had been appropriately structured and bundled into a capability, it needs to be effectively leveraged in order to yield value. Nonetheless, many respondents reported challenges with effectively deploying this newly developed capability to capitalize on the investments and efforts made. For instance, an overall uncertainty was observed on how to mobilize such a capability to i) adopt an acceptable level of CE, ii) outperform rivals in the short term, and iii) maintain a competitive advantage in the long term. Many respondents pointed to this being a result of lacking market demand, internal awareness, and the overall fast-moving pace of the field. In other words, this can be summarized as environmental uncertainty, which can be defined as a general condition of ambiguity and unpredictability of customer needs and technology developments Pavlou and El Sawy (2006). According to the ROV, this can be understood as an information deficit that affects the type of resources and capabilities needed to outperform rivals and the leveraging strategies required to realize a competitive advantage (Sirmon et al., 2007). The respondents credited CE with strategic relevance for reducing overall risks and for building the material sourcing flexibility needed for a turbulent business environment. However, the respondents cited difficulties with generating societal value and evaluating the impact of their efforts, as for instance mentioned by R6:

"What is difficult is to take the last step from business value to social value. You have to think long enough for the business cases you create. You can easily evaluate the effect of a single solution, but what is difficult is evaluating the overall effect because you have a self-reinforcing effect over time that is exponential. But it takes time to measure it, and it takes time to change the behavior of humans."

Circular economy implementation

In line with the growing interest for sustainable solutions by researchers and industry alike, the respondents demonstrated a general consensus on the strategic importance and business opportunities of transitioning to the CE. Throughout the interviews, a number of prospective circular strategies leveraging insights from BA were presented, such as identification of optimal life cycle extending activity and timing of interventions for reduced production downtime through predictive maintenance, simulation of economic and environmental impacts in different life cycle scenarios, automated triggering, and scheduling of reverse logistics requests, optimization of product use for minimal product wear and degradation.

Furthermore, many respondents highlighted that they experienced an increasing number of firms making great strides to incorporate the UN Sustainable Development Goals, for which the CE could prove beneficial in generating business value from these efforts. From the analysis, apart from assisting with general competitive performance, were seen to improve firms' brand and reputation, provide new differentiation strategies, and had an indirect positive benefit for firms through social and environmental impacts (see Table 8). However, most all respondents experienced challenges with effectively scaling circular strategies because of barriers outside of the organization, such as:

- Lack of common reporting standard and database
- Missing regulatory alignment and CE frameworks
- Imprecise pricing of environmental externalities
- Conflicting micro- and macroeconomic targets for the CE

Competitive performance

Considerable discussion concerned the potential of BA and CE to increase the overall competitive performance of the firm. Notwithstanding the numerous comments on business value made throughout the findings, three themes, or leverage points, were found to be particularly relevant in improving firm performance and gaining a competitive advantage. First, gaining foresight and the ability to predict possible future outcomes for improved operational and strategic planning was seen as one of the main competitive drivers for investing in BA. This was repeated throughout most interviews and unfolded both in the choice of KPIs and goodness requirements. Second, the overall vision and societal contributions of the CE were seen to boost firms' appeal for new talent, both directly reducing costs for high employee turnover rates and operational excellence through attaining highly sought-after talent. Third, the unique procurement ecosystem and partnership arrangements enabled through the CE was seen to help firms diversify their portfolio and supply chain dependencies, reducing risks, inefficiencies, and cost.

Conceptual model

To structure our understanding and inform future studies on how BA can be leveraged towards CE, we synthesized our findings in a conceptual model (as seen in Fig. 2). The underlying logic of our model incorporates resource-picking (from the RBV) and capability-building (from the ROV) theory to demonstrate: i) how core BA resources are directly orchestrated through structuring, bundling, and leveraging activities into a BAC, and ii) how the hypothetical causal chain of the effects of BA on competitive performance is mediated through CE implementation and resource orchestration capability. As such, we theorize that by developing a strong BAC, firms are in a better position to strengthen existing circular strategies, implement new ones, improve

their resource orchestration capability, and enhance their competitive performance. As such, the effect of BAC on competitive performance can be seen as a mediating effect by firms' resource orchestration capability and their degree of CE implementation. Support for this can be found in related empirical studies on the effect of BAC for improved sustainable supply chain management and circular strategy implementation (Dubey et al., 2016; Gupta et al., 2019; Hazen et al., 2016; Wang et al., 2016; Wu et al., 2017; Zhao et al., 2017). Accordingly, similar to studies on internal capabilities for realizing innovation and driving competitive performance (Barney, 1991; Chadwick et al., 2015; Chang, 2018; Sirmon et al., 2007), BAC can improve firms' resource orchestration capability. As such, BAC may reduce the risk of investing in CE implementation, increasing the overall effect on competitive performance.

