Blockchain adoption and operational performance: A secondary data analysis on effects and contingencies

Giovanna Culot
Polytechnic Department of Engineering and Architecture, University of Udine, Udine, Italy
Matteo Podrecca
Faculty of Engineering, Free University of Bozen-Bolzano, Bolzano, Italy, and
Guido Nassimbeni
Polytechnic Department of Engineering and Architecture, University of Udine, Udine, Italy

Received 14 June 2023
Revised 29 November 2023
22 December 2023
5 February 2024
Accepted 9 February 2024

Abstract

Purpose – This study analyzes the performance implications of adopting blockchain to support supply chain business processes. The technology holds as many promises as implementation challenges, so interest in its impact on operational performance has grown steadily over the last few years.

Design/methodology/approach – Drawing on transaction cost economics and the contingency theory, we built a set of hypotheses. These were tested through a long-term event study and an ordinary least squares regression involving 130 adopters listed in North America.

Findings – Compared with the control sample, adopters displayed significant abnormal performance in terms of labor productivity, operating cycle and profitability, whereas sales appeared unaffected. Firms in regulated settings and closer to the end customer showed more positive effects. Neither industry-level competition nor the early involvement of a project partner emerged as relevant contextual factors.

Originality/value – This research presents the first extensive analysis of operational performance based on objective measures. In contrast to previous studies and theoretical predictions, the results indicate that blockchain adoption is not associated with sales improvement. This can be explained considering that secure data storage and sharing do not guarantee the factual credibility of recorded data, which needs to be proved to customers in alternative ways. Conversely, improvements in other operational performance dimensions confirm that blockchain can support inter-organizational transactions more efficiently. The results are relevant in times when, following hype, there are signs of disengagement with the technology.

Keywords Blockchain, Distributed ledger, Operational performance, Event study, Transaction cost economics, Contingency theory

Paper type Research paper

1. Introduction

The debate on supply chain (SC) applications of blockchain technology (BT) is characterized by a yet unsolved dilemma. On the one hand, the technology has been hailed as the ultimate

Funding: This paper is part of research activities of the project BT-OSCM funded by the Free University of Bozen-Bolzano with the RTD 2020 call (No: CUP I54I20001030005).

International Journal of Operations & Production Management
Vol. 44 No. 13, 2024
pp. 69-99
Emerald Publishing Limited
0144-3577
DOI 10.1108/IJOPM-05-2023-0346

solution for managing inter-organizational information flows (Iansiti and Lakhani, 2017). BT has been related to better product traceability and trackability, fewer errors and delays, more efficient inventory management, and faster payments and financing (Peng *et al.*, 2022; Li *et al.*, 2021; Centobelli *et al.*, 2021). On the other hand, the slow uptake of BT, coupled with failures of firms' pilot projects, has cast doubts (Bai and Sarkis, 2020; Pournader *et al.*, 2020). Observers have associated BT with hype, while questioning the superiority of its technological features over standard SC software solutions (Ahmed *et al.*, 2022; Klöckner *et al.*, 2022). Further concerns have followed the discontinuation of popular initiatives, such as TradeLens and B3i, which were well known BT in logistics and insurance, respectively (Cecere, 2022; Muir, 2022).

In essence, BT is a digital, decentralized, and distributed database of transactional records, which — unlike traditional databases — is neither stored in a single location nor controlled by a central authority (Schmidt and Wagner, 2019; Treiblmaier, 2018). As BT was created for cryptocurrencies (Nakamoto, 2008), SC professionals have long seen it as a "solution looking for a problem" (Markus and Buijs, 2022). Academic efforts to clarify use cases, implementation challenges, and benefits have been substantial (Peng *et al.*, 2022; Müßigmann *et al.*, 2020). There is now a sharper understanding of technological options, setups, and application areas, but questions remain regarding the effects on the operational performance of adopting firms.

Research on BT performance implications has concerned expectations, which still need to be empirically verified. Thus far, researchers have conceptually anticipated potential benefits (e.g. Schmidt and Wagner, 2019; Babich and Hilary, 2020), developed analytical demonstrations (e.g. Ji *et al.*, 2022; Chod *et al.*, 2020), run expert studies and surveyed managers' opinions (e.g. Tan *et al.*, 2023; Fosso Wamba *et al.*, 2020a), and analyzed self-reported implications from primary and secondary cases (e.g. Rogerson and Parry, 2020; Nandi *et al.*, 2020). The few extensive investigations have addressed stock market performance as a predictor of future business value (Liu *et al.*, 2022; Klöckner *et al.*, 2022; Xiong *et al.*, 2021). Only two studies have considered measures derived from financial statements but provide partial answers to the issue. Specifically, Sharma *et al.* (2023) analyzed a sample consisting largely of technology developers, whose drivers for value creation are different from those of BT implementers. Tse *et al.* (2023) examined Chinese-listed firms; however, they neither compared adopters against non-adopters nor clarified whether performance increases stemmed from revenue growth or process improvement.

As firms progressively move past the pilot phase of BT implementation, there are growing opportunities to validate current judgments. This is the aim of this study in addressing the following research questions (RQs):

RQ1. What are the effects of BT adoption for SC purposes on firms' operational performance?

RQ2. What are the contingencies affecting the relationship between BT adoption and firms' operational performance?

Operational performance is defined as the measure of a firm's ability to transform diverse inputs into value-added outputs in the process of producing goods and providing services (Li *et al.*, 2010). We considered sales performance, labor productivity, operating cycle, and profitability. The hypotheses were developed after reviewing previous BT research in view of the principles of transaction cost economics (TCE) (Williamson, 1987) and the contingency theory (CT) (Donaldson, 1987; Lawrence and Lorsch, 1967). We performed a long-term event study (RQ1) and an ordinary least squares (OLS) regression (RQ2). The dataset consisted of 130 firms, listed in North America, which have adopted BT to support SC business processes, namely those related to the production of goods and the provision of services (Klöckner *et al.*, 2022; Babich and Hilary, 2020). Our approach is consistent with previous studies addressing firms' performance following the implementation of new technologies (e.g. Yiu *et al.*, 2021; Hill *et al.*, 2018; Hendricks *et al.*, 2007).

The article makes three main contributions. To begin with, this is one of the first studies based on large-scale empirical evidence and the first that analyzes different operational performance dimensions. Our results are important in closing the gap between expectations and the reality of BT, as amply advocated by previous literature (Xie *et al.*, 2022; Liu *et al.*, 2022; Karakas *et al.*, 2021). Specifically, the sample firms showed significant positive abnormal performance for all investigated measures except sales, suggesting that BT is neither influencing customer preferences nor determining a price premium. Second, we clarified the role of some contextual factors in affecting the relationship between BT adoption and operational performance. We found that a firm's position along the SC and its being part of a regulated industry — although the latter with a time lag — positively moderated performance improvements. Conversely, the level of competition in the industry was not found to be influential. We also evaluated the early involvement of project partners versus initiatives launched by single firms. This additional variable also did not lead to significant results. The analysis of contextual factors is in line with the growing interest in the contingencies of BT, whose application needs to be carefully assessed depending on the industry and institutional setting (Ahmed *et al.*, 2022; Sauer *et al.*, 2022). Third, the study contributes to the ongoing debate about the value of technology (Hendricks *et al.*, 2007; Hill *et al.*, 2018). By grounding our reasoning in TCE and the CT, we showed that emerging dynamics can be read through the lenses of established theoretical models, whose core concepts can also explain the mechanisms driving performance improvements. From a practical standpoint, we provide evidence of the value that can be expected from BT. This is relevant since a limited understanding of performance implications has been mentioned as an adoption barrier (Kouhizadeh *et al.*, 2021; Fosso Wamba *et al.*, 2020a).

The rest of the study is structured as follows. The next section reviews research on BT for SC management purposes and introduces the theoretical lenses underpinning this study. Thereafter, we formulate the hypotheses and illustrate the data and methodology. After presenting the results, we conclude by discussing how our findings relate to the previous literature and outlining contributions and limitations.

2. Literature background

2.1 BT in supply chain management

BT became popular in 2008 with the advent of Bitcoin, a currency system based on a fully distributed digital ledger (Nakamoto, 2008). The technology can be applied to various kinds of transactional records. Unlike other databases, the ledger is not stored in a central location, but a full copy is kept by each member involved in the network (i.e. "nodes"). The data are encrypted and updated through a computational peer-to-peer consensus mechanism (Iansiti and Lakhani, 2017; Durach *et al.*, 2021). The technological aspects are already known to supply chain management (SCM) scholarship (e.g. Pournader *et al.*, 2020; Cole *et al.*, 2019); it should be noted that newer generations of BT are rapidly overcoming some of the limitations stressed by previous literature, such as poor scalability in the number of transactions, long and energy-intensive computational processes, and integration issues with legacy information systems (Ghadge *et al.*, 2022; Liu *et al.*, 2021). By now, most protocols are based on fast-track consensus mechanisms and BT suites are directly available on mainstream cloud services (Bag *et al.*, 2022).

According to Babich and Hilary (2020), five characteristics make BT different from traditional SC software solutions. These are visibility, aggregation, validation, automation, and resilience. Visibility is related to good tracking and process monitoring (Lumineau *et al.*, 2021). Aggregation is made possible thanks to BT acting as an interoperability layer (Tian *et al.*, 2022). Validation concerns the authentication mechanisms that make the ledger tamper-proof and a single source of truth among network participants (Fosso Wamba *et al.*, 2020a; Cole *et al.*, 2019). Automation denotes BT's ability to execute transactions based on pre-specified conditions, as exemplified by smart contracts (Kopyto *et al.*, 2020). Resilience refers to the condition of operation continuity in cases where some nodes are disabled (Fosso Wamba *et al.*, 2020b).

Research has been flourishing since 2016, when the first non-technical paper was published (Müßigmann *et al.*, 2020). With regard to SCM, several literature reviews have mapped the scientific landscape in this milieu (e.g. Peng *et al.*, 2022; Karakas *et al.*, 2021; Centobelli *et al.*, 2021; Chang *et al.*, 2020; Wang *et al.*, 2019; Cole *et al.*, 2019). These show that the debate has been characterized by the need to rigorously define BT's potential against overenthusiastic narratives brought about by technology providers and early implementers. This seems justified by the fact that BT was not originally conceived as an SC technology, with its popularity being driven by excitement around cryptocurrencies (Cheng *et al.*, 2019; Cahill *et al.*, 2020). Significant thought has thus been devoted to where BT could be or has already been applied (e.g. Pournader *et al.*, 2020; Durach *et al.*, 2021). Researchers have leveraged theory to frame opportunities and pitfalls (e.g. Lumineau *et al.*, 2021; Babich and Hilary, 2020), resorted to expert opinions (e.g. Kopyto *et al.*, 2020), and analyzed primary and secondary cases to explicate projects' characteristics (Rogerson and Parry, 2020; Nandi *et al.*, 2020; Ahmed *et al.*, 2022). The more commonly reported applications relate to good traceability and trackability and the automation and digitalization of business processes, including those related to payments. It has also been noted that BT could be adopted to monitor firms' sustainability commitments (Bai and Sarkis, 2020).

Although the literature highlights the potential of BT for SCM, its uptake has fallen short of expectations. Researchers have thus also investigated adoption drivers and barriers (Kouhizadeh *et al.*, 2021). The main motivations include the need to improve trust among business partners, the levels of data security guaranteed by the technology, and the benefits of integrating SCs (Wang *et al.*, 2019). Possible barriers are thought to be related to a lack of technical expertise, a still low level of technological maturity, managerial skepticism, poor cooperation among SC partners, and uncertain returns on investment (Queiroz *et al.*, 2021; Mathivathanan *et al.*, 2021; Karakas *et al.*, 2021; Wong *et al.*, 2020). In general, performance improvements have been recognized as a key factor driving adoption (Fosso Wamba *et al.*, 2020a).

2.2 TCE and BT performance implications

The performance implications of adopting BT for SCM can be framed with consideration to its peculiarities as a transactional database (Babich and Hilary, 2020; Iansiti and Lakhani, 2017). Overall, BT-enabled data sharing and execution conditions can support a reduction in transaction-related inefficiencies. From a theoretical standpoint, this can be explained leveraging the core tenets of TCE (Williamson, 1985, 1987, 1996). Other theoretical lenses can be used when investigating BT (Treiblmaier, 2018), including principal–agent theory (PAT) (Jensen and Meckling, 1976), the resource-based view (RBV) (Wernerfelt, 1984; Barney, 1991), and the network theory (NT) (Hakansson, 1987; Oliver, 1990). In SCM, they are common perspectives and offer complementary views on governance structures and inter-organizational relationships (Halldorsson *et al.*, 2007). When addressing the implications on operational performance of adopting BT, TCE appears to be the most appropriate due to its primary focus on the optimization of transaction costs (Schmidt and Wagner, 2019; Roeck *et al.*, 2020). In contrast, PAT may be more properly applied to analyze the implementation of BT-enabled smart contracts, RBV to determine the influence of BT on implementers' resources and capabilities, including those stemming from inter-organizational routines, and NT to explore how firms mutually adapt their relationships and the effects on network structures (Treiblmaier, 2018).

