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Digital technology and innovation:The impact of blockchain application on enterprise innovation

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A R T I C L E I N F O

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A B S T R A C T

Blockchain as a frontier digital technology provides new opportunities for innovation. This paper builds a theoretical framework utilizing the Resource-Based View (RBV), and empirically examines the impact of blockchain application on enterprise innovation, based on panel data from Chinese listed companies spanning from 2007 to 2020. This paper finds that the adoption of blockchain applications significantly promotes enterprise innovation, through mechanisms of improving operational efficiency and expanding operational scope. With regard to contextuality, the positive effect of blockchain applications on innovation is more pronounced in enterprises with higher levels of technological and capital accumulation. With regard to temporality, innovation at faster paces can better realise the benefits of blockchain applications. This paper provides robust empirical evidence derived from a large sample, thereby enhancing our understanding of this dynamic relationship and suggesting directions for future research.

1. Introduction

Innovation has received increasing recognition for its contributions towards improving organizational performance and sustained survival and success (Anderson et al., 2014; Carmona-Lavado et al., 2023; Abril and Gimenez-Fernandez, 2024). It is highly valued as a capability within an organization, viewed not only as a desirable outcome but also as a crucial avenue for maintaining consistent organizational performance (Oh et al., 2016). Extensive research has investigated ways to promote and foster innovation activities within organizations (e.g. Anthony et al., 2008; Gupta, 2006; Turró et al., 2014; Stroh et al., 2023; Parolin et al., 2024). More recently, blockchain has risen as a promising foundational technology that has the potential to reshape our social and economic systems (Iansiti and Lakhani, 2017; Upadhyay et al., 2021; Böhmecke-Schwafert, M., & Moreno, 2023). In navigating the innovation challenge in a progressively digitized business environment, it is vital to have a thorough understanding of the role of information technologies such as blockchain and how they can be strategically utilized to shape business operations (Hileman, 2017). In recognising the potential, there are studies that discuss blockchain-enabled applications in business settings (e.g. Casino et al., 2019; Aloini et al., 2023; Aslam et al., 2023).

In the quest to study the impact of blockchain on innovation and explore how the resources possessed by organizations contribute to their ability to adopt and leverage blockchain for innovation, this study adopts the Resource-Based View (RBV) as the theoretical lens. While RBV focuses on firms' internal resources and capabilities, it also encourages businesses to seek a "strategic fit" by aligning their internal resources and capabilities with the external environment in which they operate (Madhani, 2010). In this process, both internal and external perspectives are incorporated in understanding and analysing firms' competitive advantage where both tangible and intangible resources are considered (Joseph et al., 2022). In the context of blockchain, a number of studies have coined its significant potential and promise to serve as a strategic intangible resource for organizations, contributing to the attainment of sustained advantages (e.g. Kant, 2021; Kant and Anjali, 2020). Current studies on blockchain and innovation have largely focused on particular aspects of blockchain (e.g. role, functionality, issues of applications), and often discussed in specific cases or industry settings (e.g. health, finance, insurance, logistics and supply chain, education, government). To our knowledge, there is also limited quantitative empirical research looking at the topic at a large aggregated scale across different sectors.

In response to the research gap, this study aims to empirically

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investigate the impact of blockchain applications on innovation in Chinese listed firms and the mechanisms by which the impact is realised. Though few large-scale empirical studies (such as Chin et al., 2021) have explored the impact of blockchain technology on innovation quality, our study complements prior findings by broadening the scope to include a more diverse range of sectors, focusing the temporality of innovation in broader aspects and exploring additional mechanisms through which the impact is realised. More specifically, three research questions (RQs) have been developed in order to address this aim comprehensively:

RQ1: What kind of impact on innovation is observed upon the application of blockchain?
RQ2: Through what mechanism such impact is realised?
RQ3: Does the impact vary in different contexts or temporalities? If so, in what ways?

By answering the three RQs, we believe we make not only theoretical contributions, but also practical significance. Understanding the impact of blockchain on innovation's temporality (RQ1) can help businesses leverage this technology to accelerate development cycles, optimize resources and improve decision-making. Identifying the mechanisms through which blockchain drives innovation (RQ2), such as enhanced operational efficiency and expanded operational scope, provides deeper insights into its transformative potential, allowing businesses to optimize processes, develop capabilities, and ensure compliance with industry standards (Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016). Exploring the variability of blockchain's impact across different contexts (RQ3) allows businesses to tailor applications to specific contexts such as different levels of technological and capital accumulation, ensuring more nuanced and effective implementations. This contextual understanding can help businesses make tailored decisions and adapt strategies to their own contexts (Gomber et al., 2018).

