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Do blockchain and circular economy practices improve post COVID-19 supply chains? A resource-based and resource dependence perspective

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Santosh Nandi
Division of Business Administration and Economics, University of South Carolina Sumter, Sumter, South Carolina, USA and School of Business Administration, University of South Carolina Aiken, Aiken, South Carolina, USA

Joseph Sarkis
Foisie Business School, Worcester Polytechnic Institute, Worcester, Massachusetts, USA and Hanken School of Economics, Humlog Institute, Helsinki, Finland

Aref Hervani
University of South Carolina Aiken, Aiken, South Carolina, USA, and

Marilyn Helms
Dalton State College, Dalton, Georgia, USA

Abstract

Purpose – Using the resource-based and the resource dependence theoretical approaches of the firm, the paper explores firm responses to supply chain disruptions during COVID-19. The paper explores how firms develop localization, agility and digitization (L-A-D) capabilities by applying (or not applying) their critical circular economy (CE) and blockchain technology (BCT)-related resources and capabilities that they either already possess or acquire from external agents.

Design/methodology/approach – An abductive approach, applying exploratory qualitative research was conducted over a sample of 24 firms. The sample represented different industries to study their critical BCT and CE resources and capabilities and the L-A-D capabilities. Firm resources and capabilities were classified using the technology, organization and environment (TOE) framework.

Findings – Findings show significant patterns on adoption levels of the blockchain-enabled circular economy system (BCES) and L-A-D capability development. The greater the BCES adoption capabilities, the greater the L-A-D capabilities. Organizational size and industry both influence the relationship between BCES and L-A-D. Accordingly, research propositions and a research framework are proposed.

Research limitations/implications – Given the limited sample size, the generalizability of the findings is limited. Our findings extend supply chain resiliency research. A series of propositions provide opportunities for future research. The resource-based view and resource-dependency theories are useful frameworks to better understanding the relationship between firm resources and supply chain resilience.

Practical implications – The results and discussion of this study serve as useful guidance for practitioners to create CE and BCT resources and capabilities for improving supply chain resiliency.

Social implications – The study shows the socio-economic and socio-environmental importance of BCES in the COVID-19 or similar crises.

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Originality/value – The study is one of the initial attempts that highlights the possibilities of BCES across multiple industries and their value during pandemics and disruptions.

Keywords Blockchain, Circular economy, Supply chain, COVID-19, Resource-based view, Resilience
Paper type Research paper

1. Introduction

The COVID-19 virus and the ensuing world pandemic resulted in unprecedented disruption to global supply chains (Hobbs, 2020; Singh *et al.*, 2020), especially in meeting customer demand. Along with increased attention on ways to improve supply chains and build their resilience (Ivanov and Das, 2020), there has emerged a call for more sustainable supply chain perspectives which are important to long-term viable supply chains (Ivanov, 2020; Sarkis *et al.*, 2020).

Given the COVID crisis, supply chain resilience has come to the forefront. Sustainable supply chains and circular economy (CE) principles may provide long-term avenues for building economic and supply chain resilience while contributing to social and environmental sustainability (Sarkis *et al.*, 2020). CE has served as a driver of change to increase sustainability leading to resilience (e.g. Bag *et al.*, 2019; Wuyts *et al.*, 2020). As a COVID-19 example, the CE practices have helped establish closed resource loops for raw materials of medical supplies to alleviate shortages. Localization efforts are also enhanced given that end-of-life materials can be found locally and through CE practices have been identified as ways to reinforce materials, furthering supply chain resilience. Technological solutions and innovations, such as Industry 4.0 and blockchain technology, can further strengthen CE, sustainable supply chains and overall supply chain resilience (Bag *et al.*, 2020; Golan *et al.*, 2020).

Technologies, especially information technologies with digitalization, can provide timely information, transparency and visibility into the supply chain and help build supply chain resilience. In this regard, the emerging blockchain technology (BCT) can support CE practices (Kouhizadeh *et al.*, 2020) helping to also build resilience.

Due to a greater focus on cost-saving measures, supply chain brittleness is more evident during this COVID-19 crisis (Choi *et al.*, 2020) with disruptions from significant unexpected shifts or volatility in demand. Global supply chain vulnerabilities became evident during the COVID-19 crisis due to border regulations, shutdowns and lack of control. Together CE and BCT have the potential to support supply chain resilience factors including building localized, agile and digitalized supply chains (Sarkis *et al.*, 2020; Choi, 2020; Queiroz *et al.*, 2020). We take this joint emergent perspective and evaluation in this paper. The perspective is important for current and future supply chain resilience study and understanding, as well as broader contributions to understanding environmental and social sustainability and has yet to be fully investigated.

To address supply chain brittleness, we argue that CE can aid localization, agility and digitization (L-A-D) of supply chains. First, CE can aid localization by providing a localized closed-loop supply chain. Second, CE can facilitate agility by allowing for various options such as byproducts and waste exchanges for materials, in addition to supporting sharing economy activities allows for greater resource flexibility. Third, although CE may not initially include digitalization, CE efforts along with blockchain technology can enhance L-A-D. When BCT-based digitalization is applied to CE conceptualizations such as identifying various local materials, waste or by-products and supporting a sharing economy to take advantage of unused capacities in a system, CE and BCT are complementary. Together we define the CE and BCT amalgamation as a blockchain-enabled circular economy system (BCES).

Accordingly, we argue BCES capabilities lead to L-A-D capabilities that organizations and their supply chains can counter major disruptions of pandemic situations and their aftermath. Together, these capabilities can help build competitive advantage or resilience in times of crisis, but potentially in non-crisis periods as well. Our contribution is to support this argument and provide research direction based on learning of responses of organizations and their supply chains to the COVID-19 crisis. Additionally, our study contributes to the supply chain resilience literature by proposing how firms should integrate BCES capabilities to facilitate supply chain L-A-D in efforts to counter supply chain disruptions. This study provides managerial insights that contribute to supply chain practice. In making these practical and theoretical contributions, we ask and seek to answer the following research questions:

RQ1. What are the BCES resources and capabilities that firms *possess* to build L-A-D capabilities in response to post-pandemic disruptions?

RQ2. What are the BCES resources and capabilities that firms *need to acquire* to build L-A-D capabilities in response to post-pandemic disruptions?

RQ3. Do industry and organizational size affect the relationship between BCES and L-A-D capabilities?

RQ4. Do industry supply chain characteristics play a role in the relationship between BCES and L-A-D?

To study the relationship between BCES and L-A-D capabilities of a supply chain at the firm level, we conduct an abductive qualitative exploratory study of the critical resources and capabilities requirements and positions using the resource-based view (RBV) (Barney, 1991) and resource dependence theory (RDT) (Pfeffer and Salancik, 2003) lenses. For our analysis, we apply the technology, organizational and environmental (TOE) theoretical framework (Baker, 2012) to categorize organizational resources and capabilities of organizations.

We organized this paper into six sections. In Section 2, we present the theoretical background of the study. In Section 3, we explain the methodology used to achieve the research objectives of the study including the data collection method, the development of identification frameworks for content analysis and the data analysis methods. In Section 4, we discuss the findings of the data analysis of each research question and related propositions. In Section 5, we discuss the theoretical and practical implications of our study. Section 6 concludes the study with limitations and directions for future research.

2. Literature review

In this section, we present the theoretical background of the circular economy, blockchain technology, supply chain outcomes, the RBV and the RDT. The following sections begin with an overview of the circular economy. Blockchain technology—an emerging technology—only recently finding applications among supply chain participants is next (Saberi *et al.*, 2019). The RBV theoretical underpinning considers organizational capabilities available for a firm is also reviewed. Resource dependence is evaluated through resources available externally to the firm or supply chain that can be leveraged in a partnership or other relationship to benefit the firm and the supply chain collectively along with end-users and consumers. The TOE framework used to categorize capabilities is also introduced in this section. The foundations of these concepts and theories are presented separately and, in more detail, below.

2.1 The circular economy (CE)

The CE—although viewed as an *essentially contested concept* (Kirchherr *et al.*, 2017; Korhonen *et al.*, 2018)—typically has a goal to reduce waste and minimize the use of limited natural resources, while improving the economic performance of regions and firms. CE integrates closed-loop systems where limited waste is generated rather than historically linear production systems with multiple waste streams (Geissdoerfer *et al.*, 2017; Jabbour *et al.*, 2019; Murray *et al.*, 2017) contributing to a more sustainable society (De Jesus *et al.*, 2018; Geng *et al.*, 2016; Genovese *et al.*, 2017). There is a call for industrial and tier-wise supply chain linkages along the life cycle of products—transforming upstream production and consumption processes (Nandi *et al.*, 2020b; Nandi and Kaynak, 2020). The circular economy is related to creating circular supply chains and can address resource needs in pandemics.