TCE is based on the notion that each business transaction comes with costs related to inter-organizational coordination (Grover and Malhotra, 2003; Williamson, 1985). These costs cover *ex-ante* initiation (i.e. search and information gathering), agreement formulation (i.e. decision making and negotiation), and *ex-post* monitoring (i.e. controls and adjustments) (Ketokivi and Mahoney, 2020). TCE is grounded on two assumptions about the characteristics of human behavior. One is the concept of bounded rationality (Simon, 1985), as there are cognitive limitations in receiving and processing information; the other is opportunism, because each party is expected to act out of self-interest (Williamson, 1987). Higher transaction costs are expected to occur in the case of asset-specific investments (i.e. investments characterized by little or no value outside of the relationship) (Williamson, 1987), high-volume and frequent transactions (Rindfleisch and Heide, 1997), and whenever there is high uncertainty in the external environment and in the other party's behavior (Grover and Malhotra, 2003). Depending on these factors, different governance structures are more appropriate (Ellram *et al.*, 2008).

As far as SCM is concerned, TCE has been largely used to theorize on the governance of transactions along SCs, thus investigating how goods can be transferred efficiently from one production stage to another and how transacting firms can ensure they do not waste resources in exchange relationships (Ketokivi and Mahoney, 2020; Halldorsson *et al.*, 2007). Once the sourcing setup is defined, governance mechanisms provide institutional arrangements between transaction parties. These are traditionally subsumed into two broad categories, namely mechanisms that are contractual (i.e. legal clauses) or relational (i.e. informal norms stemming from social interactions) (Poppo and Zenger, 2002). Significant efforts have been devoted to demonstrating the impact of diverse arrangements for supplier governance on the financial and operational performance of the SC, and specifically of the focal firm (Wacker *et al.*, 2016; Grover and Malhotra, 2003).

Since the advent of BT, SCM researchers have argued about the potential of the technology to lower transaction costs by mitigating issues related to bounded rationality and opportunism (Treiblmaier, 2018; Schmidt and Wagner, 2019; Roeck *et al.*, 2020). Accordingly, efficiency gains can manifest across all phases in a transaction — in the *ex-ante* selection of suppliers, in the definition of the agreement, and in *ex-post* monitoring activities — by accessing reliable and timely information, as well as through automated execution enabled by smart contracts (Lumineau *et al.*, 2021; Roeck *et al.*, 2020; Treiblmaier, 2018). Overall, research has argued that BT may represent a governance mechanism different from and substantially superior to hitherto available practices (Roeck *et al.*, 2020; Lumineau *et al.*, 2021). In contrast to contractual governance, BT may ensure that agreements are enforced through protocols and validated by the network of nodes, thus removing the need for legal entities and trusted third parties (Treiblmaier, 2018). BT can thus generate cost savings through disintermediating middlemen positions (Durach *et al.*, 2021; Cole *et al.*, 2019). Different from relational governance, BT may limit the need for personal trust by building tamper-proof time-stamped aggregated records of transactions (Babich and Hilary, 2020).

Against the strengths of these theoretical arguments, thus far, the relative novelty of the technology has unfortunately limited opportunities to extensively verify BT's effects on transaction costs (Sharma *et al.*, 2023). The viability of BT for industrial application is amply corroborated by analytical models and field experiments (e.g. Tian *et al.*, 2022; Ji *et al.*, 2022; Casino *et al.*, 2021; Yoon *et al.*, 2020; Chod *et al.*, 2020) as well as by case study research (e.g. Ahmed *et al.*, 2022; Markus and Buijs, 2022; Nandi *et al.*, 2020). Across several potential application areas (e.g. product traceability and trackability, logistics optimization, payments and financing), previous studies indicate improvements in the speed, cost, quality, flexibility, and dependability of SC business processes. Moreover, it has been shown that BT-enabled traceability can increase firms' reputation and prevent revenue loss from counterfeiting (Danese *et al.*, 2021; Moretto and Macchion, 2022). Nevertheless, some studies point to the challenges of implementing BT for SCM purposes, ultimately casting doubt on the real advantages of a technology that may be excessively complex and comparatively less cost-effective than other available solutions (Sauer *et al.*, 2022; Rogerson and Parry, 2020). Such tradeoffs can be clarified only through large-scale empirical evidence.

Extensive studies on BT performance implications exist; however, these only partially confirm the value of the technology in support of SC business processes. The reason is inherent in their design. Primary research has focused mainly on expert judgment. For example, Gupta *et al.* (2020) find BT to be in the top three digital technologies to improve SC performance, according to their panel. Along these lines, several surveys indicate that SC practitioners attribute the performance improvements stemming from BT adoption to higher SC transparency and integration (Tan *et al.*, 2023; Paul *et al.*, 2021; Fosso Wamba *et al.*, 2020a). Improvements can also derive from the BT affecting customer retention (Bag *et al.*, 2022) and supporting firms' innovation toward higher resilience (Li *et al.*, 2022). Overall, these studies have the merit to posit and test how BT can improve SC processes toward higher efficiency, while establishing a link between process improvement and adopting firms' operational performances. However, the results are based on perceptual measures, which mostly do not reflect the actual experience of firms with the technology, but rather opinions and expectations.

Extant research based on secondary data analysis does not validate BT performance implications either, as published studies analyze mostly stock market reactions upon the announcement of a firm's intention to adopt BT. Through the event study methodology, Cahill *et al.* (2020) and Cheng *et al.* (2019) examine speculative announcements (i.e. vague plans to adopt BT not tied to a specific project) to show that market reactions are correlated with peaks in Bitcoin quotations. Conversely, Klöckner *et al.* (2022), Liu *et al.* (2022), and Xiong *et al.* (2021) investigate firms announcing substantiated initiatives (i.e. specific projects defining a clear use case) and base their studies on the assumption of share price being an indicator of future business value. Both Klöckner *et al.* (2022) and Liu *et al.* (2022) find positive evidence of abnormal returns. Xiong *et al.* (2021) instead demonstrate that BT adopters were less negatively impacted by the COVID-19 pandemic. Only two studies partially address operational performance through selected measures. Sharma *et al.* (2023) examine the return on equity (ROE), the return on assets (ROA), and Tobin's Q for firms included in the Nasdaq Blockchain Economy Index. They find only Tobin's Q to be impacted as "*a market-based measure of future earnings*" (Sharma *et al.*, 2023, p. 2). The result can be explained by considering the nature of their sample (i.e. the 60 firms included in the Index), which is heavily skewed toward technology providers that do not adopt BT in support of their business processes, but are usually evaluated in terms of their potential to develop novel technologies. Tse *et al.* (2023) analyze adopters among firms listed on the Chinese stock exchange. They regress an aggregate measure of operational efficiency on the characteristics of the BT initiative, finding that companies pursuing both efficiency and innovation are characterized by a better performance; however, they neither control for a selection effect nor compare the performance of adopting and non-adopting firms.

To summarize, there are solid theoretical arguments supporting the view that BT can reduce transaction costs, ultimately impacting the operational performance of implementing firms. There is, however, only a partial empirical verification of these claims, as the early stages of technological adoption have thus far limited the opportunities for extensive studies on the matter. This is a clear gap in the literature that prevents the validation of theoretical claims raised by prior studies (Treiblmaier, 2018; Schmidt and Wagner, 2019; Roeck *et al.*, 2020). From a practical standpoint, this gap ought to be addressed in light of ongoing concerns about the cost-effectiveness of the technology and possible managerial hype.

2.3 The contingent view of TCE and the context of BT application

Transactions and governance arrangements are embedded in broader institutional environments, namely within the structures characterizing political, economic, and social interactions (North, 1992). These structures not only enable and constrain the behavior of firms but, together with the technologies employed, are also a key determinant of transaction costs. In TCE theorizing, the concept of shift parameters encapsulates the effects of different environmental conditions on the comparative costs of governance arrangements (Williamson, 1996). The presence of such shift parameters poses significant theoretical and managerial challenges for TCE, as lessons learned in one context are difficult to extend to other contexts (Ketokivi and Mahoney, 2020). These challenges can be addressed by integrating TCE with CT (Donaldson, 1987; Lawrence and Lorsch, 1967). CT states that there is no best way to manage a firm, but strategic choices and operational practices depend on a set of contingent internal and external factors. CT can thus complement TCE, as the salient characteristics of the context where a transaction occurs can be theoretically identified and operationalized (e.g. Buttermann *et al.*, 2008; Ketokivi, 2006).

CT has been broadly applied to investigate the fit between technology, the external environment, and the characteristics of the organization (e.g. Søgaard *et al.*, 2018; Mikalef *et al.*, 2015; Sambamurthy and Zmud, 1999; Jelinek, 1977). In terms of contingencies affecting technology performance, the literature stresses the need to align technological setups with the firm's strategic objectives and organizational structure. However, the relevance of external factors depends largely on the kind of technology being adopted (e.g. purely internal or inter-organizational technologies) (Lam *et al.*, 2019).

Reading through industry-focused literature reviews (e.g. Liu *et al.*, 2021; Li *et al.*, 2021) (addressing food and maritime matters, respectively), it appears clear that there are sectoral differences concerning BT. Its progressive spread across industries and countries has sparked interest in the contingencies behind those differences, which have emerged as a central topic in recent articles (Ahmed *et al.*, 2022; Sauer *et al.*, 2022). Three main dimensions have been identified: the business environment (e.g. market and customer demand, standards, and regulations), the structural characteristics of the SC (e.g. complexity and governance), and the nature of the product/transaction (e.g. value and volume) (Sauer *et al.*, 2022). Looking at the business environment, companies in regulated industries, such as pharmaceuticals and food, are more concerned with BT implementation for product quality and traceability, whereas firms operating in other contexts, such as logistics, are mostly targeting process efficiency objectives (Nandi *et al.*, 2020). Traceability is also demanded in high-end segments for authenticity (Moretto and Macchion, 2022) and in case of safety concerns (e.g. baby formula in China) (Rogerson and Parry, 2020). In terms of SC characteristics, the presence of multiple production steps and a high market fragmentation is highlighted as an implementation challenge (Hastig and Sodhi, 2020). Finally, it has been argued that BT may be too costly for low-value products and low-volume transactions (Sauer *et al.*, 2022).

Some contextual variables have been analyzed in previous studies on BT performance. These include industry- (research and development intensity, munificence, and market and technology dynamisms), country- (data restriction), and firm-level variables (size, innovation ability, intangible capital) (Tse *et al.*, 2023; Sharma *et al.*, 2023; Liu *et al.*, 2022; Klöckner *et al.*, 2022; Fosso Wamba *et al.*, 2020a).

3. Research framework and hypothesis development

In this section, we formulate a set of hypotheses on the relationship between BT adoption and operational performance and the presence of contextual factors affecting this relationship. The use of theory allows us to formulate general predictions to consistently integrate fragmented empirical evidence.

3.1 The relationship between BT and operational performance

The unit of analysis in TCE is the transaction (Williamson, 1985, 1987). Transaction costs can be reduced by the adoption of BT, thus affecting the performance of the firms involved in the exchange. As argued in the later developments of TCE, this can influence cost-related dimensions as well as revenue (Ketokivi and Mahoney, 2020). In this respect, it is common in the SCM literature to analyze firms' operational performance under the assumption that this is impacted by efficient arrangements of inter-organizational transactions in contexts characterized by SC interdependencies (Pilbeam *et al.*, 2012).

When considering how BT can affect the operational performance of adopting firms through more efficient transaction governance, four dimensions are paradigmatic: sales, labor productivity, operating cycle time, and profitability. As we clarify in the rest of this section, sales can be influenced by a reduction in *ex-ante* transaction costs (i.e. firms can testify their reputation and the quality of their products, thus facilitating their selection and potentially demanding a price premium) (Schmidt and Wagner, 2019), labor productivity can be enhanced by automation and increased information flows throughout the various phases of a transaction (Lumineau *et al.*, 2021), and cycle time can be impacted by information sharing and the introduction of execution conditions that speed up the exchange process and *ex-post* monitoring activities (Babich and Hilary, 2020; Iansiti and Lakhani, 2017). Under this premise, profitability is also analyzed as it represents a synthetic indicator that, combining top line effects with gains in internal efficiency, can reflect the overall impact of BT on adopting firms (Konchitchki and O'Leary, 2011). These metrics are justified by the numerous studies that have investigated them in relation to the adoption of new technologies (Podrecca *et al.*, 2022; Hill *et al.*, 2018; Hendricks *et al.*, 2007).

The first hypothesis concerns ***sales performance***, as both business customers and consumers can leverage BT to obtain information. In general, it is reasonable to assume that customers would prefer to limit transaction costs related to *ex-ante* initiation, and thus look for BT-enabled visibility (Hong and Hales, 2021). This should in turn be reflected in the sales performance of the firm implementing BT. For example, transacting parties can build reputation systems regarding their business partners' performance, thus reducing the efforts involved in supplier selection and vetting (Lumineau *et al.*, 2021; Babich and Hilary, 2020; Schmidt and Wagner, 2019). In the consumer sector, thanks to mobile applications, individuals can verify product provenance, authenticity, and quality. This may drive consumer preferences and justify a price premium (Danese *et al.*, 2021; Moretto and Macchion, 2022; Rogerson and Parry, 2020). The following hypothesis (H) is thus formulated:

H1. The adoption of BT leads to improved sales performance.