Discussion

Correctly managing BA resources will be central for firms when navigating the CE transition and may even prove vital for obtaining a competitive advantage in this new business landscape. The impact of such as transition will far outreach mere financial gains for firms and can ultimately contribute to sustained environmental and social gains towards sustainable development. The respondents reported great strides being made by their firms and competitors in utilizing BA to connect material and information flows. This suggests competitive gains to be achieved by effectuating such a connection. Based on this, we theorize that the future control of the data translates to control of the material and subsequent market shares.

However, to reap these benefits, firms have to go beyond sheer incremental efficiency gains and take a holistic view of their firm and its value chain, re-assess both upstream and downstream impacts, and expand their criteria of business success. This requires firms to restructure existing organizational resources, make relevant recruitments and investments, and cultivate a new organizational culture of data-driven decision-making for circular-oriented innovation. While parallels can be made between the BA resources required for supply chain management and CE, the latter differs in particular on the degree of systems thinking skills required. Circular strategies span beyond the traditional supply chain and require a broader understanding of the context of the firm over a longer period of time. Companies need to look at new connections, patterns, and relationships throughout their value chain and increase their degree of data collection, integration, and sharing. While our work builds on previous related works from BA and CE theory, several additions and adjustments have been made towards the description of a firm-wide BAC for CE, as can be seen in Table 3.

Research implications

Effectively leveraging the hype around big data and BA is highlighted as pivotal for the operationalization of the CE. While practitioners seem to be leading the way for such novel uses of data, academics have only recently begun to investigate the synergies of BA and CE (Gupta et al., 2019; Kristoffersen et al., 2020). Consequently, gaps remain in the literature on defining the building blocks of a BAC for CE and how firms can create one. From a theoretical perspective, our study contributes both to the emerging literature on CE and strategic management literature on BAC and managers' role in resource orchestration (Ahuja and Chan, 2017; Kristoffersen et al., 2020; Lahti et al., 2018; Mikalef et al., 2018; Rialti et al., 2019; Sirmon et al., 2011). In particular, this work extends the Smart CE framework proposed by Kristoffersen et al. (2020) by providing empirical insights into the key organizational resources and practices needed to leverage the Smart CE.

Moreover, this study makes important contributions to the existing literature in five main areas. First, we propose eight constructs, as shown in Table 3, that make up the key resources of this capability. These constructs provide valuable insights for future studies by offering a lens to analyze both qualitative and quantitative data. Second, we further extend the ROV by explaining how the processes of structuring, bundling, and leveraging influence the conversion of organizational resources into firm-wide capabilities along with the effect of variance in firms' contexts. Third, we explore the role of managers for supporting these processes along with how their efforts interrelate to the resources present in the organization. Fourth, we provide a deeper understanding of how organizations leverage this capability to transition towards the CE and realize a competitive advantage. Finally, we present a theoretically grounded conceptual model to inform future quantitative studies on how to examine a BAC for CE, seen in Fig. 2. This extends the literature on RBV and ROV by combining them with BA and CE literature and empirical insights.

Practical implications

In terms of practical implications, managers may find this research useful in three main areas. First, to seek inspiration on how BA can leverage their organization's CE transition by i) understanding the conceptual relationship between BA, CE, and competitive performance (as seen in Fig. 2) and ii) gather insights from the experience of the respondents. Circular strategies supported by BA represent a new form of value creation and innovative and forward-looking business models. While practitioners may be paving the way in several new uses of analytics towards more sustainable business strategies, they lack support and examples of how to systematically innovate existing business strategies with BA and CE (Kristoffersen et al., 2020). Second, identify which artifacts, or organizational resources, are important leveraging BA for CE (as detailed in Section 4.1). As firms reposition and restructure their organization to meet new market and governance demands for sustainable operation, priorities have to be made that will be decisive for the future survival and competitiveness of firms. Hence, correctly identifying which resources to invest in and capabilities to build will be crucial. Third, understand how to appropriately structure, bundle, and leverage their organizational resources to build a firm-wide BAC to i) leverage their organization's CE transition and ii) realize competitive performance gains (as detailed in Section 4.2). As covered extensively in strategic management theory, only acquiring and holding resources of strategic relevance does not directly translate into competitive gains in itself. The resources first have to be appropriately managed to form firm-wide capabilities, which then needs to be effectively leveraged and deployed. Organizations may find this work useful for understanding how such a process can be orchestrated together with the role of managers for facilitating change.