Hussain and Malik (2020) note that CE relates to supply chain resilience and capabilities. Industry 4.0 resources, such as big data, cloud computing and the internet of things (IoT), can support a CE system (Bag *et al.*, 2020). Redesigning supply chains to meet CE goals and its effectiveness in developing supply chain resilience is still a nascent phenomenon (Takeda *et al.*, 2018). Due to the COVID-19 pandemic, this CE-supply chain resilience linkage has gained momentum (Ivanov and Dolgui, 2020; Sarkis *et al.*, 2020). Combining BCT with CE can help CE progress (Kouhizadeh *et al.*, 2021. The BCT-CE linkage has not been investigated from a supply chain resilience perspective (Fahimnia *et al.*, 2019). In this study, we seek to consider these linkages.

2.2 Blockchain technology (BCT)

BCT is a decentralized transaction and data management technology used most popularly for Bitcoin cryptocurrency (Nakamoto, 2009). BCT helps create a decentralized environment where no third party is in control of digital transactions and data (Yarmack, 2017). A blockchain network has no central authority. Since it is a shared and immutable ledger, the information in it is open for participants in the supply chain to access and see. This situation creates transparency and is a crucial tenet of traceability necessary for global supply chain management and can aid in localization efforts. There are growing concerns among corporations and consumers regarding social and environmental sustainability (Groening *et al.*, 2018). BCT helps address various sustainability dimensions through decentralized and immutable data, reliable data, transparency, traceability, smart contracts and incentivization (Nandi *et al.*, 2020a). BCT positively influences supply chain resilience strategies, particularly through collaboration, agility, velocity and visibility (Kalla *et al.*, 2020; Lohmer *et al.*, 2020; Min, 2019).

BCT can aid multiple supply chain stages by providing data across supply chain stages incorporating multiple stakeholders, valuing supply chain socio-environmental sustainability (Kouhizadeh *et al.*, 2021; Kouhizadeh and Sarkis, 2018; Saberi *et al.*, 2019). BCT traceability considerations contribute to this resilience (Behnke and Janssen, 2020). Supply chain systems must be modified, and boundary conditions established before successful BCT information sharing. BCT smart contracts can contribute to agility and supply chain resilience (Nandi *et al.*, 2020a). BCT can also act as an incentivizing mechanism, encouraging stakeholders to adopt new products and processes (Kouhizadeh *et al.*, 2020). Blockchain incentives can include cryptocurrencies or tokens (Chen, 2018). These incentives may support a wide variety of sustainability practices, products and processes including CE (Kouhizadeh *et al.*, 2020). BCT-enabled CE systems can effectively create shared value, scale innovation and generate new ideas (Narayan and Tidström, 2020). BCT can help incentivize cooperative efforts within the CE ecosystem. For example, circularise, a technology start-up, developed a web-based blockchain system that allows information exchange between participating CE ecosystem members (Circularise, 2020). Consider the neurological damage that high-mercury fish can cause to consumers (Amidor, 2009).

2.3 The resource-based view and the resource dependence perspective of blockchain-enabled circular economy system

RBV, also known as *resource-based theory*, focuses on resources and its capabilities that an organization already owns and/or could own to build competitive advantages. RDT presents relationships to resources that organizations might obtain from their environment building competitiveness. RBV provides an examination of intra-organizational relationships of resources and its capabilities to explain why and how some organizations outperform others—gain competitive advantages (Barney, 1991; Newbert, 2008). RBV argues the more customer added value an organization provides than competing organizations the more competitive advantage for the organization (Barney and Clark, 2007; Nandi *et al.*, 2020a). RDT assumes that organizational performance is dependent on its environment, and stresses inter-organizational efforts to secure resources and reduce environmental uncertainty (Pfeffer and Salancik, 2003; Bode *et al.*, 2011; Tashman, 2020). RDT identifies two major organizational objectives: to *minimize their dependence on other organizations* and to *maximize other organizations' dependence on themselves* (Ulrich and Barney, 1984).

Organizational resources and capabilities have emerged as core strategic theoretical lenses. Tangible and intangible resources help firms establish relational competitive capabilities. Knowledge capability can build intangible resources and allow dynamic organizational learning in organizations for the natural environment (Beske *et al.*, 2014; Bhupendra and Sangle, 2015; Hart, 1995). Relational capability is meant to augment the resources of alliance partners to create, extend or modify their resource bases (Teece, 2000; Hefalt and Peteraf, 2003). Few studies have used both RBV and RDT theories concurrently to investigate organizational dominant resources and capabilities (c.f. Blomsma *et al.*, 2019; Frączkiewicz-Wronka and Szymaniec, 2012; Nemati *et al.*, 2010; Tehseen and Sajilan, 2016). Taking cues from prior literature, we stress upon the complementary role of RBV and RDT lenses in identifying critical BCT and CE firm resources and capabilities required to build or reinforce L-A-D supply chain capabilities. L-A-D capabilities help organizations respond to supply chain disruptions especially those evidenced in the COVID-19 crisis (Asamoah *et al.*, 2020; Sweeney, 2020; Mishra *et al.*, 2019). This assimilation of internal and external capabilities and resources is aligned with the concepts of *buffering* and *bridging* strategies (Manhart *et al.*, 2020).

CE from an RBV perspective would identify organizational resources that can support cascading circular strategies across their supply chains (Miles and Snow, 1978; de Sousa Jabbour *et al.*, 2019). RBV resources exist within the organization's boundary as input materials, parts, finished goods/services, machinery, facilities and infrastructure. Organizational competencies include knowledge, skills and applicability of business processes related to planning, leading, organizing and controlling CE configurations (Schnittfeld and Busch, 2016; Blomsma *et al.*, 2019). As an example, design-for-recycling capabilities and technologies are internal capabilities and resources that an organization may have to support CE practices. Not only that, possessing technological resources that can be bundled to run Industry 4.0-based sustainable operations can be classified as strategic resource amalgamations to achieve a competitive edge (Bag *et al.*, 2020). Such technological resources may include cyber-physical systems, smart sensors, machine-human interactions, big-data and blockchain-based data transparency systems. In addition to owning internal CE resources and capabilities, organizations may have to depend on external agents and the external environment for CE resources and competencies. For example, a recycled plastic packaging solution firm constantly faces dynamism in securing high-quality recyclable plastic from the market. Applying the RDT concepts of organizational effectiveness, interdependence and external control from the CE perspective would allow firms to consider how resources and capabilities can be accessed from the external CE value chains. To have more power and control they would have to determine how they could minimize their dependencies for acquiring CE resources and capabilities and/or maximize the dependency of their value network on their CE resources and capabilities (Franco, 2017; Blomsma *et al.*, 2019).

Interestingly, RDT also provides effective control mechanisms to organizations on how to readjust their structure and conduct to reduce both uncertainty in and dependency on their external environment (Hillman *et al.*, 2009). Such control mechanisms include power or trust-based or legally binding forms of collaborations, coalitions, joint purchasing agreements and other types of strategic partnerships that can support CE implementations in their supply chains. An efficient organizational supply chain system provides partners with a greater ability to respond to market changes and customer requests and build competitiveness (Rogers *et al.*, 1993; Stank *et al.*, 1999). By enabling BCES-driven supply chain processes, organizations can create sustainable supply chain resources and capabilities, which are firm-specific and hard to duplicate across organizations (Powell and Dent-Micallef 1997; Wu *et al.*, 2006; Nandi *et al.*, 2020a). Large organizations have shown significant interest in advancing their supply chain BCT resources and capabilities. BCT can help build stronger supply chain capabilities through collaboration, agility, velocity and visibility, which are critical for firms to operate and recover during supply chain disruption. An RBV analysis could help identify BCT-linked strategic and operational capabilities of a CE nature—BCES—that organizations already possess; RDT can enable organizations to develop governance and control mechanisms to access such capabilities for implementing BCES practices (Bode *et al.*, 2011; Paulraj and Chen, 2007).

2.4 TOE (technology, organizational and environmental) framework

We will use the TOE framework to evaluate organizational resources and capabilities (Clohessy and Acton, 2019). TOE theory suggests that when firms advance their assets and knowhows to gain competitive leverages, the impact of such advancements can be related to the technological (T), organizational (O) and environmental (E) contexts (Baker, 2012; Kouhizadeh *et al.*, 2020). The technological context explains the importance and readiness of a technological improvement resulting from such advancements. The organizational context identifies the firm's organizational decision-making structure and strengths to facilitate such advancements. The environmental context explains the eagerness of markets, industries and the regulatory environment to adopt those advancements, and overall relationship to competitive environmental concerns. Baker's (2012) research has been extended to BCT evaluation in operations and supply chain management (Wong *et al.*, 2020), sustainability technology and blockchain technology (Bai and Sarkis, 2020) and information service competence (Hung *et al.*, 2020) and a host of other academic research studies.