Moving to ***labor productivity*** (i.e. the efficiency of organizational routines and working practices) (Orzes *et al.*, 2020), there may be constraints preventing organizations from reaping the benefits of BT, at least in the initial phase, due to the need to integrate existing processes and solutions while upskilling the workforce and stimulating acceptance (Sodhi *et al.*, 2022). Despite a likely learning curve, extant research has highlighted that, when fully operational, the technology supports employees by providing timely/reliable information and automating certain tasks (Roeck *et al.*, 2020; Schmidt and Wagner, 2019). BT replaces other forms of information exchange, such as emails and phone calls, while direct access to reliable data minimizes the time wasted waiting for documents and authorizations (Malhotra *et al.*, 2022; Lumineau *et al.*, 2021; Wang *et al.*, 2019). In addition, smart contracts can eliminate the need for human intervention (Nandi *et al.*, 2020). The presence of a distributed system, moreover, reduces data reconciliation from different sources (Hastig and Sodhi, 2020; Sauer *et al.*, 2022). Thanks to more complete, reliable, and timely data, it is also possible to take more informed decisions, thus reducing the costs of human errors (Roeck *et al.*, 2020; Schmidt and Wagner, 2019). In sum, BT can support human decisions, eliminate unnecessary information exchanges and data reconciliation activities, and automate several tasks, freeing up time and resources to be deployed elsewhere. We thus posit that:

H2. The adoption of BT leads to improved labor productivity.

For what concerns the ***operating cycle time***, BT can facilitate the flow of goods, services, finance, and information due to data availability and automation (Lumineau *et al.*, 2021). From a TCE perspective, BT-enabled information sharing and automation may lower environmental and behavioral uncertainty (Babich and Hilary, 2020). This, in turn, can reduce the need for buffer resources and speed up operational and financial processes (Roeck *et al.*, 2020). Overall, the research has amply demonstrated that firms with higher SC visibility are more flexible and efficient, as increased information processing capabilities reduce the need to hold inventory and build extra capacity to cope with unexpected circumstances (Srinivasan and Swink, 2018). The technological features of BT enable forecasting and planning activities to be based on more reliable and timely data. Firms can thus adjust their processes more effectively, with direct implications in terms of inventory and capacity buffers (Peng *et al.*, 2022; Nandi *et al.*, 2020; Kopyto *et al.*, 2020). Considering financial flows, similar gains can be obtained. As a distributed ledger, BT can bridge buyers, suppliers, and banks, thus removing the need for verification and reconciliation (Iansiti and Lakhani, 2017). Current research also indicates improvements in cash collection and financing practices due to the automation of several process steps (Chod *et al.*, 2020; Malhotra *et al.*, 2022). As fewer actors are involved in the process, less time is needed to settle payments (Wong *et al.*, 2020; Wang *et al.*, 2019). The following hypothesis is thus formulated:

H3. The adoption of BT leads to improved operating cycle time.

Finally, ***profitability*** can be affected by a reduction in transaction costs during the whole process, besides being positively impacted by the potential improvements in sales performance posited in H1. First, costs related to *ex-ante* initiations can be abated by visibility of a firm's past performance and current operations (e.g. reputational systems, inventory visibility) (Chod *et al.*, 2020). BT directly facilitates transparency and discourages misbehavior that could be exposed. Consequently, there is a limited need to invest time and resources in building long-term partnerships (Lumineau *et al.*, 2021; Schmidt and Wagner, 2019). Second, in negotiating and formulating an agreement, BT allows the implementation of self-contained and autonomous systems of rules through smart contracts (Lumineau *et al.*, 2021; Kopyto *et al.*, 2020). These eliminate costs related to contract registration and updating, potential issues with payment withholding, and the need for intermediaries (Wang *et al.*, 2019). Third, as far as *ex-post* transaction costs are concerned, smart contracts allow speed and accuracy in executing adjustments as the conditions are coded (Schmidt and Wagner, 2019). BT grants higher data transparency, reliability, and timeliness than traditional software solutions based on multiple systems (Schmidt and Wagner, 2019; Treiblmaier, 2018). Thanks to data access, firms can reduce behavioral uncertainty about their partners and adapt their activities rapidly (e.g. demand planning, production scheduling, product recalls) (Enrique *et al.*, 2022; Rogerson and Parry, 2020; Hastig and Sodhi, 2020; Gong *et al.*, 2022).

In general, theoretical elaborations, as well as current studies on BT, suggest reductions in transaction costs. Some concerns have been highlighted regarding the risks of committing to an early-stage technology (Fosso Wamba *et al.*, 2020b; Schmidt and Wagner, 2019), the potential costs of technical expertise (Kouhizadeh *et al.*, 2021; Treiblmaier, 2018), and additional expenses to ensure the factual credibility of data (e.g. through a third party or by using sensors) (Babich and Hilary, 2020). Despite these precautions and considering the arguments presented above, we conclude proposing the following hypothesis:

H4. The adoption of BT leads to improved firm profitability.

3.2 Contingent factors affecting the relationship

By adopting a contingent view of TCE, our premise was that the context may affect the relationship between BT and the operational performance of the adopting firms. By leveraging CT, we were able to identify the salient dimensions and operationalize them into variables that could moderate the relationship between BT adoption and operational performance. We decided to examine three contingent factors that are central to the current debate, but whose implications are not yet fully understood. In this sense, building on previous BT literature and further theoretical reasoning, we formulate three hypotheses whereby we present arguments supporting both a positive effect and a negative one.

The first hypothesis concerns regulation [1], namely those rules and acts with which organizations must comply in terms of transparency, disclosure, traceability, and obligations/restrictions associated with their activities (Hartley *et al.*, 2022; Kalmenovitz, 2023). Regulation has different intensity levels depending on the industry; thus, it is a relevant contingent factor to investigate. Relevant examples of such regulations mentioned in the BT literature are customs clearance, the Restriction of Hazardous Substances (RoHS) directive, the conflict minerals rule (Dodd-Frank Act), the European Union's Registration, Evaluation, Authorization, Restriction of Chemicals (REACH) regulation, and the US Drug Supply Chain Security Act (DSCSA) (Hartley *et al.*, 2022). Regardless of the specific aspects covered by such directives, extant research emphasizes that "*in heavily regulated industries, the managing of data can be overwhelming. Keeping track of retention rules, document types, and formats – as well as making sure you keep only what is necessary – can be an enormous task*" (Iannarelli and O'Shaughnessy, 2014, p. 26) and "*the abundance of paperwork is reputed to impose a heavy economic toll on companies*" (Kalmenovitz, 2023, p. 3312).

Although BT adoption is not mandatory to fulfill any of such requirements, firms can embrace BT to comply more effectively and cost-efficiently with regulations (Ghadge *et al.*, 2022). In fact, BT allows the minimization of extensive paperwork and data reconciliation, making it possible to share auditable records with external stakeholders (Peng *et al.*, 2022; Li *et al.*, 2021; Hastig and Sodhi, 2020; Casino *et al.*, 2021). Firms can also use the technology to enforce adherence to rules and obligations. This can be done through validation mechanisms that detect improper transaction characteristics and the use of smart contracts for automated compliance (Schmidt *et al.*, 2017; Durach *et al.*, 2021; Ahmed *et al.*, 2022); for instance, these tools can verify the authenticity of products and automatically terminate supply contracts in the case of violations (Van Hoek, 2019).

Despite the potential benefits, firms operating in regulated industries may face more severe implementation challenges. Systems, processes, and procedures need to be tailored to industry standards (e.g. good manufacturing practices and good distribution practices) (Hastig and Sodhi, 2020), whereas laws, regulations, and institutions vary across countries (Schmidt *et al.*, 2017). In such industries, it is complex for firms adopting new technologies to demonstrate compliance and align on data formats and validation procedures. Considering these arguments, we test the following hypothesis:

H5. The effect of BT adoption on operational performance is affected by the regulation intensity of the industry.

The second aspect is related to industry-level competition. High levels of competition have often been associated with better operational performance in adopting information technologies (Raguseo *et al.*, 2020; Dong *et al.*, 2009; Melville *et al.*, 2007). This is explained by the fact that, under competitive pressures, firms become more innovative in exploiting their technological assets. This view seems, however, not to be fully supported by empirical research on BT. Although the effects of competition have not been explicitly analyzed as yet, the implementing firms' innovation ability has not been found to be a significant moderating factor in the relationship between BT adoption and performance (Liu *et al.*, 2022; Klöckner *et al.*, 2022).

From another angle, as an inter-organizational technology, BT is subject to network effects, namely there is a positive relationship between the number of adopters and the benefits that any one firm can derive (Sodero *et al.*, 2013). Limited standardization and the existence of many projects within the same industry may prevent each BT initiative from scaling up the number of users while creating inefficiencies (Hartley *et al.*, 2022; Durach *et al.*, 2021; Babich and Hilary, 2020; Schmidt and Wagner, 2019). It is well known that network effects depend on the role that dominant firms play in onboarding SC partners and forming standard-setting consortia (Sodero *et al.*, 2013; Zhu *et al.*, 2006; Bala and Venkatesh, 2007; Zhao *et al.*, 2007). Based on this, firms in less competitive environments may exert their clout over customers and suppliers to convince them to join a BT initiative and avoid the otherwise high expenses needed for promoting network participation, thus experiencing higher benefits (Mathivathanan *et al.*, 2021; Liu *et al.*, 2022; Klöckner *et al.*, 2022; Schmidt and Wagner, 2019). In light of the above, we formulate the following hypothesis:

H6. The effect of BT adoption on operational performance is affected by the competition intensity of the industry.

The last factor refers to the position of the firm along the SC. Downstream companies are typically held accountable for any incidents occurring along the SC (Schmidt *et al.*, 2017; Buysse and Verbeke, 2003). They thus set up monitoring activities and controls, deploying internal resources or engaging third parties and bearing the related costs (Mena *et al.*, 2013; Jia *et al.*, 2019). As has previously been mentioned, these activities can be streamlined using BT for data gathering and automation (e.g. Li *et al.*, 2022; Rogerson and Parry, 2020; Hastig and Sodhi, 2020). Moreover, access to data could have positive consequences on buyers' bargaining power by lowering information asymmetries toward suppliers (Roeck *et al.*, 2020). Similarly, when considering service provision, companies leverage data access (Sorescu, 2017; Zaki, 2019). In this respect, BT can represent an effective technology in a business-to-consumer setting, where there is a higher level of complexity (Ahmed *et al.*, 2022). However, there may be some benefits for upstream firms too, as adopting BT can mitigate the bullwhip effect (Babich and Hilary, 2020), which is higher for firms at initial positions in the SC (Bode and Wagner, 2015).

These arguments lead us to propose the following hypothesis:

H7. The effect of BT adoption on operational performance is affected by the position along the SC of the implementing firm.

The hypotheses are summarized in Table 1.

Hypothesis	Main arguments	Theoretical lens	Supporting references
H1: The adoption of BT leads to improved sales performance	• BT enables the development of reputation systems for evaluating business partners, streamlining the supplier selection and vetting process • BT allows individuals to check product provenance, authenticity, and quality, potentially influencing consumer choices and supporting higher pricing strategies	Transaction cost economics	Hong and Hales (2021), Lumineu *et al.* (2021), Danese *et al.* (2021), Moretto and Macchion (2022)
H2: The adoption of BT leads to improved labor productivity	• BT automates tasks and reduces the need for traditional communication methods, freeing up time and resources to be deployed elsewhere • BT decreases the time spent reconciling data and waiting for approvals, leading to more informed decision making and lower error-related costs	Transaction cost economics	Malhotra *et al.* (2022), Lumineau *et al.* (2021), Sauer *et al.* (2022), Roeck *et al.* (2020)
H3: The adoption of BT leads to improved operating cycle time	• BT minimizes environmental and behavioral uncertainty, reducing the need for buffer resources and accelerating operations • BT enhances financial flows by connecting buyers, suppliers, and banks on a distributed ledger, reducing the need for manual verification and speeding up payments	Transaction cost economics	Babich and Hilary (2020), Nandi *et al.* (2020), Chod *et al.* (2020), Wang *et al.* (2019)
H4: The adoption of BT leads to improved firm profitability	• BT decreases costs along all the phases of a transaction: *ex-ante* (strengthened visibility and transparency), negotiation (easier contract registration and fewer payment withholding issues), and *ex-post* (lower activities adjustment effort) • BT improves sales performance (H1)	Transaction cost economics	Chod *et al.* (2020), Kopyto *et al.* (2020), Enrique *et al.* (2022), Gong *et al.* (2022)

Table 1.
Summary of the hypotheses underlying the study

(*continued*)

Hypothesis	Main arguments	Theoretical lens	Supporting references
H5: The effect of BT adoption on operational performance is affected by the regulation intensity of the industry	• BT enhances regulatory compliance by streamlining data handling and reducing paperwork through automated processes • BT adopters may be subject to implementation challenges in terms of industry-specific regulatory alignment	Contingency theory	Ghadge *et al.* (2022), Peng *et al.* (2022), van Hoek (2019), Hastig and Sodhi (2020)
H6: The effect of BT adoption on operational performance is affected by the competition intensity of the industry	• High levels of competition are often associated with enhanced operational performance when firms adopt information technologies like BT. • BT benefits are linked to network effects; less competitive environments allow dominant firms to influence and expand BT adoption among business partners	Contingency theory	Raguseo *et al.* (2020), Hartley *et al.* (2022), Mathivathanan *et al.* (2021), Schmidt and Wagner (2019)
H7: The effect of BT adoption on operational performance is affected by the position along the SC of the implementing firm	• Downstream companies benefit from BT in terms of monitoring and control activities, reducing costs, and information asymmetries • Upstream companies benefit from BT with regard to bullwhip effect mitigation	Contingency theory	Li *et al.* (2022), Rogerson and Parry (2020), Roeck *et al.* (2020), Babich and Hilary (2020)

Source(s): Author's own creation

Table 1.