Limitations and future research

This study is an early attempt to detail the organizational resources required to leverage BA for CE. As such, the work is not without limitations. First, while our purposeful sampling technique was successful in covering variance in breadth and life cycle of the firms, given the limited scope of our study, we were unable to cover variance in depth (levels of hierarchy) within the firm. This can, for instance, be addressed through an in-depth multiple case study with interviews of multiple levels of managers from the same firm, increasing the overall transferability of this work. Second, we recognize more longitudinal studies would be required to better understand and explicate how differences in firms' environmental uncertainty and the life cycle stage affect the structuring, bundling, and leveraging processes of resource orchestration. Further, while these processes can occur at the operational, tactical, and strategic levels in the firm, it is important to note that no such differentiation was made in this study. Third, we would like to emphasize that the conceptual model and constructs presented in this study were uncovered on the basis of 15 expert interviews. While this is a starting point, it can by no means be confirmed through a single qualitative analysis of such a sample. Addressing this, a large-scale quantitative analysis could be performed to test the validity of the constructs and generalizability of

the conceptual model. This could also provide more granularity of the presented constructs and shed some light on the impact of contextual factors when leveraging BA for CE. Our propositions, to be tested empirically in future studies, are summarized below:

- Proposition 1: The resources identified are positively related to a firm-wide BAC for CE.
- Proposition 2: The structuring, bundling, and leveraging processes are positively related to forming BA capabilities.
- Proposition 3: The BAC identified is positively related to increased CE implementation, resource orchestration capability, and competitive advantage.
- Proposition 4: The effects of BA on competitive performance is mediated through obtaining a CE implementation and resource orchestration capability.

Building on the theoretical underpinnings and rich insights into the factors described in this study, the authors firmly believe that these issues may hold merit in contributing to future studies. The Smart CE strategies and enablers mapped by previous literature along with the empirical findings of this study clearly outline the novelty and pre-paradigmatic nature of this research stream. Hence future qualitative and quantitative studies should target the cause-and-effect relationship between BA and CE to leverage the transition towards sustainable development.

Validity and reliability

The amalgamation of the quantitative paradigm with qualitative research through validity and reliability have changed the traditional meaning of these terms and what constitutes quality research from the qualitative researcher's perspectives Golafshani (2003). Quantitative and qualitative studies are different in nature, while the former generally has a purpose of explaining, the latter has a purpose of understanding. This difference in purposes makes evaluating the quality of studies in quantitative and qualitative research dissimilar, Stenbacka (2001) even argues for the concept of reliability to be irrelevant and misleading in qualitative research. Similar arguments can be seen for the term of validity, but at the same time, qualitative researchers realize the need for some criteria of quality measures of their research Creswell and Miller (2000). As a result, several concepts for assessing the quality of qualitative studies have been proposed, such as credibility, neutrality, consistency, transferability, rigor, and trustworthiness (Davies and Dodd, 2002; Lincoln and Guba, 1990; Seale, 1999; Stenbacka, 2001). To discuss the validity and reliability of our study, we utilized the eight "big-tent" criteria for excellent qualitative research by Tracy (2010) (as seen in Table 9). The eight criteria are: worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethics, and meaningful coherence. These markers provide a rigorous conceptualization of qualitative quality and a common language to discuss the excellence of qualitative research recognizable across difference in paradigms and variety of audiences.

Conclusion

This work was motivated by the great interest in using data and analytics to leverage CE efforts by both practitioners and academics. It analyzed insight from 15 expert interviews along with theory from RBV, ROV, past BAC literature, and recently published work on the Smart CE. In summary, we have explored the role of BA resources and capabilities for adopting circular strategies using the lens of RBV, ROV, and the Smart CE. We have proposed a novel conceptual model that breaks down the process of developing a BAC into structuring, bundling, and leveraging and theorized how obtaining a competitive advantage are mediated through CE implementation and resource orchestration capability. Based on this, eight resources were suggested that, when combined, likely create a BAC for CE. Specifically, the three tangible resources of data, technology, and basic resources, the three intangible resources of data-driven culture, circular-oriented innovation culture, and openness and co-creation, and the two human skills of systems thinking and data science was suggested. In addition, the extensive and diverse industry experience of the respondents covered in this study enabled a deep understanding of how organizations and managers leverage this capability to gain CE and competitive advantage.

Declaration of Competing Interest

The authors declare no conflict of interests regarding the publication of this article.

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