Scholars often use the TOE framework to study how the existing state of the three elements influence and/or are influenced in the process of adopting and implementing and implementation of a given phenomenon (Kouhizadeh *et al.*, 2021; Baker, 2012; Tornatzky *et al.*, 1990). In RBV-grounded studies, scholars tend to frequently apply the TOE framework to understand barriers and enablers of a given technological trend, such as determinants of mobile-business use and value (Picoto *et al.*, 2014), drivers of IT-enablement (Wu and Chiu, 2015), determinants of ERP use and value for small and medium manufacturing and services firms (Ruivo *et al.*, 2016; Jayeola *et al.*, 2020), drivers for business analytics adoption (Kumar *et al.*, 2020). The application of the TOE framework from an RDT perspective requires further development and this study builds on that relationship. Recent studies in the information and data systems discipline have used the TOE framework to highlight BCT adoption-related organizational characteristics. The TOE framework can evaluate the socio-technical adoption factors of data-sharing initiatives (Wang and Lo, 2016) and digital transformation initiative enablers and inhibitors (Modiba and Kekwaletswe, 2020). BCT adoption largely depends on top management support and organizational readiness of organizations to adopt BCT and that large-sized firms are more likely to adopt BCT than small- to medium-sized firms due to their unique resource sufficiency positions. In the sustainable supply chain context—but not necessarily from an RDT perspective—the TOE framework has been recently applied to analyze BCT adoption barriers in utilities, food, healthcare and logistics supply chains (Kouhizadeh *et al.*, 2021).

2.5 Localization, agility and digitization (L-A-D) as post-pandemic supply chain resilience capabilities

Supply chain resilience commonly stresses a firm's ability to absorb disruptions or to return to state conditions faster (Sheffi and Rice, 2005). Key characteristics and drivers of supply chain resilience include agility, visibility, flexibility, collaboration and information sharing (Hosseini *et al.*, 2019). Using the COVID-19 context, we have focused our research on supply chain resilience capabilities related to L-A-D. The L-A-D capabilities arose from early crisis supply chain disruptions and remain pertinent in the post-pandemic improvement discourse (Nandi *et al.*, 2020c). We assert these three capabilities also relate to BCES. COVID-19 has arguably renewed attention on CE, sustainable supply chains and production (Ivanov and Dolgui, 2020; Queiroz *et al.*, 2020; Sarkis *et al.*, 2020). Localization stresses the need for government subsidies and technology to encourage and incentivize localization and to use transportation logistics and technologies in an innovative change in the prior business model (Choi, 2020). L-A-D relationships and issues are now summarized.

2.5.1 Localization. With COVID-19 and globalization lockdown or ill employees in one part of the globe quickly resulted in shortages in other areas. Localized sourcing, for example for PPE and even food, became critical. Localization can address supply chain brittleness while leading to sustainable supply chain co-benefits—local sourcing is usually greener and strongly socially supported. Localization benefits include lessened transportation requirements and fewer greenhouse gas emissions and saves fuel. Initiatives including reshoring of manufacturing closer to the end-user (insourcing activities) share the same advantages with shorter supply chains that are agile and can respond faster. However, the ability to localize depends on the presence of material and resources for sourcing in each area. The circular economy model depends on local wastes that can be used as raw materials to make new products that can be used in the local area making localization and CE inexorably linked. BCT can support localization by identifying and tracing local sources. For example, in weather or humanitarian crises or disaster, localization is designed to foster local capabilities and targets the efforts based on the needs of the area.

2.5.2 Agility. Agility—as a supply chain resilience response—also emerged during the COVID-19 pandemic (Ivanov, 2020). Demand and supply for some goods increased at a rapid rate causing shortages and insecurity while demand for other goods quickly decreased. The volatility of these patterns caused significant uncertainty. With consumers largely working at home, larger quantities of industrial products for cleaning and hygiene plummeted while consumer sizes of such products increased overnight. Products for home offices and homeschooling grew as did the need for increased Internet and energy usage by households. Public transportation along with air travel decreased but the demand for online meetings increased. This volatility and rapid shift in demand and supply highlighted the need for agility within supply chains (Ketchen and Craighead, 2020). Many suppliers and producers could not respond quickly or with the flexibility to meet demand. The lockdown by manufacturers in China rippled through other countries and forced local manufacturers to switch their production lines to manufacture needed products. Thus, agility was highlighted as a preferred approach for organizations and their supply chains versus the more cost-focused and just-in-time (JIT) management principles of the past which led to shortages and anguish (Golan *et al.*, 2020).

Agility is a way to meet customer demands allowing organizations to compete within rapid market changes and rapid opportunism (Al Humdan *et al.*, 2020). Agility requires information from markets, on demand and a supply chain partner's integrated capability to resolve demand needs; BCT can offer this information. It is timely, flexible and must be responsive. In a supply chain, agility demands a rapid response to changes both upstream and downstream; CE practices such as local sourcing, byproducts development and repair offer opportunities for agility (Sarkis *et al.*, 2020). The long-lasting effects of COVID-19 will include the growth of online grocery delivery and prioritization of local food supply chains that can more rapidly adjust to shock and changes in buying patterns (Hobbs, 2020). Agility helps supply chain networks return to normal in post-pandemic situations (McMaster *et al.*, 2020). The building of agility in various ways—such as through excess capacity, multiple sourcing and flexibility investments—can overcome some of this volatility. Lastly, agility when combined with digitalization can improve supply chain resilience (Das *et al.*, 2019; Gligor *et al.*, 2019; Russell and Swanson, 2019).

2.5.3 Digitization. The COVID-19 pandemic has necessitated social distancing and isolation practices socially and at work. Individuals substituted air travel and work from the office for virtual business meetings and working from home—digitization of content and meetings increased during the COVID crisis. The COVID-19 disruption has pushed firms to create new norms for operations (Borowski, 2020). While a few firms operating in the digital business spaces (e.g. Zoom and Netflix) and their interconnected partners (e.g. e-pharmaceuticals and e-gymnasiums) have gained above-normal profits. Other firms that continued to rely on non-digital brick-and-mortar operations faced staffing layoffs, limited operations, postponing production and/or temporarily closing during the pandemic (Nagar, 2020). The pandemic has also impacted supply chains by creating shortages of materials and delays in the delivery of ordered products and services in almost every industry sector. Firms must deploy suitable digitization approaches to resume normalcy within and outside their supply chain scopes. In their meta-analytic review, Anthony and Abbas Petersen (2020) find that a firm's ability to digitize operations depends on how well it can create or provide an adequate sense of urgency, budgeting adequacy, staffing skillsets, management support, senior leadership and overall corporate culture towards digital transformation.

Supply chain digitization has helped firms maintain shipments of goods and services, allowing for work meetings and family socialization and even on-line purchases that may not have been available to consumers in their home markets (Matthews, 2020). Theoretically, digitization drives visibility, information sharing and collaboration capabilities of supply chains, which in turn may infuse agility and visibility of supply chains (Hosseini *et al.*, 2019). Moreover, combining Industry 4.0 and CE can enhance the operational and logistical concerns of the supply chain partners for sustainability performance (Bag *et al.*, 2020). Digitization is vital to CE and sustainable supply chains because it lessens transportation costs, pollution and personnel to build agility through the application of digital methods and delivery. BCES can aid all three L-A-D effectively. Ting *et al.* (2020) noted digital technologies like BCT can be used to remediate the COVID-19 outbreak. The links within L-A-D have yet to be fully analyzed in the literature for supply chain resilience (Pereira *et al.*, 2019; Reza-Gharehbagh *et al.*, 2020). Each of the L-A-D measures plays a role in building supply chain resilience using BCES.

3. Research methodology

New knowledge can be acquired using three research approaches—inductive, deductive and abductive. Each of the three research approaches asks three common questions to the researcher. First, what is the aim of the research that is, whether the research objectives are oriented toward theory development or theory testing. Second, what is the starting point of the research process, whether the research process begins with an existing theoretical base or an empirical base, or both. Third, what is the juncture where hypotheses or propositions can be established. An inductive research approach begins with the collection of observations of specific instances and seeks to establish common patterns (or new theoretical bases) that may emerge from the empirical observations. A deductive research approach begins with an established theoretical base and seeks to extend upon the existing theoretical knowledge within a specific research context (Kovács and Spens, 2005). An abductive research approach chooses a middle ground of theory matching and theory refining (Kovács and Spens, 2005). More specifically, it follows a complex reasoning process in which explanations to a real-life phenomenon are formed and evaluated iteratively moving back and forth between existing theory and the real-life phenomenon with existing real-world data in the background (Dunne and Dougherty, 2016). In an abductive approach, all three steps–theory development, data collection and analyses—can occur simultaneously and interdependently. The outcomes of an abductive research approach are normally those deviations from the general structure that a purely inductive or deductive approach could not possibly examine and/or identify (Kovács and Spens, 2005). New knowledge thus generated may suggest hypotheses or propositions that can later be tested using deductive research methods (Nandi *et al.*, 2020a).