4. Methodology

To test our hypotheses, we developed a secondary data analysis relying on the combination of a long-term event study (RQ1) and an ordinary least squares (OLS) regression (RQ2). Overall, using publicly available data drawn from firms' financial statements increases the objectivity of the measures, avoiding the biases connected to self-reported (perceptual) data (e.g. Podrecca *et al.*, 2022). In this respect, long-term event studies represent the most widely acknowledged and robust statistical method to investigate the performance effects of events such as the introduction of new technologies (e.g. Hendricks *et al.*, 2007; Hill *et al.*, 2018; Yiu *et al.*, 2021) and managerial practices (e.g. Orzes *et al.*, 2017; Shou *et al.*, 2021).

Long-term event studies analyzing accounting-based measures [2] are structured to exclude major causes of endogeneity and bias in the results, which appear as a core challenge when investigating the performance implications of firms' strategic choices, such as the adoption of a new technology or managerial practice (Klöckner *et al.*, 2022; Corbett *et al.*, 2005). In fact, firms with certain characteristics and/or performance levels may be more likely to pursue a certain strategic decision (i.e. in the case of this study, to adopt BT), thus being structurally subject to a non-random self-selection process (Klöckner *et al.*, 2022; Xiong *et al.*, 2021).

Endogeneity concerns caused by non-random self-selection processes can be addressed by comparing the performance of the firms identified as adopters of a specific technology/managerial practice with a control sample built by identifying, for each adopter, a portfolio of companies that match its characteristics (i.e. typically industry, size, and performance prior to the event) but do not resort to the technology/practice under examination (Orzes *et al.*, 2017, 2020; Podrecca *et al.*, 2022).

By analyzing the abnormal performance (i.e. comparing adopting firms with the control sample), event studies allow the addressing of selection biases stemming from observable firm-specific features and the effect of prior performance (Hill *et al.*, 2018; Podrecca *et al.*, 2022; Barber and Lyon, 1996). As explained in more detail in the following paragraphs, we carefully adopted the guidelines suggested by previous research to avoid any pitfalls in the application of the methodology. Robustness tests (presented in the online Supporting Material) were also performed to further validate our results. The remaining limitations are clarified in Section 6.

4.1 Sample firms

The reference population is made up of public companies listed in North America. This choice was motivated by the higher adoption rates of BT in North American firms as opposed to other regions (GVR, 2020). This also allowed us to access financial statements elaborated under the same accounting frameworks, thus improving the comparability of the data (Lo *et al.*, 2009).

To identify a sample of adopters, we performed a search of the Factiva commercial news database (Xiong *et al.*, 2021; Podrecca *et al.*, 2022). Our focus was on BT implementation for SCM purposes. We thus aimed to build a sample of companies that have adopted BT to support business processes related to the production of goods or delivery of services (Klöckner *et al.*, 2022). Therefore, the research was based on BT-related keywords (e.g. blockchain, block data, distributed ledger, consensus-based ledger, decentralized ledger, decentralized distributed database, digital ledger, and immutable ledger) and SC-related keywords (e.g. supply chain, supplier, customer, tracking, traceability, trackability, warehousing, logistics, purchasing, procurement, inventory, distribution, and transport). The research covered the period 2010–2020, with the first record found being for 2015. The announcements were analyzed to exclude unsubstantiated initiatives and cases where BT was not adopted to support SC business processes (e.g. cryptocurrencies). For each potential sample firm, we conducted a supplementary news search and screened official websites and annual reports to: i. ascertain that the company had actually implemented BT and not discontinued it, and the exact implementation year; ii. exclude initiatives that were still in an initial phase (proof of concepts and pilot projects); and iii. identify any other event that might affect firms' performance (McWilliams and Siegel, 1997; Nelson *et al.*, 2008).

The process resulted in a sample of 130 companies. The demographic of firms by adoption year and by industry is reported in Table S1 in the Supporting Material; the distribution is consistent with extant research (Xiong *et al.*, 2021).

4.2 Analysis of BT performance implications

The hypotheses related to operational performance (H1, H2, H3, and H4) were tested through a long-term event study. From the text of the announcements, it emerged that BT implementation requires 12–18 months on average. The event period was thus defined as the year in which BT was introduced (year t) and the previous year (t-1). Year t-2 was set as the base year (i.e. the event-free year) (Orzes *et al.*, 2017) and used to build the sample of control firms. Year t-3 was considered to control for endogeneity issues, that is, to verify that the performance changes appeared only after the technology had been implemented (Podrecca *et al.*, 2022; Lo *et al.*, 2014).

The operationalization of the performance measures followed that of other event studies (Lo *et al.*, 2014; Treacy *et al.*, 2019; Orzes *et al.*, 2020). We used the year-over-year sales growth for *sales performance* (H1); the ratio between operating income and the number of employees for *labor productivity* (H2); the sum of account receivables and inventory days for the *operating cycle* (H3); and return on asset (ROA) for *profitability* (H4). The data were extracted from the Bureau van Dijk Orbis database.

For each BT-adopting firm, and for each performance dimension, a distinct control portfolio of non-BT adopting firms was identified (Hendricks *et al.*, 2007; Podrecca *et al.*, 2022). Consistent with the recommendations of Barber and Lyon (1996) [3], three criteria were considered: industry (control firms should operate in the same first two-digit SIC code industry), size (the total assets of the control firms should be comprised in the 50–200% interval of the BT-adopting firm's total assets in the base year), and performance (control firms' performance should range between 90% and 110% of the BT-adopting firm performance in the base year). If no firm matched, the industry criterion was relaxed to the first one-digit SIC code and then removed (Podrecca *et al.*, 2022; Orzes *et al.*, 2017). The resulting average ratio of sampled firms to control firms is 1: 6.21; this is considered normal for event studies (Orzes *et al.*, 2020).

The abnormal performance (AP) change was determined as:

$$AP_{(t+b)} = PS_{(t+b)} - EP_{(t+b)}$$

$$EP_{(t+b)} = PS_{(t+a)} + \left(PC_{(t+b)} - PC_{(t+a)}\right)$$

Where PS is the actual performance of the BT-adopting companies, EP is the expected performance, PC is the median performance of the control companies, t is the year of blockchain implementation, a is the starting year of comparison (−3, −2, −1, 0, 1), and b is the ending year of comparison (−2, −1, 0, 1, 2). As the Shapiro–Wilk tests showed that the data were not normal, we resorted to non-parametric tests to verify whether AP differed significantly from zero. Following Podrecca *et al.* (2022) and Orzes *et al.* (2017), we performed the Wilcoxon signed-rank test (WSR) for symmetric distributions and the sign test for skewed ones.

4.3 Analysis of contextual factors

Consistent with previous research (e.g. Swink and Jacobs, 2012; Yang *et al.*, 2021; Podrecca *et al.*, 2022), we tested H5, H6, and H7 through an OLS regression on the abnormal ROA between t-2 to t+1 (short-term effects) and t-2 to t+2 (medium–long-term effects). ROA "*refers to a firm's ability to make use of its total assets to generate net operating income*" (Yiu *et al.*, 2021, p. 3956) and is therefore affected by both the top and the bottom-line of the company (De Jong *et al.*, 2014; Podrecca *et al.*, 2022). Moreover, according to Barber and Lyon (1996), ROA represents the best synthetic indicator of overall operational performance.

Three independent variables were included:

(1) *Regulation* (H5) was operationalized through the Regulation Index of the RegData database (Quantgov, 2023). By building on text mining and machine learning techniques, RegData analyzes the text of federal laws, rules, and norms enacted in the US and Canada to create an index for the number of regulations affecting each industry in each year (Al-Ubaydli and McLaughlin, 2017; McLaughlin and Sherouse, 2019; Quantgov, 2023). Previous adoption of this index can be found, among others, in Martin *et al.* (2018) and Espinosa (2021).

(2) *Industry competition* (H6) was operationalized as 1-Herfindahl–Hirschman index in the base year with the industry defined by the first two-digit SIC code (Lo *et al.*, 2013).

(3) *Supply chain position* (H7) was included as a categorical variable following the approach of Gualandris *et al.* (2021) and Schmidt *et al.* (2017). Two authors independently categorized each firm's position based on its industry, the information available on the company website, and the SEC filings. To ensure rigor and inter-rater reliability, an external researcher was also involved. A four-level scale was developed: "1" raw material suppliers, raw material-related service providers (e.g. contract drilling), utilities; "2" component suppliers, business to business (B2B) service providers; "3" original equipment manufacturers (OEM), service providers addressing both the business and consumer markets (B2B and B2C); "4" distributors, retailers, B2C service providers. In case of a firm operating across multiple lines of business at different positions along the SC, the announcement and publicly available information were analyzed to identify the unit of interest.

Additional variables were added to the model to control for some aspects that could affect the outcomes of BT adoption:

(1) *Firm size* (total assets in the base year, logarithmic transformation to correct for skewness) (Zhan *et al.*, 2021) as the impact may differ between small and large companies (Xiong *et al.*, 2021).

(2) *Year* (year of adoption) (Lo *et al.*, 2014) as BT is a rapidly evolving technology, firms that have implemented it more recently may have more advanced solutions (Ghadge *et al.*, 2022; Liu *et al.*, 2021).

(3) *Capital intensity* (ratio of assets over revenues in the base year) (Su *et al.*, 2015) as more capital-intensive firms are usually characterized by high investment risks and capital layouts and may experience higher benefits from improving the control of operational activities (Ramamurthy *et al.*, 2008).

(4) *Industry efficiency* (median ROA of the industry, first two-digit SIC code) (Podrecca *et al.*, 2022) as the marginal performance improvement may be lower for companies operating in more efficient contexts (Lo *et al.*, 2013).

(5) *Industry size* (total assets of the industry in the base year, first two-digit SIC code, logarithmic transformation to correct for skewness) (Malighetti *et al.*, 2011) as firms in larger industries may gain more benefits from technology adoption (Yiu *et al.*, 2021).

To control for continual influence over time, we also included the *pre-adoption ROA* (operationalized as the ROA in the base year) (Orzes *et al.*, 2017). Dummy variables were added to control for industry heterogeneity (Xiong *et al.*, 2021).

Finally, we included two dummy variables to account for different applications of BT. All projects undertaken by the firms in our sample involved the use of BT in relation to SC business processes. Among these, the literature shows that applications for tracing (upstream) or tracking (downstream) physical products along the SC are prevalent (Nandi *et al.*, 2020; Ahmed *et al.*, 2022); however, the benefits are not clear (Klöckner *et al.*, 2022; Liu *et al.*, 2022). The variable *Physical object* has thus been added to verify the presence of different effects. The other dummy variable considers whether BT included smart contracts as executable software elements (*Smart contracts*). This was motivated by smart contracts offering machine-based automation, with possible effects on performance (Babich and Hilary, 2020; Lumineau *et al.*, 2021). The coding of BT initiatives was performed by two researchers who were involved in the project and an external one.

Table S2 in the online Supporting Material shows the correlation matrix.

5. Results

5.1 BT performance implications

The effects on operational performance were investigated by analyzing the presence of abnormal performance between BT adopters and comparable non-BT adopting firms. For each performance dimension and time interval, Table 2 shows whether the data are normal and/or skewed, the number of observations, the median and mean values of the abnormal performance (AP median, AP mean), and the results of the tests.

The results indicate that, with regard to sales, no statistically significant abnormal performance was found (H1 not supported). With respect to labor productivity, there is a positive and statistically significant abnormal performance in t-2 to t, t to t+2, t-2 to t+1, t-2 to t+2, and t to t+1 (H2 supported). In terms of operating cycle, abnormal performance is negative and significant in t-2 to t, t-2 to t+1, t-2 to t+2, and t-1 to t. This indicates a better performance of BT adopters compared to their peers (H3 supported). To conclude, ROA shows a positive and statistically significant abnormal performance in the following time intervals: t-2 to t-1, t-2 to t, t to t+2, t-2 to t+1, t-2 to t+2, and t+1 to t+2 (H4 supported).

To verify whether the results could be explained by the adoption of BT and were not following a prior trend (i.e. rule out endogeneity issues), we tested for the presence of abnormal performance before the implementation period (i.e. t-3 to t-2) (Podrecca *et al.*, 2022; Orzes *et al.*, 2017; Lo *et al.*, 2014). The results (Table 2) highlight no statistically significant abnormal performance changes in the period t-3 to t-2, but only from t-1 onwards, when the firms entered the event period. This test confirms the absence of systematic biases. Additional robustness tests are available in the online Supporting Material. These were conducted to verify the potential effect of the COVID-19 pandemic, address multiple testing issues, and check for unexpected outcomes associated with BT adoption.

5.2 Contextual factors

Table 3 presents the results of the OLS regression. These indicate that firms belonging to more regulated industries gain superior benefits only in the medium–long-term (i.e. from t-2 to t+2), while no effect is detected in the short-term (i.e. from t-2 to t+1) (H5 partially supported). No statistically significant effect results for industry competition (H6 not supported). The moderating effect of the SC position of the BT-adopting firm is significant and positive (i.e. the closer companies are to the end customer, the better the results from BT adoption) (H7 supported).

With regard to the control variables, the results appear to be negatively affected by the *pre-adoption ROA*. In terms of different applications of BT, we found that smart contracts lead to higher benefits for adopting firms. The variance inflation factors (VIF) were <10 for all the parameters included in the model (Hair *et al.*, 2009); no multicollinearity issues emerged. To further strengthen our findings, we controlled for self-selection through the Heckman two-step estimation approach (Heckman, 1979), ascertained that there was no bias due to the COVID-19 pandemic, and adopted a different approach to operationalize the variable “Supply chain position” (see Supporting Material-Tables S4-S9).

	Period	Normality	Skewness	N	AP mean	AP median	*p*-value (WSR)	*p*-value (Sign test)
Profitability								
Single-year periods	t-3 to t-2	NO	S	126	−0.93%	0.10%	0.676	0.465
	t-2 to t-1	NO	S	128	1.87%	0.77%	0.006***	0.003***
	t-1 to t	NO	S	128	−1.04%	0.19%	0.317	0.213
	t to t+1	NO		128	1.23%	0.48%	0.130	0.092*
	t+1 to t+2	NO	S	118	0.31%	0.39%	0.236	0.048**
Multi-year periods	t-2 to t (adoption window)	NO		128	0.84%	0.87%	0.041**	0.013**
	t to t+2 (post-adoption window)	NO		118	1.23%	0.79%	0.032**	0.010**
	t-2 to t+1 (first-year post-adoption)	NO	S	128	2.07%	1.73%	0.000***	0.000***
	t-2 to t+2 (full event window)	NO	S	118	2.05%	1.99%	0.000***	0.000***
Labor productivity								
Single-year periods	t-3 to t-2	NO	S	120	−2966.39	−885.41	0.544	0.842
	t-2 to t-1	NO	S	120	−16658.61	1809.97	0.065*	0.158
	t-1 to t	NO	S	120	30961.81	719.31	0.149	0.392
	t to t+1	NO	S	120	5766.89	4582.19	0.086*	0.027**
	t+1 to t+2	NO		110	9051.87	4477.23	0.210	0.147
Multi-year periods	t-2 to t (adoption window)	NO		120	14303.20	4730.75	0.021**	0.018**
	t to t+2 (post-adoption window)	NO	S	110	15504.19	9068.78	0.014**	0.003***
	t-2 to t+1 (first-year post-adoption)	NO		120	20070.09	9066.60	0.001***	0.004***
	t-2 to t+2 (full event window)	NO		110	29935.49	14656.81	0.000***	0.000***
Operating cycle								
Single-year periods	t-3 to t-2	NO	S	107	−0.28	1.72	0.916	0.877
	t-2 to t-1	NO	S	111	1.52	−1.19	0.091*	0.171
	t-1 to t	NO	S	109	−6.51	−2.06	0.099*	0.027**
	t to t+1	NO	S	110	−3.67	1.30	0.727	0.805
	t+1 to t+2	NO	S	103	−5.86	1.30	0.532	0.916

(*continued*)

Table 2.
Event study results

	Period	Normality	Skewness	N	AP mean	AP median	p-value (WSR)	p-value (Sign test)
Multi-year periods	t-2 to t (adoption window)	NO	S	110	−7.03	−3.84	0.004***	0.000***
	t to t+2 (post-adoption window)	NO	S	100	0.89	0.96	0.829	0.816
	t-2 to t+1 (first-year post-adoption)	NO		113	−4.64	−3.07	0.023**	0.045**
	t-2 to t+2 (full event window)	NO	S	103	−10.14	−3.21	0.040**	0.005***
Sales performance								
Single-year periods	t-3 to t-2	NO		119	−1.50%	1.27%	0.245	0.136
	t-2 to t-1	NO	S	123	4.71%	−0.92%	0.424	0.765
	t-1 to t	NO		123	−0.86%	−1.30%	0.660	0.706
	t to t+1	NO		123	2.88%	0.04%	0.274	0.500
	t+1 to t+2	NO	S	114	−3.03%	1.53%	0.625	0.200
Multi-year periods	t-2 to t (adoption window)	NO	S	123	3.85%	−0.26%	0.409	0.572
	t to t+2 (post-adoption window)	NO		114	−0.94%	−1.39%	0.596	0.611
	t-2 to t+1 (first-year post-adoption)	NO	S	123	6.74%	0.10%	0.145	0.500
	t-2 to t+2 (full event window)	NO	S	114	3.38%	1.68%	0.257	0.200

Note(s): *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$
Source(s): Author's own creation

Table 2.

5.3 Extension

As H6 was not supported, we posited that — independently from industry competition — BT initiatives initiated by firms' consortia could onboard SC partners more easily than those led by single players, thus generating higher network effects and benefits (Mathivathanan *et al.*, 2021; Schmidt and Wagner, 2019). We developed an analysis including a dummy variable with the value "1" for consortium initiatives and "0" otherwise, as done by Liu *et al.* (2022). No statistically significant effect was found (Table S3 in the online Supporting Material).

6. Discussion, implications, and future research directions

In this study, we have empirically shown how adopting BT to support SC business processes affects operational performance. We analyzed 130 firms listed in North America that,

	OLS regression (n = 128)		
Dependent variable = *ROA (t-2 to t+1)*	Estimated coefficients (Robust standard errors)	Statistical significance	VIF
Independent variables			
Regulation	0.024 (0.040)	0.5516	1.5274
Industry competition	−0.437 (0.854)	0.6096	2.0182
Supply chain position	0.047 (0.014)	0.0012***	1.4788
Control variables			
Firm size	0.022 (0.023)	0.3265	2.1962
Year	0.014 (0.014)	0.3394	1.2435
Pre-adoption ROA	−0.668 (0.318)	0.0379**	2.0022
Capital intensity	−0.002 (0.003)	0.5475	1.4339
Industry efficiency	0.182 (0.353)	0.6068	2.2698
Industry size	−0.023 (0.035)	0.5125	2.8672
Physical object	−0.043 (0.038)	0.2608	1.3697
Smart contract	0.064 (0.035)	0.0747*	1.3680
Industry dummies	Included		
Adjusted R^2	19.69%		

	OLS regression (n = 118)		
Dependent variable = *ROA (t-2 to t+2)*	Estimated coefficients (Robust standard errors)	Statistical significance	VIF
Independent variables			
Regulation	0.053 (0.026)	0.0393**	1.5930
Industry competition	−0.687 (0.434)	0.1163	1.9832
Supply chain position	0.047 (0.014)	0.0008***	1.5755
Control variables			
Firm size	0.005 (0.011)	0.6217	2.3321
Year	−0.006 (0.013)	0.6203	1.1827
Pre-adoption ROA	−0.203 (0.101)	0.0462**	2.0355
Capital intensity	0.000 (0.002)	0.9492	1.6795
Industry efficiency	−0.323 (0.281)	0.2534	2.9306
Industry size	0.006 (0.014)	0.6977	2.8469
Physical object	0.005 (0.029)	0.8725	1.4404
Smart contract	0.046 (0.023)	0.0459**	1.3268
Industry dummies	Included		
Adjusted R^2	15.93%		

Note(s): *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$
Source(s): Author's own creation

Table 3.
OLS analysis results

compared with a control sample of non-adopting firms, displayed significant abnormal performance in terms of labor productivity (H2), operating cycle (H3), and profitability (H4). The hypotheses were built on previous BT research seen through the theoretical lens of TCE. We could not find statistically significant results for sales performance (H1). The hypothesis was formulated assuming that BT-enabled visibility (e.g. product authenticity, process traceability, and performance of the business partner) would imply a reduction in *ex-ante* transaction costs for the customer due to reduced uncertainty (Lumineau *et al.*, 2021; Schmidt and Wagner, 2019). In turn, we posited this to drive buying preferences and justify a price premium (Danese *et al.*, 2021; Rogerson and Parry, 2020). The fact that the hypothesis is not supported can be explained when considering that the use of BT does not guarantee *per se* the veracity of data. A key issue is the need to establish a link between the digital ledger and the physical reality, as incorrect information can be introduced by mistake or by a malicious agent (Peng *et al.*, 2022; Babich and Hilary, 2020). In this sense, provided that the firm publicizes its use of BT, the customer may need the data to be certified.

We also built and tested three hypotheses regarding the contingent factors affecting the relationship between BT adoption and performance. We found stronger effects for firms operating closer to the end customers (H7). The level of regulation in the industry (H5) appeared as a statistically relevant moderator only in the medium–long-term. A possible interpretation is that BT allows easier compliance with standards and regulations (Casino *et al.*, 2021; Schmidt *et al.*, 2017); however, in such contexts, time is needed to align the relevant stakeholders, including institutions (Hastig and Sodhi, 2020).

As we could not confirm any effect with respect to industry competition (H6), we checked whether BT initiatives initiated by consortia were characterized by a better performance than those led by single firms. The reasoning was based on the possibility that partnerships could be more effective in promoting network participation than single players (Schmidt and Wagner, 2019; Mathivathanan *et al.*, 2021). Consistent with the results of Klöckner *et al.* (2022), this additional variable was also not significant. Both the original hypothesis (H6) and this extension assumed that BT is subject to network effects (Hartley *et al.*, 2022; Schmidt and Wagner, 2019). We thus concluded that — at least at the current level of maturity and diffusion (Durach *et al.*, 2021; Klöckner *et al.*, 2022) — the relevance of network effects in determining the value of BT is limited, as firms mostly implement initiatives involving their current supplier/customer base. In this sense, our results suggest that the technical features of BT make it a superior solution to the hitherto available SC software technologies, regardless of the ability of a firm to build cross-industry multi-tier BT platforms. A further element to support this view is that BT proved to be effective independently from the data being shared, whereas we found positive implications due to the use of smart contracts granting higher levels of automation.

6.1 Implications for research

This is one of the first studies to analyze the relationship between BT adoption and operational performance through a secondary data analysis on a large-scale sample of adopters. Since previous research was based mostly on analytical models, expert studies, and case research, this addresses a clear gap. Most importantly, different from extensive studies on stock market reactions (Xiong *et al.*, 2021; Liu *et al.*, 2022; Klöckner *et al.*, 2022), we substantiate BT effects on specific performance dimensions. Our results show statistically significant effects on all investigated measures, except for sales. We explained this through the "garbage in, garbage out" dynamic, namely considering that BT does not ensure the factual credibility of the data (Babich and Hilary, 2020). A similar argument was put forward by Klöckner *et al.* (2022) in relation to lower stock market reactions for initiatives aimed at tracing physical objects. We add to this by specifying that, at this stage, the customer may not perceive a differential value in BT-enabled data sharing. More generally, this contributes to the debate on trust in BT research (e.g. Cole *et al.*, 2019; Treiblmaier, 2018). Whereas in the cryptocurrency domain BT constitutes a "trustless system" (i.e. there is no need to trust network participants as data cannot be forged) (Cole *et al.*, 2019), we confirm that SC applications seem more suited to *trusted networks* where participants are responsible for data veracity.

Our analysis further adds to the current knowledge as it clarifies the effects of three contingencies widely discussed in the literature, but whose implications had not been established. We demonstrate a moderating effect for industry regulation (partially) and the position along the SC of the implementing firm. The fact that neither industry competition nor the early involvement of project partners was found to be a significant moderator was explained through the limited relevance of network effects today, as most BT initiatives are still not launched with an industry-wide ambition (Sauer *et al.*, 2022; Malhotra *et al.*, 2022).

Besides the contributions made to the BT literature, we also add to the broader debate on the value of technology in SCM (e.g. Hill *et al.*, 2018; Hendricks *et al.*, 2007). Research has highlighted the need to address disruptive technologies to identify their potential (Liu *et al.*, 2022). We demonstrate that the effects of BT can be predicted through TCE and CT. This result is significant, considering recent calls toward a sharper understanding of the fit between established theoretical perspectives and the transformative changes brought about by new digital technologies (Hanelt *et al.*, 2021).