In our study, we adopt an abductive approach for three key reasons. First, our study investigates the advances made by firms along with two technological phenomena—BCT and CE—that could bring sufficient complementarities in improving supply chain resilience. Even though the knowledge bodies of both BCT and CE have significantly grown in recent years, they appear incongruently complex and unstable when it comes to their performance appraisal in a sustainable supply chain context (Bai and Sarkis, 2020). As a result, neither inductive nor deductive approaches appear as suitable alternatives for drawing appropriate conclusions (Krippendorf, 2004). Second, our research objectives are geared toward improving the current understandings of BCT and CE from a supply chain resilience perspective, instead of proposing a new resiliency theory (Dubois and Gadde, 2002). Our research questions are framed to derive meaningful interpretations abductively by thoroughly examining organizational plans, adoptions and practices for BCES. Third, our study aims to develop a set of propositions that are supported by theoretical justifications and empirical observations of the BCT and CE phenomena, in isolation or combination as BCES (Lin *et al.*, 2013).

Using abduction logic previously suggested by Nandi *et al.* (2020a), we proceeded with our qualitative evaluation of the collected secondary data as shown in Figure 1. The collected sample data for the study comprise: (1) the first set of secondary data generated from articles from health-related, general and industry-specific supply chain disruption issues that described how firms are being or might be affected by COVID-19; and (2) the second set of secondary data generated from firm-specific corporate reports, patents, press releases about their advances in BCT and CE activities of a selected set of firms from different industries that are operating within the United States or globally.

The first set of articles highlighted some of the core supply chain disruption issues in different settings in the wake of COVID-19. The second set of articles provided data for representative cases per core supply chain disruption issue. Next, we developed an evaluation framework to identify appropriate data that related our theorization of BCES approaches for L-A-D outcomes when supply chain disruptions occur. The purpose of the identification framework is to guide in identifying critical BCT and CE resources and capabilities that each representative firm already possesses and/or needed to acquire and the likely L-A-D outcomes.

We refined our initial identification framework as we iteratively progressed through the analysis. Therefore, our abductive research approach appears neither constrained by existing supply chain theories nor turns out to be inundated for data fit, instead our data interpretations were both theoretically and empirically balanced (Karatzas *et al.*, 2017).

Moreover, the abduction process applied in our qualitative analysis facilitated the identification of interlinkages between CE and BCT and further supported the role of management theories (namely, RBV and RDT in our case) to adjudicate between proposed conditions of resources and capabilities relating to how to build L-A-D based supply chain capabilities (outcomes) (Lipscomb, 2012; Lin *et al.*, 2013).

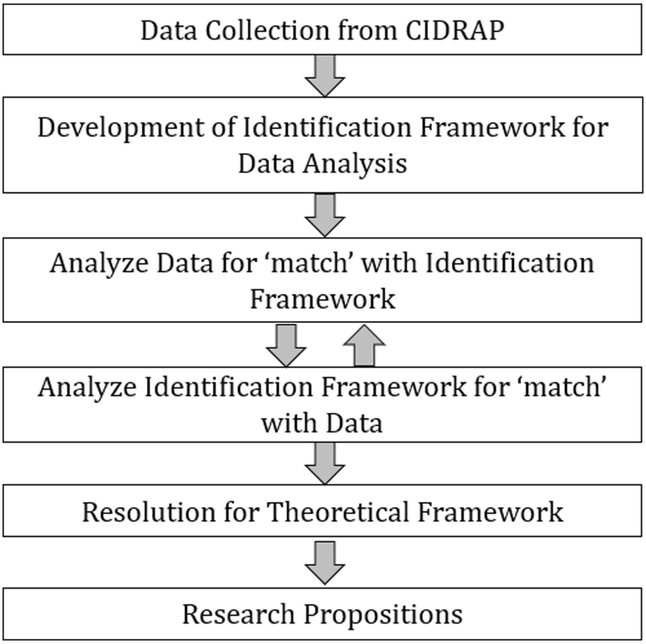

Figure 1.
Research Methodology adapted from Nandi *et al.* (2020)

3.1 Data collection

We initially identified COVID-19 impact on supply chains from the CIDRAP [1] website. These initial empirical points—*leads*—were qualified based on the relevancy of the supply chain disruption event they captured. Qualified leads acted as our first set of the data link to identify health-related, general and industry-specific supply chain disruption issues. Each data point was augmented with other data sources including industry trade journals, business news and business sections of leading newspapers during the March to September 2020 time frame; most pandemic-related supply chain concerns peaked during this period. For this exploratory research, we created our first level of data by exploring over 200 news articles highlighting challenges across 19 industries classified by 4-digit SIC code.

Based on our first level of data, we created our second level of data by qualifying 24 representative firms of varying size that are spread across industries and operate in the United States or globally. For each of the 24 representative firms, we searched Web sources using the combination of the keywords "Firmname + blockchain", "Firmname + circular economy", "Firmname + reverse logistics", "Firmname + waste management", "Firmname + sustainable supply chain" and "Firmname + sustainability" to find information related to their CE and BCT advancements. We eliminated those news articles that provided general discussions on BCT and CE about the industry state and were not specifically linked to the representative firm.

We focused on searching CE and BCT information in company released announcements, corporate reports such as sustainability reports, academic papers and patent records. Table 1 presents the selected cases by industry and data sources. After the screening, the final data set comprising evidence of firm efforts for CE and BCT advancements in their supply chains, in terms of planning, piloting, prototyping, partnering, implementing and committing to invest.

3.2 Identification framework for data analysis

The authors developed an evaluation framework for coding the validity of our case study's critical BCT and CE resources and capabilities that each representative firm already possesses and/or needed to acquire and the likely L-A-D outcomes. We used the RBV as the theoretical grounding to identify resources and capabilities that firms already possessed to their competitive advantage for L-A-D outcomes (Barney, 1991). We relied on RDT to describe those BCT resources and capabilities that firms might have to depend on their external environment to gain L-A-D outcomes.

Using TOE theory, we evaluated the strength of firm resources and capabilities from technological, organizational and environmental contexts (Baker, 2012). We applied literature in supply chain resilience (Sabahi and Paraset, 2020; Behzadi *et al.*, 2020; Remko, 2020; Centobelli *et al.*, 2020; Hosseini *et al.*, 2020; Wang *et al.*, 2019; Hendry *et al.*, 2019; Bugert and Lasch, 2018; Qazi *et al.*, 2018) to identify consequent L-A-D effects in their supply chains as a result of adopting BCES strategy. In Table 2, we present the identification framework in greater detail.

3.3 Data analysis

Resources and capabilities that organizations already possess within their firm boundary can be evaluated using an RBV lens; resources and capabilities that organizations need to depend on or makes others depend on them—given their inter-organizational relationships—can be evaluated using RDT. Our data sample includes observations and empirical information about BCES and L-A-D characteristics gathered from a data sample of 24 case firms and their responses to the COVID-19 pandemic. In compliance with the abductive approach (Beghetto, 2019), the data analysis followed an iterative process of consultation between theories, data sources, data collection, data clarification and data interpretation among the research team to test the hypotheses generated. Following the recommendations of Żelechowska *et al.* (2020), we evaluated our generated hypotheses designing a context for analysis to allow the data gathered to be appropriate for both qualitative and quantitative analysis. Also, we followed the methodological approach proposed by Oh (2008) in stages of inquiry beginning with exploration, examination, selection and finally explanation (see also Vertue and Haig, 2008; Kwon *et al.*, 2009). The exploration stage of our analysis provided the prior background and literature review of the constructs and variables leading to our hypotheses. Our examination consisted of recent literature on supply chain responses during the COVID-19 pandemic and the selection phase consisted of a sample of 24 case firms for in-depth analysis using the deductive methodological approach. All co-authors participated in the selection phase, collectively choosing the final sample.

For the sample of 24 case firms, we randomly divided the data interpretation tasks between four members of the research team. The authors independently coded the sample firms based on their assessment of the BCT and CE efforts and likely L-A-D outcomes following the evaluation framework proposed. In several instances, the authors consulted additional data sources to gain a more comprehensive understanding of the case, whether a company or industry, and the current state of BCT, CE and L-A-D of supply chain aspects. For example, in the case of Edmunds, the authors consulted supply chain collaboration literature covering the collaborative partnering concept that relates to the CE principles of sharing platform and BCT plays a big role in creating L-A-D outcomes (Ramanathan and Gunashekaran, 2014).