6.2 Implications for practice

From a practical standpoint, our analysis makes three important contributions. First, we bridge the gap between narrative and reality by providing solid evidence to corporate decision makers. As performance expectancy drives technology adoption, a greater managerial awareness can help to overcome current skepticism (Kouhizadeh *et al.*, 2021; Fosso Wamba *et al.*, 2020a).

Second, our results for sales performance show that BT is not a substitute for other forms of signaling quality, authenticity, and reliability. Unless automated solutions are adopted (e.g. sensors), BT can only add efficiency to the process of making relevant data available. Their reliability depends instead on the trustworthiness of the business partners. This is relevant when answering the question of "who is paying for it," as firms may consider subsidizing the investment through a price premium on the customer (Ji *et al.*, 2022; Moretto and Macchion, 2022).

Third, we clarify that the benefits can be higher for firms operating in regulated industries (after a time lag) and those closer to the customer. Our results for industry regulation indicate the importance of all relevant stakeholders working on common frameworks.

6.3 Limitations and future research

The findings should be interpreted considering some limitations. First, although an approach based on secondary data provides robust and reliable results, it imposes some restrictions in the considered performance; we could only take into account metrics derived from financial statements. Moreover, the mechanisms through which these performance improvements occur could only be inferred from a theoretical point of view, lacking practical verification. Surveys could be particularly helpful to bridge this gap.

Second, some limitations stem from the choice of the theoretical lenses underpinning this study. We selected TCE as the main theoretical anchor, as its key focus is on the efficient management of exchange transactions that can be impacted using BT as a new kind of transactional database. The integration of CT helped us to address some limitations of the theory by considering the moderating effects of some relevant contextual variables. Of course, the choice of theory is a question of fit: other lenses could be applied to certain aspects, but it is important to select the one that provides the clearest and most comprehensive explanation of the issue at hand. Under this premise, future studies can leverage other theories for investigations targeted at clarifying specific points. For example, as PAT focuses on the optimal contract form to control a relationship, it would be interesting to sample only projects that use BT as the basis of smart contract implementation to investigate their effectiveness.

Third, although the focus on firms listed in North America was methodologically justified by the need to retrieve comparable and reliable financial data, it reduces the generalizability of the findings. The outcomes for sales performance may depend on the considered geographical setting, particularly given the differences in the level of BT adoption and awareness (GVR, 2020). Future studies could verify the results in other contexts. This is particularly relevant given the challenges of operating in emerging markets (Liu *et al.*, 2022) and the existence of different regulations affecting data handling (Klöckner *et al.*, 2022; Rogerson and Parry, 2020). In doing this, researchers should consider the penetration of BT in the country of interest. This is because it may prevent the identification of adequately sized samples (GVR, 2020), the availability of reliable and comparable financial data (many studies have used secondary data for Chinese companies, whereas this is not the case for other emerging countries) (e.g. Chen *et al.*, 2023; Liu *et al.*, 2022, Shou *et al.*, 2021; Yang *et al.*, 2021), and the need to deal with announcements and databases in local languages. Depending on these challenges, surveys can also represent a viable approach.

Another limitation stems from the point in time when our research was conducted. In the future, it will be possible to investigate the impact of BT over a longer timeframe. Moreover, further research will be needed as technology standardization moves forward and more and more BT initiatives evolve toward multi-tier industry-wide platforms (Sauer *et al.*, 2022; Malhotra *et al.*, 2022). Should network effects become crucial, the sources of value creation may be substantially different (Hastig and Sodhi, 2020).

Finally, although we considered the possible effects of different applications, there are opportunities to further investigate this aspect. For example, some studies have classified BT initiatives based on the aim (tracking, tracing, process efficiency, and service provision) (Nandi *et al.*, 2020; Ahmed *et al.*, 2022) and scope (upstream/downstream and multi-tier/single-tier/internal) (Sauer *et al.*, 2022). Given the current diffusion of BT, it was challenging for us to find the numbers to test a typology. As firms increasingly implement BT initiatives with different aims/scope, there will be growing opportunities for a more nuanced view.

Notes

1. The Cambridge Dictionary (2023) defines regulations as "*an official rule or the act of controlling something*".
2. Long-term event studies concern the analysis of abnormal performance upon an "event" over the timeframe of multiple calendar periods (i.e. quarters or years). The analysis may consider both stock market indicators and accounting-based measures, whereas short-term event studies address only stock market returns over a maximum period of 40 days (Ding *et al.*, 2018).
3. An alternative approach would have been propensity score matching; however, recent studies have criticized this technique (e.g. Siqueira *et al.*, 2018) as it enhances "*imbalance, inefficiency, model dependence, and bias*" (King and Nielsen, 2019, p. 1).

References

Ahmed, W.A., MacCarthy, B.L. and Treiblmaier, H. (2022), "Why, where and how are organizations using blockchain in their supply chains?", *International Journal of Operations and Production Management*, Vol. 42 No. 12, pp. 1995-2028, doi: 10.1108/ijopm-12-2021-0805.

Al-Ubaydli, O. and McLaughlin, P.A. (2017), "RegData: a numerical database on industry-specific regulations for all United States industries", *Regulation and Governance*, Vol. 11 No. 1, pp. 109-123, doi: 10.1111/rego.12107.

Babich, V. and Hilary, G. (2020), "Distributed ledgers and operations: what operations management researchers should know about blockchain", *Manufacturing and Service Operations Management*, Vol. 22 No. 2, pp. 223-240, doi: 10.1287/msom.2018.0752.

Bag, S., Rahman, M.S., Gupta, S. and Wood, L.C. (2022), "Understanding and predicting the determinants of blockchain technology adoption", *The International Journal of Logistics Management*, Vol. 34 No. 6, pp. 1781-1807, doi: 10.1108/ijlm-01-2022-0017.

Bai, C. and Sarkis, J. (2020), "A supply chain transparency appraisal model for blockchain technology", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2142-2162, doi: 10.1080/00207543.2019.1708989.

Bala, H. and Venkatesh, V. (2007), "Assimilation of interorganizational business process standards", *Information Systems Research*, Vol. 18 No. 3, pp. 340-362, doi: 10.1287/isre.1070.0134.

Barber, B.M. and Lyon, J.D. (1996), "Detecting abnormal operating performance: the empirical power of test statistics", *Journal of Financial Economics*, Vol. 41 No. 3, pp. 359-399, doi: 10.1016/0304-405x(96)84701-5.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99-120, doi: 10.1177/014920639101700108.

Bode, C. and Wagner, S.M. (2015), "Structural drivers of upstream supply chain complexity and the frequency of disruptions", *Journal of Operations Management*, Vol. 36 No. 1, pp. 215-228, doi: 10.1016/j.jom.2014.12.004.

Buttermann, G., Germain, R. and Iyer, K.N. (2008), "Contingency theory 'fit' as gestalt: an application to supply chain management", *Transportation Research Part E*, Vol. 44 No. 6, pp. 955-969, doi: 10.1016/j.tre.2007.05.012.

Buysse, K. and Verbeke, A. (2003), "Proactive environmental strategies: a stakeholder perspective", *Strategic Management Journal*, Vol. 24 No. 5, pp. 453-470, doi: 10.1002/smj.299.

Cahill, D., Baur, D.G., Liu, Z.F. and Yang, J.W. (2020), "I am a blockchain too", *Journal of Banking and Finance*, Vol. 113, 105740, doi: 10.1016/j.jbankfin.2020.105740.

Cambridge dictionary (2023), "Regulation", available at: https://dictionary.cambridge.org/dictionary/english/regulation (accessed 16 October 2023).

Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S., Stachtiaris, S., Pagoni, M. and Rachaniotis, N.P. (2021), "Blockchain-based food supply chain traceability", *International Journal of Production Research*, Vol. 59 No. 19, pp. 5758-5770, doi: 10.1080/00207543.2020.1789238.

Cecere, L. (2022), "Tradelens discontinues operations. Why you should care", *Forbes*, available at: https://www.forbes.com/sites/loracecere/2022/12/05/tradelens-discontinues-operations-why-you-should-care/?sh=5b5829204cec (accessed 11 February 2023).

Centobelli, P., Cerchione, R., Esposito, E. and Oropallo, E. (2021), "Surfing blockchain wave, or drowning?", *Technological Forecasting and Social Change*, Vol. 165, 120463, doi: 10.1016/j.techfore.2020.120463.

Chang, Y., Iakovou, E. and Shi, W. (2020), "Blockchain in global supply chains and cross border trade", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2082-2099, doi: 10.1080/00207543.2019.1651946.

Chen, L., Li, T., Jia, F. and Schoenherr, T. (2023), "The impact of governmental COVID-19 measures on manufacturers' stock market valuations", *Journal of Operations Management*, Vol. 69 No. 3, pp. 404-425, doi: 10.1002/joom.1207.

Cheng, S.F., De Franco, G., Jiang, H. and Lin, P. (2019), "Riding the blockchain mania", *Management Science*, Vol. 65 No. 12, pp. 5901-5913, doi: 10.1287/mnsc.2019.3357.

Chod, J., Trichakis, N., Tsoukalas, G., Aspegren, H. and Weber, M. (2020), "On the financing benefits of blockchain adoption", *Management Science*, Vol. 66 No. 10, pp. 4378-4396, doi: 10.1287/mnsc.2019.3434.

Cole, R., Stevenson, M. and Aitken, J. (2019), "Blockchain technology: implications for operations and supply chain management", *Supply Chain Management*, Vol. 24 No. 4, pp. 469-483, doi: 10.1108/scm-09-2018-0309.

Corbett, C.J., Montes-Sancho, M.J. and Kirsch, D.A. (2005), "The financial impact of ISO 9000 certification in the United States", *Management Science*, Vol. 51 No. 7, pp. 1046-1059, doi: 10.1287/mnsc.1040.0358.

Danese, P., Mocellin, R. and Romano, P. (2021), “Designing blockchain systems to prevent counterfeiting in wine supply chains”, *International Journal of Operations and Production Management*, Vol. 41 No. 13, pp. 1-33, doi: 10.1108/ijopm-12-2019-0781.

De Jong, P., Paulraj, A. and Blome, C. (2014), “The financial impact of ISO 14001 certification: top-line, bottom-line, or both?”, *Journal of Business Ethics*, Vol. 119 No. 1, pp. 131-149, doi: 10.1007/s10551-012-1604-z.

Ding, L., Lam, H.K., Cheng, T.C.E. and Zhou, H. (2018), “A review of short-term event studies in operations and supply chain management”, *International Journal of Production Economics*, Vol. 200, pp. 329-342, doi: 10.1016/j.ijpe.2018.04.006.

Donaldson, L. (1987), “Strategy and structural adjustment to regain fit and performance”, *Journal of Management Studies*, Vol. 24 No. 1, pp. 1-24, doi: 10.1111/j.1467-6486.1987.tb00444.x.

Dong, S., Xu, S.X. and Zhu, K.X. (2009), “Information technology in supply chains: the value of it-enabled resources”, *Information Systems Research*, Vol. 20 No. 1, pp. 18-32, doi: 10.1287/isre.1080.0195.

Durach, C.F., Blesik, T., von Düring, M. and Bick, M. (2021), “Blockchain applications in supply chain transactions”, *Journal of Business Logistics*, Vol. 42 No. 1, pp. 7-24, doi: 10.1111/jbl.12238.

Ellram, L.M., Tate, W.L. and Billington, C. (2008), “Offshore outsourcing of professional services”, *Journal of Operations Management*, Vol. 26 No. 2, pp. 148-163, doi: 10.1016/j.jom.2007.02.008.

Enrique, D.V., Lerman, L.V., de Sousa, P.R., Benitez, G.B., Santos, F.M.B.C. and Frank, A.G. (2022), “Being digital and flexible to navigate the storm”, *International Journal of Production Economics*, Vol. 250, 108668, doi: 10.1016/j.ijpe.2022.108668.

Espinosa, M. (2021), “Labor boundaries and skills: the case of lobbyists”, *Management Science*, Vol. 67 No. 3, pp. 1586-1607, doi: 10.1287/mnsc.2020.3598.

Fosso Wamba, S., Queiroz, M.M. and Trinchera, L. (2020a), “Dynamics between blockchain adoption determinants and supply chain performance”, *International Journal of Production Economics*, Vol. 229, 107791, doi: 10.1016/j.ijpe.2020.107791.

Fosso Wamba, S., Kala Kamdjoug, J.R., Epie Bawack, R. and Keogh, J.G. (2020b), “Bitcoin, blockchain and fintech”, *Production Planning and Control*, Vol. 31 Nos 2-3, pp. 115-142, doi: 10.1080/09537287.2019.1631460.

Ghadge, A., Bourlakis, M., Kamble, S. and Seuring, S. (2022), “Blockchain implementation in pharmaceutical supply chains”, *International Journal of Production Research*, Vol. 61 No. 19, pp. 6633-6651, doi: 10.1080/00207543.2022.2125595.

Gong, Y., Xie, S., Arunachalam, D., Duan, J. and Luo, J. (2022), “Blockchain-based recycling and its impact on recycling performance”, *Business Strategy and the Environment*, Vol. 31 No. 8, pp. 3717-3741, doi: 10.1002/bse.3028.

Grover, V. and Malhotra, M.K. (2003), “Transaction cost framework in operations and supply chain management research”, *Journal of Operations Management*, Vol. 21 No. 4, pp. 457-473, doi: 10.1016/s0272-6963(03)00040-8.

Gualandris, J., Longoni, A., Luzzini, D. and Pagell, M. (2021), “The association between supply chain structure and transparency”, *Journal of Operations Management*, Vol. 67 No. 7, pp. 803-827, doi: 10.1002/joom.1150.

Gupta, H., Kumar, S., Kusi-Sarpong, S., Jabbour, C.J.C. and Agyemang, M. (2020), “Enablers to supply chain performance on the basis of digitization technologies”, *Industrial Management and Data Systems*, Vol. 121 No. 9, pp. 1915-1938, doi: 10.1108/imds-07-2020-0421.

GVR (2020), “Global blockchain technology market size, share, and trends analysis report, 2019-2025”, available at: https://www.grandviewresearch.com/industry-analysis/blockchain-technology-market (accessed 21 December 2022).

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2009), *Multivariate Data Analysis*, Pearson, Upper Saddle River.

Hakansson, L. (1987), *Industrial Technological Development: A Network Approach*, Croom Helm, Uppsala.

Halldorsson, A., Kotzab, H., Mikkola, J.H. and Skjøtt-Larsen, T. (2007), "Complementary theories to supply chain management", *Supply Chain Management*, Vol. 12 No. 4, pp. 284-296, doi: 10.1108/13598540710759808.

Hanelt, A., Bohnsack, R., Marz, D. and Antunes Marante, C. (2021), "A systematic review of the literature on digital transformation", *Journal of Management Studies*, Vol. 58 No. 5, pp. 1159-1197, doi: 10.1111/joms.12639.

Hartley, J.L., Sawaya, W. and Dobrzykowski, D. (2022), "Exploring blockchain adoption intentions in the supply chain: perspectives from innovation diffusion and institutional theory", *International Journal of Physical Distribution and Logistics Management*, Vol. 52 No. 2, pp. 190-211, doi: 10.1108/ijpdlm-05-2020-0163.

Hastig, G.M. and Sodhi, M.S. (2020), "Blockchain for supply chain traceability: business requirements and success factors", *Production and Operations Management*, Vol. 29 No. 4, pp. 935-954, doi: 10.1111/poms.13147.

Heckman, J.J. (1979), "Sample selection bias as a specification error", *Econometrica: Journal of the Econometric Society*, Vol. 47 No. 1, pp. 153-161, doi: 10.2307/1912352.

Hendricks, K.B., Singhal, V.R. and Stratman, J.K. (2007), "The impact of enterprise systems on corporate performance", *Journal of Operations Management*, Vol. 25 No. 1, pp. 65-82, doi: 10.1016/j.jom.2006.02.002.

Hill, C.A., Zhang, G.P. and Miller, K.E. (2018), "Collaborative planning, forecasting, and replenishment and firm performance", *International Journal of Production Economics*, Vol. 196, pp. 12-23, doi: 10.1016/j.ijpe.2017.11.012.

Hong, L. and Hales, D.N. (2021), "Blockchain performance in supply chain management", *Industrial Management and Data Systems*, Vol. 121 No. 9, pp. 1969-1996, doi: 10.1108/imds-10-2020-0598.

Iannarelli, J.G. and O'Shaughnessy, M. (2014), *Information Governance and Security*, Elsevier, Oxford.

Iansiti, M. and Lakhani, K.R. (2017), "The truth about blockchain", *Harvard Business Review*, Vol. 95 No. 1, pp. 118-127.

Jelinek, M. (1977), "Technology, organizations, and contingency", *Academy of Management Review*, Vol. 2 No. 1, pp. 17-26, doi: 10.5465/amr.1977.4409151.

Jensen, M.C. and Meckling, W.H. (1976), "Theory of the firm: managerial behavior, agency costs and ownership structure", *Journal of Financial Economics*, Vol. 3 No. 4, pp. 305-360, doi: 10.1016/0304-405x(76)90026-x.

Ji, G., Zhou, S., Lai, K.H., Tan, K.H. and Kumar, A. (2022), "Timing of blockchain adoption in a supply chain with competing manufacturers", *International Journal of Production Economics*, Vol. 247, 108430, doi: 10.1016/j.ijpe.2022.108430.

Jia, F., Gong, Y. and Brown, S. (2019), "Multi-tier sustainable supply chain management", *International Journal of Production Economics*, Vol. 217, pp. 44-63, doi: 10.4337/9781786434272.00035.

Kalmenovitz, J. (2023), "Regulatory intensity and firm-specific exposure", *The Review of Financial Studies*, Vol. 36 No. 8, pp. 3311-3347, doi: 10.1093/rfs/hhad001.

Karakas, S., Acar, A.Z. and Kucukaltan, B. (2021), "Blockchain adoption in logistics and supply chain", *International Journal of Production Research*, pp. 1-24 (In press), doi: 10.1080/00207543.2021.2012613.

Ketokivi, M. (2006), "Elaborating the contingency theory of organizations: the case of manufacturing flexibility strategies", *Production and Operations Management*, Vol. 15 No. 2, pp. 215-228, doi: 10.1111/j.1937-5956.2006.tb00241.x.

Ketokivi, M. and Mahoney, J.T. (2020), "Transaction cost economics as a theory of supply chain efficiency", *Production and Operations Management*, Vol. 29 No. 4, pp. 1011-1031, doi: 10.1111/poms.13148.

King, G. and Nielsen, R. (2019), "Why propensity scores should not be used for matching", *Political Analysis*, Vol. 27 No. 4, pp. 435-454, doi: 10.1017/pan.2019.11.

Klöckner, M., Schmidt, C.G. and Wagner, S.M. (2022), "When blockchain creates shareholder value", *Production and Operations Management*, Vol. 31 No. 1, pp. 46-64, doi: 10.1111/poms.13609.

Konchitchki, Y. and O'Leary, D.E. (2011), "Event study methodologies in information systems research", *International Journal of Accounting Information Systems*, Vol. 12 No. 2, pp. 99-115, doi: 10.1016/j.accinf.2011.01.002.

Kopyto, M., Lechler, S., Heiko, A. and Hartmann, E. (2020), "Potentials of blockchain technology in supply chain management", *Technological Forecasting and Social Change*, Vol. 161, 120330, doi: 10.1016/j.techfore.2020.120330.

Kouhizadeh, M., Saberi, S. and Sarkis, J. (2021), "Blockchain technology and the sustainable supply chain", *International Journal of Production Economics*, Vol. 231, 107831, doi: 10.1016/j.ijpe.2020.107831.

Lam, H.K., Ding, L., Cheng, T.C.E. and Zhou, H. (2019), "The impact of 3D printing implementation on stock returns", *International Journal of Operations and Production Management*, Vol. 39 Nos 6/7/8, pp. 935-961, doi: 10.1108/ijopm-01-2019-0075.

Lawrence, P.R. and Lorsch, J.W. (1967), "Differentiation and integration in complex organizations", *Administrative Science Quarterly*, Vol. 12 No. 1, pp. 1-47, doi: 10.2307/2391211.

Li, S., Shang, J. and Slaughter, S.A. (2010), "Why do software firms fail? Capabilities, competitive actions, and firm survival in the software industry", *Information Systems Research*, Vol. 21 No. 3, pp. 631-654, doi: 10.1287/isre.1100.0281.

Li, K., Lee, J.Y. and Gharehgozli, A. (2021), "Blockchain in food supply chains", *International Journal of Production Research*, Vol. 61 No. 11, pp. 3527-3546, doi: 10.1080/00207543.2021.1970849.

Li, G., Xue, J., Li, N. and Ivanov, D. (2022), "Blockchain-supported business model design, supply chain resilience, and firm performance", *Transportation Research Part E*, Vol. 163, 102773, doi: 10.1016/j.tre.2022.102773.

Liu, J., Zhang, H. and Zhen, L. (2021), "Blockchain technology in maritime supply chains", *International Journal of Production Research*, Vol. 61 No. 11, pp. 3547-3563, doi: 10.1080/00207543.2021.1930239.

Liu, W., Wang, J., Jia, F. and Choi, T.M. (2022), "Blockchain announcements and stock value", *International Journal of Operations and Production Management*, Vol. 42 No. 5, pp. 713-742, doi: 10.1108/ijopm-08-2021-0534.

Lo, C.K., Yeung, A.C. and Cheng, T.C.E. (2009), "ISO 9000 and supply chain efficiency", *International Journal of Production Economics*, Vol. 118 No. 2, pp. 367-374, doi: 10.1016/j.ijpe.2008.11.010.

Lo, C.K., Wiengarten, F., Humphreys, P., Yeung, A.C. and Cheng, T.C.E. (2013), "The impact of contextual factors on the efficacy of ISO 9000 adoption", *Journal of Operations Management*, Vol. 31 No. 5, pp. 229-235, doi: 10.1016/j.jom.2013.04.002.

Lo, C.K., Pagell, M., Fan, D., Wiengarten, F. and Yeung, A.C. (2014), "OHSAS 18001 certification and operating performance", *Journal of Operations Management*, Vol. 32 No. 5, pp. 268-280, doi: 10.1016/j.jom.2014.04.004.

Lumineau, F., Wang, W. and Schilke, O. (2021), "Blockchain governance—a new way of organizing collaborations?", *Organization Science*, Vol. 32 No. 2, pp. 500-521, doi: 10.1287/orsc.2020.1379.

Malhotra, A., O'Neill, H. and Stowell, P. (2022), "Thinking strategically about blockchain adoption and risk mitigation", *Business Horizons*, Vol. 65 No. 2, pp. 159-171, doi: 10.1016/j.bushor.2021.02.033.

Malighetti, P., Meoli, M., Paleari, S. and Redondi, R. (2011), "Value determinants in the aviation industry", *Transportation Research Part E*, Vol. 47 No. 3, pp. 359-370, doi: 10.1016/j.tre.2010.11.007.

Markus, S. and Buijs, P. (2022), "Beyond the hype: how blockchain affects supply chain performance", *Supply Chain Management*, Vol. 27 No. 7, pp. 177-193, doi: 10.1108/scm-03-2022-0109.

Martin, K.D., Josephson, B.W., Vadakkepatt, G.G. and Johnson, J.L. (2018), "Political management, research and development, and advertising capital in the pharmaceutical industry: a good prognosis?", *Journal of Marketing*, Vol. 82 No. 3, pp. 87-107, doi: 10.1509/jm.15.0297.

Mathivathanan, D., Mathiyazhagan, K., Rana, N.P., Khorana, S. and Dwivedi, Y.K. (2021), "Barriers to the adoption of blockchain technology in business supply chains", *International Journal of Production Research*, Vol. 59 No. 11, pp. 3338-3359, doi: 10.1080/00207543.2020.1868597.

McLaughlin, P.A. and Sherouse, O. (2019), "RegData 2.2: a panel dataset on US federal regulations", *Public Choice*, Vol. 180 Nos 1-2, pp. 43-55, doi: 10.1007/s11127-018-0600-y.

McWilliams, A. and Siegel, D. (1997), "Event studies in management research", *Academy of Management Journal*, Vol. 40 No. 3, pp. 626-657, doi: 10.2307/257056.

Melville, N., Gurbaxani, V. and Kraemer, K. (2007), "The productivity impact of information technology across competitive regimes", *Decision Support Systems*, Vol. 43 No. 1, pp. 229-242, doi: 10.1016/j.dss.2006.09.009.

Mena, C., Humphries, A. and Choi, T.Y. (2013), "Toward a theory of multi-tier supply chain management", *Journal of Supply Chain Management*, Vol. 49 No. 2, pp. 58-77, doi: 10.1111/jscm.12003.

Mikalef, P., Pateli, A., Batenburg, R.S. and Wetering, R.V.D. (2015), "Purchasing alignment under multiple contingencies", *Industrial Management and Data Systems*, Vol. 115 No. 4, pp. 625-645, doi: 10.1108/imds-10-2014-0298.

Moretto, A. and Macchion, L. (2022), "Drivers, barriers and supply chain variables influencing the adoption of the blockchain to support traceability", *Operations Management Research*, Vol. 15 Nos 3-4, pp. 1470-1489, doi: 10.1007/s12063-022-00262-y.

Muir, M. (2022), *Case for Blockchain in Financial Services Dented by Failures*, Financial Times, available at: https://www.ft.com/content/cb606604-a89c-4746-9524-e1833cd4973e (accessed 11 February 2023).

Müßigmann, B., von der Gracht, H. and Hartmann, E. (2020), "Blockchain technology in logistics and supply chain management", *IEEE Transactions on Engineering Management*, Vol. 67 No. 4, pp. 988-1007, doi: 10.1109/tem.2020.2980733.

Nakamoto, S. (2008), "Bitcoin: a peer-to-peer electronic cash system", *Decentralized Business Review*, 21260.

Nandi, M.L., Nandi, S., Moya, H. and Kaynak, H. (2020), "Blockchain technology-enabled supply chain systems and supply chain performance", *Supply Chain Management*, Vol. 25 No. 6, pp. 841-862, doi: 10.1108/scm-12-2019-0444.