After individual coding, another co-author of the four-member team also coded the same article (company and/or industry) alone. Then all four authors collectively validated the data findings of the study sample through structured discussions to reach a final classification consensus. Any initial differences in interpretations among the four authors were resolved by

Industry by SIC	Company name	2019 revenue (in millions)	Patents	Research article	Press, news article	Corporate report	Supporting source
Pharmaceutical preparations	Roche	$63,400 (Large)	–	–	√	√	√
	Sanofi	$42,634 (Medium)	–	√	√	√	√
Electronic and other electrical equipment (no computer equip)	Pine electronics	$3 (Small)	–	–	√	–	√
Poultry slaughtering and processing	Tyson foods	$42,405 (Large)	–	√	√	√	√
Motor vehicles and passenger car bodies	Toyota	$272,031 (Large)	–	√	√	√	√
Tires and inner tubes	GRI–Sri Lanka	$5 (Small)	–	–	√	–	√
Specialty cleaning, polishing and sanitation preparations	Clorox	$6,214 (Medium)	–	–	√	√	√
Coin-operated laundries and dry cleaning	Fl. Laundry Express	– (Small)	–	√	√	–	√
Department stores	Walmart	$514,400 (Large)	√	√	√	√	√
	JC Penney	$10,720 (Large)	–	–	√	√	√
Computer processing and data preparation and processing services	Edmunds	$212 (Small)	–	√	√	√	√
Management consulting services	Grant Thornton	$1,951 (Medium)	–	–	√	√	√
Real estate agents and managers (for others)	Simon property group	$5,658 (Medium)	–	–	√	√	√
Not elsewhere classified	Pacific Island countries and Territories (PICTs)	– (Medium)	–	√	√	√	√
Electric services	SDG&E	$2,199 (Medium)	–	–	√	√	√
Transportation and public utilities	USPS	$71,1000 (Large)	√	–	√	√	√
Arrangement of transportation of freight and cargo	Maersk	$38.890 (Large)	–	√	√	√	√
Construction and mining (except petroleum) machinery and equipment	Caterpillar	$53,800 (Large)	–	√	√	√	√
Industrial and commercial machinery and equipment, not elsewhere classified	Eaton	$21,400 (Large)	–	√	√	√	√
Rubber and plastic footwear	New balance	$4,500 (Medium)	√	–	√	√	√
Food preparations, not elsewhere classified	JM smucker	$7,840 (Medium)		√	√	√	√
Plastics products, not elsewhere classified	Sonoco	$ 5,374 (Medium)	√	√	√	√	√

Table 1.
Selected cases: industries and sources

(continued)

Industry by SIC	Company name	2019 revenue (in millions)	Patents	Research article	Press, news article	Corporate report	Supporting source
Plastics materials and basic forms and shapes	Imaginative materials and design	$0.34 (Small)	–	–	√	–	√
Chemicals and chemical preparations, not elsewhere classified	BASF	$69,990 (Large)	–	√	√	√	√

Table 1.

referring to the interpreted data of the case with additional external secondary data sources. A similar procedure was followed to reliably rank the levels of BCT, and likely L-A-D outcomes per case firm in the study sample. The final stage of the abductive methodological approach-based explanation is presented in Section 4.

4. Study findings and propositions

This section provides the study findings. These findings are summarized and analyzed in subsections 4.1, 4.2, 4.3 and 4.4. The results are shown in Figure 2 and described in this subsection to help arrive at a series of research propositions. Further analysis is based on the relationships identified in Figure 3, which is detailed in Section 5.

Figure 2 represents a summary plot of our qualitative evaluation. The plot represents two axes. The horizontal or x-axis represents the level of BCT capabilities and resources adopted or implemented by a firm during the COVID-19 pandemic. The vertical or y-axis represents the level of CE capabilities and resources adopted or implemented by a firm during the COVID-19 crisis. Figure 2 is categorized into nine different grids based on the level of BCT-CE capabilities and resources and is shaded into a spectrum of colors representing five levels.

These five levels include: no L-A-D (red), less L-A-D (yellow), moderate L-A-D (orange), high L-A-D- (light green) and very high L-A-D (dark green). Besides, the size of the colored square represents the size of the company in terms of annual revenue. Smaller boxes represent smaller companies with annual revenue of less than $1 billion; medium boxes represent mid-sized companies with annual revenues of $1 to $10 billion; and finally, the large boxes represent large companies with annual revenues of over $10 billion. Figure 2 is based on the detailed data shown in Appendix 1. Thus, the analysis in this section relies primarily on Figure 2 and the data presented in Appendix 1.

4.1 A resource-based view of BCES

A basic tenet of RBV is that organizations develop their capabilities to build their competitive advantage. In this case, the BCES capabilities—or lack thereof—will influence COVID crisis response and other potential disruptions to supply. The results show that organizations with foundational internal capabilities associated with BCES capabilities adopt L-A-D practices to overcome COVID-19 issues and influence supply chain resilience (Queiroz *et al.*, 2020). In our sample, medium to larger companies have the characteristics—and likely the financial and slack capacity—to build various BCES resources and capabilities. For example, Caterpillar—realizing that some materials and components were likely to be scarce—shifted their production capabilities to utilize some CE principles such as remanufacturing products that could be easily repaired or upgraded.

Similar end-of-life product materials management was a focus of Eaton Corporation engines. Caterpillar, an original equipment manufacturer, differed from Eaton on building

	Main source
Part 1: data collection	
Step 1: What is the main supply chain disruption event resulting from COVID-19 that the articles are referring to?	CIDRAP, others
Step 2: Does the supply chain disruption event corroborate with the theorization of L-A-D? If Yes, include, and explain	Sarkis *et al.* (2020), Hosseini *et al.* (2020), Wang *et al.* (2019), Hendry *et al.* (2019), Bugert and Lasch (2018), Qazi *et al.* (2018)
Step 3: Do those articles refer to a firm (or more firms) that have been impacted by COVID-19?	–
Step 4: Identify the firm name, Industry by SIC code, size by revenue and list data sources to evaluate BCT and CE resources and capabilities	USSEC; Annual reports; Press releases, research articles, corporate reports, patent database, industry reports
Part 2: data evaluation	
Step 5: Identification of the resource-based orientation for the firm's BCT resources and capabilities	
(1) From a Technological-Organizational-Environmental perspective, what are the critical BCT "resources and capabilities" that the organization and its stakeholders' currently possess?	Barney (1991), Wu *et al.* (2006), Baker (2012), Kouhizadeh *et al.* (2020), Nandi *et al.* (2020a), Treiblmaier (2018)
(2) Interpret the TOE-levels of such BCT resources/capabilities as Low/Medium/High. State your reasoning	
Step 6: Identification of the resource-based orientation for the firm's CE resources and capabilities	
(1) From a Technological-Organizational-Environmental perspective, what are the critical CE "resources and capabilities" that the organization and its stakeholders' currently possess?	Barney (1991), Wu *et al.* (2006), Desing *et al.* (2020), Nand *et al.* (2020c), Kouhizadeh *et al.* (2020)
(2) Interpret the TOE-levels of such CE resources/capabilities as Low/Medium/High. State your reasoning	
Step 7: Identification of the Resource dependence orientation for the firm's BCT resources and capabilities	
(1) From a Technological-Organizational-Environmental perspective, what are the critical BCT "resources and capabilities" that the organization needs to acquire from its environment?	Pfeffer and Salancik (2003), Bharadwaj (2000), Schmidt and Wagner (2019)
Step 8: Identification of the Resource dependence orientation for the firm's CE resources and capabilities	
(1) From a Technological-Organizational-Environmental perspective, what are the critical CE "resources and capabilities" that the organization needs to acquire from its environment?	Pfeffer and Salancik (2003), Bharadwaj (2000), Blomsma *et al.* (2019)
Step 9: Interpretation of TOE positions of the firm's BCT resources and capabilities. (High/Medium/Low)	Baker (2012), Kouhizadeh *et al.* (2020)

(*continued*)

Table 2. Identification framework for data collection and data evaluation

	Main source
Step 10: Interpretation of TOE positions of the firm's CE resources and capabilities. (High/Medium/Low)	Baker (2012), Kouhizadeh *et al.* (2020)
Step 11: Interpretation of the likely L-A-D outcomes in the firm's supply chain because of BCES adoption (1) What are the likely Localization outcomes? (2) What are the likely Agility outcomes? (3) What are the likely Digitization outcomes?	
Step 12: Interpretation of the strength of L-A-D outcome. (Very High/High/Moderate/Less/None)	Sarkis *et al.* (2020)

Table 2.

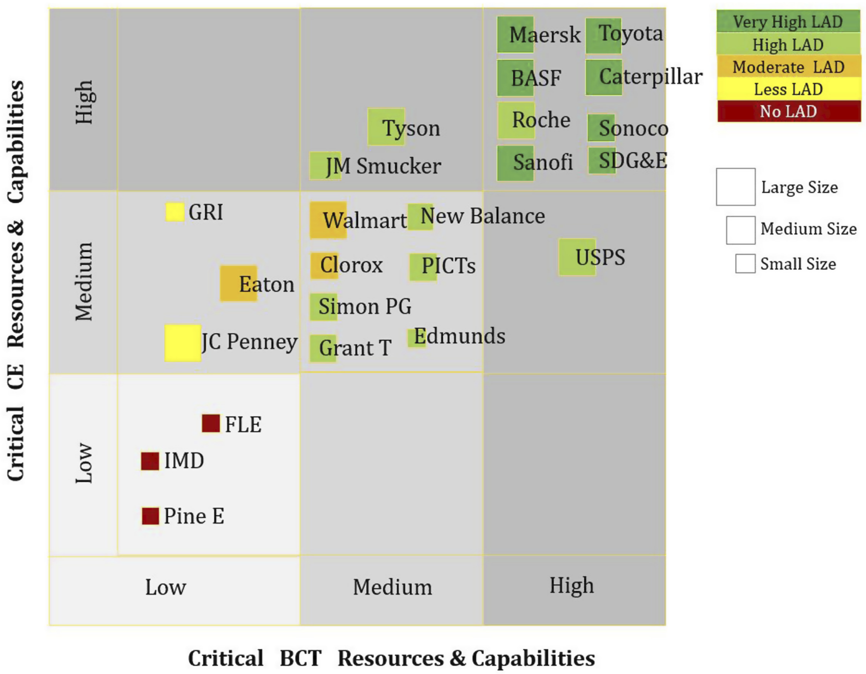

Figure 2.
Critical BCT and CE Resources/Capabilities of Firms by position, size and L-A-D status

BCT capabilities. Caterpillar felt that tracing materials, whether for remanufacturing or otherwise, would benefit from BCT capabilities and partnering with a blockchain service provider. Eaton Corporation did not pursue these BCT capabilities. In some cases, such as BASF, the firms implemented broad BCES practices. BASF introduced a BCT platform called ReciChain to improve plastic circularity including sorting, tracing and monitoring. Traceability of materials seems to be important for building digitization and potentially localization and agility activities—a comprehensive capability from the BCES perspective that aligns well with the L-A-D capabilities for supply chain resilience.

All the organizations with lower levels, on the lower-left cell of Figure 2 are smaller companies, and from multiple industries. Interestingly there are some larger companies such as JC Penney and Eaton Corporation that are at the lower end of the BCT scale, although have some moderate CE capabilities. Their results also show lessened L-A-D practices when compared to other large organizations. JC Penney had been having difficulties financially

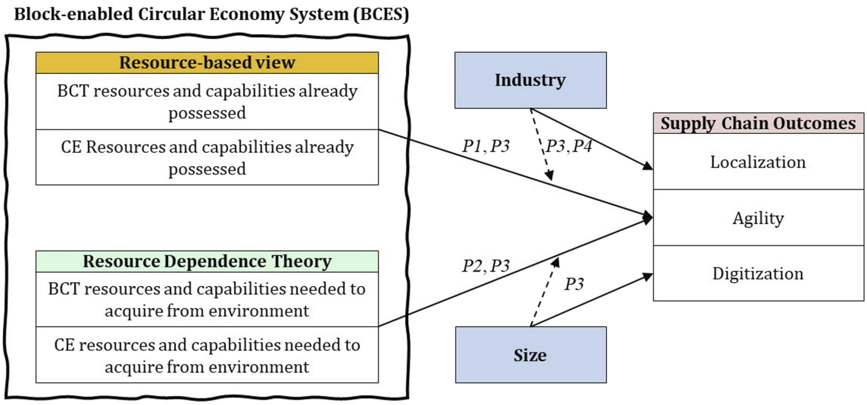

Figure 3.
Theoretical research framework

before the crisis, while Eaton may also be viewed as a *less essential* company as a first- or second-tier automotive industry supplier.

There is also a correlative pattern of organizations that have more capability in CE also have higher BCT capabilities—supporting the contention that joint BCES capabilities are likely to occur. It may be that innovative companies that adopt both these practices in a COVID crisis environment can address general concerns including L-A-D efforts. Joint innovations (Choi, 2020) and tokenized coopetition (Narayan and Tidström, 2020) seem to be a real possibility and align well for future deployment of both sets of practices reinforcing each other in the post-COVID-19 phase. Agility and digitization capabilities are important for a custom product-based market environment and can prove advantageous in non-crisis times too. While efforts to establish agility and digitization capabilities are likely to continue, localization may not be easily deployable, especially for larger companies, and therefore will require decentralized control to achieve effective and long-lasting localization, including reshoring, after the crisis (Barbieri *et al.*, 2020).

P1. Larger organizations can more effectively build internal organizational CE and BCT capabilities. Jointly implementing these capabilities—BCES—results in greater L-A-D adoption due to complementarities such as traceability of end-of-life materials. This situation is likely contingent on the industry.

4.2 A resource dependence perspective of BCES

RDT, as mentioned earlier, has two major constructs that determine how well the organization is performing on external resource dependence. These two constructs include "minimize their dependence on other organizations" and "maximize the dependence of other organizations on themselves" (Ulrich and Barney, 1984). In this way, organizations can make partners more dependent and create the power to build their resource capacities and build competitive advantages. We conducted a BCES resource dependence analysis of 24 case firms based on their Technological-Organizational-Environmental levels—using a TOE evaluation framework—mapped as high, medium or low on each TOE factor. The sample of 24 companies is composed of ten large-sized firms (41.6%), nine (37.5%) medium-sized firms and five (20.8%) small-sized firms. We observed that 20 out of 24 (83.3%) case firms had greater or equal levels of "Environmental" levels of BCT resource and capabilities than their respective "Technological" and "Organizational" capabilities. Those 20 case firms include nine large-sized firms, five medium-sized firms and four small-sized firms. A greater level of

"Environmental" resources and capabilities than their respective "Technological" and "Organizational" capabilities represent that the firm is less dependent on other organizations and with a stronger dependency by other organizations on them.

Similarly, we analyzed the CE resource dependence across the sample of 24 case firms based on their Technological-Organizational-Environmental levels. We observed that 17 out of 24 (70.8%) case firms had greater or equal levels of "Environmental" resource and capabilities than their respective "Technological" and "Organizational" capabilities. Those 17 case firms include six large-sized firms, six medium-sized firms and five small-sized firms. This external environmental resource dependence characteristic shows that many of the reported firms had built a stronger external supply chain power relationship overall; implying that these organizations could control CE and BCT practices to address COVID issues.

Our observation shows that several factors explain the resulting BCES capability of firms: size, BCT and CE resource establishment—both in isolation and in together. Most importantly, we observe that the size of the organization explains BCES capability development. In addition, we noted that those firms that have some form of BCT and/or CE-driven environment management strategies—typically large-sized firms—were able to achieve BCES capabilities that are fully or partially operational. For example, San Diego Gas and Electricity (SDG&E)'s active participation in the Clean Energy Blockchain Network secures its BCT resource position at a much higher level than its competitors who are yet to initiate or planning to initiate BCT adoption. As a result, SDG&E is not only able to "digitally" and "securely" track production and use of clean energy and their locations but also can report the earned carbon credits for government compliance.

Overall, we found that firms with higher resource dependency strength, resulting from higher Environmental (of the TOE framework) levels can more effectively build L-A-D capabilities. The higher levels of "E" than "T" and "O" dimensions imply that resource dependence strength plays a large role overall in this COVID environment in building the L-A-D capabilities. This may not always be true in other competitive situations. For example, meeting customer demands and profitability may be dependent on internal capabilities, this traditional—non-crisis—competitive situation supports the RBV perspective for building strategic advantages and competitiveness. In this crisis, due to the unique forces playing roles and for basic organizational survival in times of crisis, having stronger resource dependence capabilities—power is necessary and observed in almost all our cases (Pfeffer and Salancik, 2003).

The L-A-D capability outcome is not just internal—this supply chain resilience capability set accumulates from the firm's combination of managing resources and capabilities both internally and externally—an accumulative buffering and bridging set of capabilities. Further, it has an important implication for supply chain resilience and risk management. For example, in times of supply chain crises, RDT explains supporting resilience capability building. Internal capabilities are important but—given the higher focus on external context aspects of supply chain resilience—having networks and relationships with stronger resource dependency characteristics is more effective for managing crises. External resource dependence is an effective way to create L-A-D capability to achieve supply chain resiliency (Quieroz *et al.*, 2020).