Nelson, K.K., Price, R.A. and Rountree, B.R. (2008), "The market reaction to Arthur Andersen's role in the Enron scandal: loss of reputation or confounding effects?", *Journal of Accounting and Economics*, Vol. 46 Nos 2-3, pp. 279-293, doi: 10.1016/j.jacceco.2008.09.001.

North, D.C. (1992), *Transaction Costs, Institutions, and Economic Performance*, ICS Press, San Francisco.

Oliver, C. (1990), "Determinants of interorganizational relationships: integration and future directions", *Academy of Management Review*, Vol. 15 No. 2, pp. 241-265, doi: 10.2307/258156.

Orzes, G., Jia, F., Sartor, M. and Nassimbeni, G. (2017), "Performance implications of SA8000 certification", *International Journal of Operations and Production Management*, Vol. 37 No. 11, pp. 1625-1653, doi: 10.1108/ijopm-12-2015-0730.

Orzes, G., Moretto, A.M., Moro, M., Rossi, M., Sartor, M., Caniato, F. and Nassimbeni, G. (2020), "The impact of the United Nations global compact on firm performance", *International Journal of Production Economics*, Vol. 227, 107664, doi: 10.1016/j.ijpe.2020.107664.

Paul, T., Mondal, S., Islam, N. and Rakshit, S. (2021), "The impact of blockchain technology on the tea supply chain and its sustainable performance", *Technological Forecasting and Social Change*, Vol. 173, 121163, doi: 10.1016/j.techfore.2021.121163.

Peng, Y., Chen, X. and Wang, X. (2022), "Enhancing supply chain flows through blockchain", *International Journal of Production Research*, Vol. 61 No. 13, pp. 4503-4524, doi: 10.1080/00207543.2022.2157064.

Pilbeam, C., Alvarez, G. and Wilson, H. (2012), "The governance of supply networks: a systematic literature review", *Supply Chain Management: An International Journal*, Vol. 17 No. 4, pp. 358-376, doi: 10.1108/13598541211246512.

Podrecca, M., Culot, G., Nassimbeni, G. and Sartor, M. (2022), "Information security and value creation", *Computers in Industry*, Vol. 142, 103744, doi: 10.1016/j.compind.2022.103744.

Poppo, L. and Zenger, T. (2002), "Do formal contracts and relational governance function as substitutes or complements?", *Strategic Management Journal*, Vol. 23 No. 8, pp. 707-725, doi: 10.1002/smj.249.

Pournader, M., Shi, Y., Seuring, S. and Koh, S.L. (2020), "Blockchain applications in supply chains, transport and logistics", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2063-2081, doi: 10.1080/00207543.2019.1650976.

Quantgov (2023), "RegData", available at: https://www.quantgov.org/ (accessed 16 October 2023).

Queiroz, M.M., Fosso Wamba, S., De Bourmont, M. and Telles, R. (2021), "Blockchain adoption in operations and supply chain management", *International Journal of Production Research*, Vol. 59 No. 20, pp. 6087-6103, doi: 10.1080/00207543.2020.1803511.

Raguseo, E., Vitari, C. and Pigni, F. (2020), "Profiting from big data analytics", *International Journal of Production Economics*, Vol. 229, 107758, doi: 10.1016/j.ijpe.2020.107758.

Ramamurthy, K.R., Sen, A. and Sinha, A.P. (2008), "An empirical investigation of the key determinants of data warehouse adoption", *Decision Support Systems*, Vol. 44 No. 4, pp. 817-841, doi: 10.1016/j.dss.2007.10.006.

Rindfleisch, A. and Heide, J.B. (1997), "Transaction cost analysis: past, present, and future applications", *Journal of Marketing*, Vol. 61 No. 4, pp. 30-54, doi: 10.2307/1252085.

Roeck, D., Sternberg, H. and Hofmann, E. (2020), "Distributed ledger technology in supply chains", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2124-2141, doi: 10.1080/00207543.2019.1657247.

Rogerson, M. and Parry, G.C. (2020), "Blockchain: case studies in food supply chain visibility", *Supply Chain Management*, Vol. 25 No. 5, pp. 601-614, doi: 10.1108/scm-08-2019-0300.

Sambamurthy, V. and Zmud, R.W. (1999), "Arrangements for information technology governance", *MIS Quarterly*, Vol. 23 No. 2, pp. 261-290, doi: 10.2307/249754.

Sauer, P.C., Orzes, G. and Culot, G. (2022), "Blockchain in supply chain management", *Production Planning and Control*, pp. 1-16 (In press), doi: 10.1080/09537287.2022.2153078.

Schmidt, C.G. and Wagner, S.M. (2019), "Blockchain and supply chain relations", *Journal of Purchasing and Supply Management*, Vol. 25 No. 4, 100552, doi: 10.1016/j.pursup.2019.100552.

Schmidt, C.G., Foerstl, K. and Schaltenbrand, B. (2017), "The supply chain position paradox", *Journal of Supply Chain Management*, Vol. 53 No. 1, pp. 3-25, doi: 10.1111/jscm.12113.

Sharma, P., Shukla, D.M. and Raj, A. (2023), "Blockchain adoption and firm performance: the contingent roles of intangible capital and environmental dynamism", *International Journal of Production Economics*, Vol. 256, 108727, doi: 10.1016/j.ijpe.2022.108727.

Shou, Y., Shao, J. and Wang, W. (2021), "How does reverse factoring affect operating performance?", *International Journal of Operations and Production Management*, Vol. 41 No. 4, pp. 289-312, doi: 10.1108/ijopm-07-2020-0469.

Simon, H.A. (1985), *Models of Man: Social and Rational*, Wiley, New York.

Siqueira, A.C.O., Guenster, N., Vanacker, T. and Crucke, S. (2018), "A longitudinal comparison of capital structure between young for-profit social and commercial enterprises", *Journal of Business Venturing*, Vol. 33 No. 2, pp. 225-240, doi: 10.1016/j.jbusvent.2017.12.006.

Sodero, A.C., Rabinovich, E. and Sinha, R.K. (2013), "Drivers and outcomes of open-standard interorganizational information systems assimilation in high-technology supply chains", *Journal of Operations Management*, Vol. 31 No. 6, pp. 330-344, doi: 10.1016/j.jom.2013.07.008.

Sodhi, M.S., Seyedghorban, Z., Tahernejad, H. and Samson, D. (2022), "Why emerging supply chain technologies initially disappoint: blockchain, IoT, and AI", *Production and Operations Management*, Vol. 31 No. 6, pp. 2517-2537, doi: 10.1111/poms.13694.

Søgaard, B., Skipworth, H.D., Bourlakis, M., Mena, C. and Wilding, R. (2018), "Facing disruptive technologies", *Supply Chain Management*, Vol. 24 No. 1, pp. 147-169.

Sorescu, A. (2017), "Data-driven business model innovation", *Journal of Product Innovation Management*, Vol. 34 No. 5, pp. 691-696, doi: 10.1111/jpim.12398.

Srinivasan, R. and Swink, M. (2018), "An investigation of visibility and flexibility as complements to supply chain analytics", *Production and Operations Management*, Vol. 27 No. 10, pp. 1849-1867, doi: 10.1111/poms.12746.

Su, H.C., Dhanorkar, S. and Linderman, K. (2015), "A competitive advantage from the implementation timing of ISO management standards", *Journal of Operations Management*, Vol. 37 No. 1, pp. 31-44, doi: 10.1016/j.jom.2015.03.004.

Swink, M. and Jacobs, B.W. (2012), "Six Sigma adoption: operating performance impacts and contextual drivers of success", *Journal of Operations Management*, Vol. 30 No. 6, pp. 437-453, doi: 10.1016/j.jom.2012.05.001.

Tan, C.L., Tei, Z., Yeo, S.F., Lai, K.H., Kumar, A. and Chung, L. (2023), "Nexus among blockchain visibility, supply chain integration and supply chain performance in the digital transformation era", *Industrial Management and Data Systems*, Vol. 123 No. 1, pp. 229-252, doi: 10.1108/imds-12-2021-0784.

Tian, X., Zhu, J., Zhao, X. and Wu, J. (2022), "Improving operational efficiency through blockchain: evidence from a field experiment in cross-border trade", *Production Planning and Control*, pp. 1-16 (In press), doi: 10.1080/09537287.2022.2058412.

Treacy, R., Humphreys, P., McIvor, R. and Lo, C. (2019), "ISO14001 certification and operating performance", *International Journal of Production Economics*, Vol. 208, pp. 319-328, doi: 10.1016/j.ijpe.2018.12.012.

Treiblmaier, H. (2018), "The impact of the blockchain on the supply chain", *Supply Chain Management*, Vol. 23 No. 6, pp. 545-559, doi: 10.1108/scm-01-2018-0029.

Tse, Y.K., Wang, S., Liu, X. and Wu, C.H. (2023), "Untangling operational performance implication of ambidextrous blockchain initiatives", *Industrial Management and Data Systems*, Vol. 123 No. 2, pp. 556-577, doi: 10.1108/imds-05-2022-0298.

Van Hoek, R. (2019), "Exploring blockchain implementation in the supply chain: learning from pioneers and RFID research", *International Journal of Operations and Production Management*, Vol. 39 Nos 6/7/8, pp. 829-859, doi: 10.1108/ijopm-01-2019-0022.

Wacker, J.G., Yang, C. and Sheu, C. (2016), "A transaction cost economics model for estimating performance effectiveness of relational and contractual governance: theory and statistical results", *International Journal of Operations and Production Management*, Vol. 36 No. 11, pp. 1551-1575, doi: 10.1108/ijopm-10-2013-0470.

Wang, Y., Han, J.H. and Beynon-Davies, P. (2019), "Understanding blockchain technology for future supply chains", *Supply Chain Management*, Vol. 24 No. 1, pp. 62-84, doi: 10.1108/scm-03-2018-0148.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, Vol. 5 No. 2, pp. 171-180, doi: 10.1002/smj.4250050207.

Williamson, O.E. (1985), *The Economic Institutions of Capitalism. Firms, Markets, Relational Contracting*, Gabler, New York.

Williamson, O.E. (1987), "Transaction cost economics: the comparative contracting perspective", *Journal of Economic Behavior and Organization*, Vol. 8 No. 4, pp. 617-625, doi: 10.1016/0167-2681(87)90038-2.

Williamson, O.E. (1996), *The Mechanisms of Governance*, Oxford University Press, Oxford.

Wong, L.W., Tan, G.W.H., Lee, V.H., Ooi, K.B. and Sohal, A. (2020), "Unearthing the determinants of Blockchain adoption in supply chain management", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2100-2123, doi: 10.1080/00207543.2020.1730463.

Xie, S., Gong, Y., Kunc, M., Wen, Z. and Brown, S. (2022), "The application of blockchain technology in the recycling chain", *International Journal of Production Research*, Vol. 61 No. 24, pp. 8692-8718, doi: 10.1080/00207543.2022.2152506.

Xiong, Y., Lam, H.K., Kumar, A., Ngai, E.W., Xiu, C. and Wang, X. (2021), "The mitigating role of blockchain-enabled supply chains during the COVID-19 pandemic", *International Journal of Operations and Production Management*, Vol. 41 No. 9, pp. 1495-1521, doi: 10.1108/ijopm-12-2020-0901.

Yang, Y., Jia, F., Chen, L., Wang, Y. and Xiong, Y. (2021), "Adoption timing of OHSAS 18001 and firm performance", *International Journal of Production Economics*, Vol. 231, 107870, doi: 10.1016/j.ijpe.2020.107870.

Yiu, L.D., Yeung, A.C. and Cheng, T.C.E. (2021), "The impact of business intelligence systems on profitability and risks of firms", *International Journal of Production Research*, Vol. 59 No. 13, pp. 3951-3974, doi: 10.1080/00207543.2020.1756506.

Yoon, J., Talluri, S., Yildiz, H. and Sheu, C. (2020), "The value of Blockchain technology implementation in international trades under demand volatility risk", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2163-2183, doi: 10.1080/00207543.2019.1693651.

Zaki, M. (2019), "Digital transformation: harnessing digital technologies for the next generation of services", *Journal of Services Marketing*, Vol. 33 No. 4, pp. 429-435, doi: 10.1108/jsm-01-2019-0034.

Zhan, X., Mu, Y., Hora, M. and Singhal, V.R. (2021), "Service excellence and market value of a firm", *International Journal of Production Research*, Vol. 59 No. 14, pp. 4188-4204, doi: 10.1080/00207543.2020.1759837.

Zhao, K., Xia, M. and Shaw, M.J. (2007), "An integrated model of consortium-based e-business standardization", *Journal of Management Information Systems*, Vol. 23 No. 4, pp. 247-271, doi: 10.2753/mis0742-1222230411.

Zhu, K., Kraemer, K.L., Gurbaxani, V. and Xu, S.X. (2006), "Migration to open-standard interorganizational systems", *MIS Quarterly*, Vol. 30, pp. 515-539, doi: 10.2307/25148771.

Supplementary material

The supplementary material for this article can be found online.

Corresponding author

Matteo Podrecca can be contacted at: matteo.podrecca@unibz.it