We believe that building CE and BCT expertise internally, even if they are urgent and important, might take longer than expected. As a result, firms seek external expertise for those resource requirements. There is significant uncertainty and they wish to manage their transaction costs. They do not wish to invest in specific assets while uncertainty exists. This situation can explain why many organizations are seeking resources externally. Moreover, the length of "crisis" time remains uncertain too. Thus, firms may necessarily decide to invest fully into such resource capabilities during uncertainty, rather they will rely on short-term outsourcing of these capabilities or rely on external contractors to manage the process.

This short-term focus is especially true for blockchain technology, where companies, even larger ones with slack capacity and internal resources use external partners for blockchain applications. In our study, we noted exceptions in cases, such as Sonoco and New Balance, that remained invested in BCT verification and building open networks during the crisis. But in that case, holding their networks allowed them more control over their supply chain. How does this relate to COVID? COVID is a good time to experiment. It is also a good time to restructure a firm's product-market matrix by applying product deletion strategies that have both CE and BCT relationships (Zhu *et al.*, 2018). It is difficult to make strategic decisions in this short-term environment.

P2. Firms with high resource dependence—less control—of external agents have more difficulty building BCES capabilities.

P2a. Stronger external partnerships can more effectively implement L-A-D—and support supply chain resilience.

P2b. Short-term partnerships in times of crisis can offer the potential for L-A-D supply chain resilience.

4.3 L-A-D as post-pandemic supply chain outcomes

In our study, we seek to determine whether the resources and capabilities from BCES influence L-A-D capability development. We can term this related capability development as a tiered or cumulative capabilities evaluation. Additionally, it could be viewed as a buffering and bridging capability relationship. The basic question we ask in this section is whether these tiered capabilities relate to each other. We believe that the foundational CE and BCT resources and capabilities do lead to L-A-D outcomes to aid in the COVID crisis—as was discussed in our background review and more general observations. This question brings to the forefront how certain foundational capabilities are needed to build additional broader capabilities. For example, quality performance needs quality capabilities and these capabilities can be buttressed by other organizational or supply chain resources and capabilities. To be able to lead to quality capability we would need other capabilities such as trained workers, quality technology and quality management systems.

In this case, we argued that greater BCT and CE capabilities result in greater L-A-D—or supply chain resilience—capabilities. The pattern we would need to observe is whether there is greater adoption of L-A-D practices with greater adoption of BCES capabilities and practices. In an examination of firm BCES resource positions with their respective L-A-D status (see Figure 2), we note that the size of boxes (representing the size of the firm) generally become larger and greener (i.e. high L-A-D) as they move toward the high CE and high BCT resources and capabilities grid. This observation essentially means that larger firms and/or firms with higher levels of BCES capabilities have pursued the task of building L-A-D capabilities to counter supply chain risks from the COVID crisis.

Although there are some minor anomalies—such as Roche having a light green shade but up in the upper right grid—the pattern is relatively clear. This is observed across different industries as well. Although additional industrial supply chain nuances are discussed in the next section. Thus, we can safely arrive at our third proposition. Patterns across company size are not clear, given that some larger organizations, such as Walmart, are not as interested in using BCT and CE capabilities to build L-A-D capabilities during the COVID crisis as would be true of some smaller companies such as SDG&E or Sanofi.

P3. Greater BCT and CE capabilities relate to greater L-A-D capability. This pattern is true across industries although not consistently true across the organizational size.

4.4 Influence of industry type

In our previous sections, we alluded to some similarities and differences in industries. We further evaluate industry type correlates with BCES and L-A-D in this section. In our study, case firms represent several industries. The study sample includes service and goods industries and a series of more specific classifications based on SIC—standard industry classification—code. Pharmaceuticals, automotive, plastics and fast-moving consumer goods represent industries within the goods manufacturing sector. Service sectors include public utilities, such as the United States Postal Service (USPS), consumer retail sellers, consulting, real estate and transportation.

Clearly, the COVID crisis influenced industries in different ways. We noted that industry responses differ by industry due to regulatory policies or expectations of operations from their end-customers and stakeholders. For example, some industries and their supply chains may be viewed as essential, while others may be less so. Given the relatively large variety of industries and smaller sample size, we decided to take consideration of patterns based initially on a more general industry grouping. Accordingly, we grouped the case firms into two groups: 15 cases belonged to "goods" orientation and nine cases belonged to "service" orientation.

Overall, we found that services have medium to low adoption of BCES practices. The only services company that seems to be higher in both dimensions is SDG&E, which is a medium-sized electric services company. There are at least two explanations that may exist here. First, services companies typically do not have core material flows that would require capturing materiality, and thus CE type practices—excluding sharing platform—seem irrelevant due to lack of solid materials. Second, the lack of tangible goods and materials, and a more intangible set of services and direct relationships with people means that traceability and transparency of goods flow are not as necessary—which are offered by BCT capabilities. Services that require tracing, such as the USPS and Maersk—a transportation services provider—do have a much higher BCT requirement.

In our study, we noted that service industry firms are typically closer to end-consumers, whether they cater to another industry or individual consumers. Industrial services companies such as Maersk, SDG&E and USPS, each have greater BCT, meaning that their supply chains can more effectively achieve greater L-A-D with BCT technology. Walmart, JC Penney and FLE—which are individual consumer services—have less to moderate the need for BCT and CE practices to achieve L-A-D.

One interesting phenomenon appears with the automotive industry supply chain. In this case, we arguably have five companies in this industry, Toyota, Caterpillar, Eaton, GRI and Pine Electronics. These are all in the manufactured goods industry but represent various tiers of the automotive supply chain. The OEMs are Toyota and Caterpillar. Eaton and GRI would be considered first-tier suppliers. While Pine Electronics is, at best, a second-tier supplier. The pattern here is clear, the further upstream in the supply chain a company, the less they have of either practice to support L-A-D and the less L-A-D they need.

Yet for the retail goods industry, with the larger players further downstream being the retail outlets such as Walmart and JC Penney, the opposite is seeming to be true. Suppliers to the retail outlets for individual consumer sales, include New Balance, Tyson, JB Smucker and the pharmaceutical manufacturers. The further down the supply chain it goes, although it is only about two tiers, the more the BCES resources are used to achieve L-A-D. Thus, there are potentially very different general observations that can be made, and overall industry type and sector, play significant roles in the adoption of BCES resources for L-A-D.

P4. Industry-type effects use and structure of the circular economy and blockchain technology usage for L-A-D adoption.

P4a. Service industries are less likely than goods industries to adopt BCT and CE practices at high levels to use L-A-D capabilities to build supply chain resilience.

P4b. Downstream—versus upstream—Automotive and industrial goods companies are more likely to adopt BCT and CE practices and resources to build L-A-D capabilities for supply chain resilience.

P4c. Upstream—versus downstream—consumer goods companies are more likely to adopt BCT and CE practices and resources to build L-A-D capabilities for supply chain resilience.

5. Discussion and implications

The experiences from the COVID-19 crisis provide numerous insights for building supply chain resilience and practice—in times of crisis and also, in *normal* periods. The issue of which practices or capabilities—BCES and L-A-D—are adopted or further developed after return to normalcy requires study. Given the current observations and findings, we observe that there are some significant relationships within and between organizational and external environmental capabilities to support supply chain resilience. An initial resulting finding is an integrated framework of the study's propositions—as shown in Figure 3.

5.1 Theoretical implications

One outcome of the crisis and based on our exploratory findings is that BCT and CE barriers to adoption (Kouhizadeh *et al.*, 2021; Jaeger and Upadhyay, 2020) are likely to be reduced. This supposition needs careful investigation. The broader research context is that crises may alter the organizational and supply chain processes for the long run and institutionalize various practices that were not considered immediate and needed previously—learning and adoption are likely to occur (Ketchen *et al.*, 2014). These changes are important to study and to project additional future changes along with theory building along with the diffusion of these innovations.

One potential theoretical insight is RDT is a better perspective than RBV for understanding supply chain resiliency evaluation in times of crisis. We also observe that TOE can be an effective construct to evaluate RDT and RBV capabilities. This insight can help us understand the types of organizational capabilities. TOE can help in discriminating between RBV and RDT construct evaluation.

We introduced four general research propositions—with commensurate research questions based on this exploratory abductive research. These questions and propositions warrant additional investigation. We observe that BCES is characterized by both internal organizational capabilities and external resource-dependent capabilities. These resources can represent both buffering and bridging strategies (Manhart *et al.*, 2020) leading to L-A-D capabilities. The joint RBV-RDT perspective requires greater maturity and study. This cumulative capability perspective—building internal and then external capabilities—can be an important foundation to continue this theoretical integration.

Creating capabilities to effectively manage supply chains in pandemics like COVID-19 require investments (Juttner and Maklan, 2011). Organizations are likely to be more willing to make these investments for resilience which improves their long-term viability and profitability. Resource sufficiency—either possessed internally or found externally through purchase or partnerships—is necessary to avoid disruptions and will likely improve supply chain resilience and performance, especially if CE practices are further adopted. Research into the justification of such investments and capabilities is needed.

Organizations should take these pandemic events as opportunities for experimentation and improvement; both internally and externally in terms of capabilities (Akkermans and

Van Wassenhove, 2018; Choi, 2020; DesJardine *et al.*, 2019). The current situation is an uncertain environment and can only provide tentative organizational and supply chain insights. In these extraordinary times, when a *supply chain tsunami* hits, both BCT and CE concepts can gain insights from this crisis. Companies may wish to implement and study, at least at the pilot level, how both resilience and sustainability can improve their competitive position in this extraordinary environment and learn what can exist in normal periods. If they cannot develop and implement these practices alone, they can and should seek external support and partnerships for assistance in adding the capabilities.

As an example, cashless and card-less transaction systems for supply chain finance can be a great opportunity in the COVID crisis because it does not require a material that is contaminated (e.g. fiat money), and personal transactions (Du *et al.*, 2020). This type of effort can be implemented for non-competitive reasons but can provide competitive opportunities. Even colleges and universities transitioning to online course delivery and going paperless in class is another example of the new COVID-19 digitalization. Such research on the advantages and disadvantages of digitization can be found in this crisis and its aftermath.

5.2 Practical and managerial implications

A major issue that supply chain managers face during crises is short- and long-run responses from technological, organizational and environmental dimensions. The COVID-19 crisis brings in a multitude of managerial dilemmas. Our study offers several implications for building supply chain resilience and handling supply chain disruptions. Our study provides insights for managing a pandemic crisis environment. It provides lessons for identifying the characteristics and requirements for building a resilient supply chain.

First, and foremost, the study presents supply chain managers with case examples of CE and BCT advances in different industries. It also offers insight into L-A-D capability examples for building supply chain resilience. Managers might find immediate relevance of our case findings with their supply chain issues across industries. Our study reveals the need for BCES capabilities to generate unique L-A-D capabilities across industries. In the food industry, BCES capabilities help Tyson Foods to resolve meat supply chain bottlenecks by building a multi-layered supplier communication system to avoid wastage and logistical blockages. Such demonstrations could guide managers on how to strategize their BCT and CE efforts to meet operational and supply chain resiliency according to their industry expectations.

Second, our study helps managers to develop long- vs-short-term investment strategies. Creating capabilities to effectively manage supply chains in crises like COVID-19 requires investments. Organizations are likely to be more willing to make these investments for resilience which improves their long-term viability and profitability. Resource sufficiency, however, either possessed internally and found externally through purchase or partnerships if necessary to avoid disruptions, is likely to improve their supply chain performance, particularly if CE practices are further adopted in conjugation with BCT (Kouhizadeh *et al.*, 2021).

Third, we assert that organizations should take these pandemic events as opportunities for innovation, experimentation and improvement (Choi, 2020). Companies may wish to implement and study, at least at the pilot level, how both resilience and sustainability can improve their competitive position. Practical examples of learning exist with Walmart kiosks and Florida Laundry Express cases, cashless and card-less transaction systems can be a great opportunity in response to COVID because it does not require a material that is already contaminated (e.g. fiat money), and personal transactions.

Fourth, our study offers a simple RBV- and RDT-based theoretical model to improve managerial decisions about critical resources and capabilities that are either already possessed or need to be acquired from the environment. Managers can objectively use our proposed RBV- and RDT-based BCES and L-A-D integrated model as a guide to identify and organize BCES capabilities needed for developing L-A-D capabilities.

Fifth, if firms intend to provide greater resilience to their supply chain, building BCES capabilities can help them achieve this goal. Not all industries will benefit or approve of development in the same way, so companies need to also consider how industrial partners and norms will affect their decisions. In this case, for our sample, larger companies who typically have greater resources to bear can benefit from these activities. These limitations and concerns should also be taken into consideration by managers and organizations.

Finally, the socio-economic and socio-environmental outcomes derive from how organizations may be able to respond effectively to various community and social needs by adopting BCES practices. For example, localizing supply chains and providing agility in offering opportunities to local communities is one underlying aspect that BCES and L-A-D in providing resources and jobs to the community; especially when jobs or goods are not available otherwise. While these practices can provide opportunities for organizations to improve socio-economic performance in times of crisis, L-A-D, especially localization can improve the sustainability of supply chains given that travel distances and inventory in the pipeline are lessened. Shorter pipelines of materials mean less inventory (that is, less waste and storage energy would be needed), improved resource utilization and fewer pollutants. Transportation requirements will not be as extensive saving fuel resources and pollutant emissions as well. CE practices also contribute to lessening waste and energy usage for organizations and communities. Thus, environmental sustainability along with social sustainability benefit from BCES and L-A-D.

We expect that the conceptual and qualitative analysis provides insightful implications for practitioners to realize their BCT and CE efforts to build supply chain resiliency according to their industry characteristics.

6. Conclusion

This paper investigates how joint blockchain technology and circular economy principles and capabilities (BCES) can offer ways to build supply chain resilience. We analyzed the impacts of an unpredictable event that causes a *tsunami* (Akkermans and Van Wassenhove, 2018) disruption in a supply chain; and what is needed to build resiliency. Specifically, L-A-D capabilities were evaluated concerning BCES. This research paper is significant and introduces a new framework that could be utilized to assess the efficacy of building supply chain resilience. There are no previous studies that have investigated supply chain resilience by using integrated L-A-D and BCES. This relationship is important because it addresses issues related to supply resilience and disruption. Using an abductive research approach, we used literature and published secondary sources to investigate COVID-19 disruption and supply chain resilience responses through BCES and L-A-D capabilities.

A sample of 24 case companies were classified using a technology, organization and environment (TOE) framework for capabilities evaluation. This exploratory study shows there are significant patterns on the level of adoption of BCT and CE resources and L-A-D capability development—based on COVID-19 pressures. We found a clear pattern that the greater the BCT and CE resources and capabilities the greater the L-A-D adoption levels. Organizational size and industry had some relationships to the patterns as well; adoption patterns for L-A-D varied across industries. In some industries, downstream firms seemed to adopt supply chain resilience factors more than upstream firms; in other industries the opposite was true. This is an important observation requiring additional research.

Theoretically using the RBV of the firm and resource dependency theory we find a complementary and synergistic sequential capability development in response to COVID-19 in the supply chain, with implications for broader supply chain resilience—this expands the research on potential buffering and bridging capabilities (Manhart *et al.*, 2020). This paper has made several significant contributions in the field, extending the theoretical and methodological analysis to better understanding the organization's capabilities when faced with supply chain disruptions. Theoretically, we also linked TOE to RBV and RDT theory. We found that TOE provides an appropriate classification and theoretical framework to help understand supply chain capability development for resilience in times of crises and disruption. Our review of the existing literature shows that previous research has not focused on or developed such tools for analysis.

This study has significant contributions, as it provides insights for supply chain managers to improve supply chain function, risk management and resilience, particularly under disruptive events such as COVID-19. One of the limitations of this study was the use of a small sample of companies which amounted to 24 companies and we believe that more insights could be offered for future research with larger samples and quantitative results to extend this research for supply chain functioning. We are confident that future research, utilizing more data, will re-emphasize our finding that industry, size and type matters when developing organizational resilience while faced with sudden supply chain disruptions.

This research is exploratory and emerging as is the COVID-19 crises. But the 24 company—and their supply chain—responses to the COVID-19 pandemic helped to highlight post-COVID-19 supply chain lessons. Our research uses the blockchain and the circular economy nexus of capabilities, both of which show current and future potential to improve supply chain function, not just in times of crisis. This study took a unique approach to analyze the organizational behavior in supply chain activities and identifies some of the important factors that can contribute to the firm's improved capabilities.

Future research should also segment the larger samples by industry and stage of the life cycle to determine if there are unique modifications and improved functioning based on industry or supply chain stage. Research is needed in the various areas of our study individually including an additional study on blockchains use and efficacy in improving supply chains as well as separate research to identify the circular economy benefits. More examples of L-A-D are necessary, and this research should identify the pros and cons of firms developing their strengths in these areas versus working with partners to achieve similar benefits. Overall, the COVID-19 crisis, although with terrible and deadly outcomes, provides organizations and their supply chains lessons in how to effectively ride out a tsunami event. We feel there is much to learn from this crisis for both future crises and normal supply chain operations.

Note

1. The Center for Infectious Disease Research and Policy (CIDRAP) maintains a database of recent articles related to business supply chain issues during COVID-19. More information is available at: https://www.cidrap.umn.edu/covid-19/supply-chain-issues.

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Appendix

The Appendix is available online for this article.

Corresponding author

Santosh Nandi can be contacted at: nandisan@uscsumter.edu, technospan@gmail.com