To address the above RQs, this research employs a regression-based approach on panel data from Chinese listed companies spanning from 2007 to 2020. We set the study context in China with a specific focus on listed companies for several reasons. Firstly, China has been actively involved in embracing and promoting blockchain development (Wang et al., 2020). China is not only leading in blockchain research evidenced by publishing the most papers on the topic worldwide (Wang et al., 2020) and patent applications (Noonan, 2018), but also one of the leading countries in the global distribution of blockchain where 22% blockchain companies are based in China just after the US housing 39% of the countries in 2020 (Gong, 2020). The government ban on cryptocurrency trading and mining activities determined that blockchain applications are rooted in established industries. The overall blockchain market size in China continues to enjoy its growth and reached 8.46 billion Chinese yuan in 2022 (Statista, 2023). The concentration on established industries also provides a focused opportunity for us to examine the impact of blockchain. Moreover, the listed companies represent a substantial share of the market across diverse industries both at national and global scales. The country's significant government support and regulatory environment further contribute to a favourable ecosystem for blockchain adoption (Jiang et al., 2021; Xiao et al., 2024). Analysing data from these companies provides insights into strategic partnerships, global competitiveness, and the dynamics of the evolving enterprieses operations. Furthermore, the comprehensive data available for these large-scale operations allows for a detailed examination of the innovation implications and performance metrics associated with blockchain adoption. Overall, studying Chinese listed companies offers a comprehensive and influential perspective on the integration of blockchain into innovation within a dynamic and globally significant economic context.

Our findings reveal that the adoption of blockchain applications significantly promotes innovation outputs in enterprises, through mechanisms of improving operational efficiency and expanding operational scope. Furthermore, the study reveals that the positive influence of blockchain applications on innovation is more pronounced in enterprises with higher levels of technological and capital accumulation. With regard to the temporality of innovation, the research demonstrates that the adoption of blockchain applications is significantly associated with reducing innovation's technology cycle time. Through unpacking the impact of blockchain applications on innovation's temporality, this study provides robust empirical evidence derived from a large sample, thereby enhancing our understanding of this dynamic relationship.

The following sections are structured as follows: section 2 provides a literature review on the topic and develops key hypotheses that guide empirical analysis. Section 3 details the methodological procedure adopted in this study. Sections 4 to 6 present the empirical findings. Section 7 interprets and discusses the results and implications. The final section concludes the paper with reflections on the contributions, limitations, and future research directions.

2. Literature review and conceptual framework

Blockchain technology, initially developed as the underlying architecture for Bitcon (Nakamoto, 2009), has evolved into a versatile tool with potential applications across various industries (Morabito, 2019). At its core, blockchain is a decentralized, distributed ledger system that ensures data integrity through cryptographic hashing and consensus mechanisms (Zheng et al., 2017). The technology's key attributes include transparency, immutability, and decentralization, which collectively enable secure and efficient transaction processing without the need for intermediaries (Iansiti and Lakhani, 2017). At the same time, innovation refers to the process of translating ideas into goods, services, or processes that create value or for which customers will pay. It encompasses various dimensions such as product innovation, process innovation, business model innovation, and organizational innovation (Tidd and Bessant, 2020). Effective innovation strategies are critical for maintaining competitive advantage and achieving sustained organizational growth.

Over the past few years, as a decentralized and transparent distributed ledger, blockchain has transcended its origins in cryptocurrency to become a transformative force with far-reaching implications for various industries (Casino et al., 2019) such as accounting and finance (Brunnermeier, 2018; Schmitz and Leoni, 2019), health (Cerchione et al., 2023; Massaro, 2023), logistics and supply chain (Chod et al., 2020) and government (Walport, 2016). While innovation itself, blockchain technology is also regarded as a technological architecture (Allen et al., 2020) and foundational technology (Iansiti and Lakhani, 2017) that can serve as fundamental building blocks for a wide range of applications and innovations in diverse settings. Its inherent properties, including transparency, auditability, robustness, and security (Christidis and Devetsikiotis, 2016), have presented itself as a promising way to solve some of the most pressing issues faced by enterprises and the society (Iansiti and Lakhani, 2017). Prior studies have provided evidence of the impact of blockchain on various innovation outputs. For instance, through smart contracts, a blockchain-enabled technology that can ensure data authenticity at each access point within a distributed information cycle in a transparent manner, enterprises can improve information flow, foster innovation, and ultimately gain a competitive edge in the current dynamic market (Gupta et al., 2023). However, limited research is observed in exploring the impact of blockchain on diverse types of innovation outcomes and the mechanisms through which such impact is realised, particularly at large scale.

2.1. A resource-based view on blockchain and innovation

The RBV posits that firm-specific resources and capabilities play a pivotal role in shaping competitive advantages (Freeman et al., 2021). Strategic resources, characterised by value, rareness, inimitability, and non-substitutability (VRIO), can have a profound impact on how well businesses perform (Barney, 1991; Freeman et al., 2021). In the context of innovation, blockchain technology, considered as an "intangible resource", can drive businesses innovation through its unique characteristics that align with the VRIO framework.

Blockchain's capacity to create **value** lies in aspects such as having the ability to automate processes, reduce transaction times, and lower operational costs through smart contracts, thereby streamlining workflows and increasing efficiency (Catalini and Gans, 2020; Iansiti and Lakhani, 2017). Additionally, blockchain's immutable and transparent ledger boosts trust and reliability, crucial for collaborative innovation activities (Zheng et al., 2017). More specifically, blockchain's value can be further evidenced by its impact on supply chain management, where it enhances traceability and reduces fraud (Saberi et al., 2019). For instance, in the healthcare sector, blockchain secures patient data and streamlines consent processes, improving the efficiency and reliability of medical records management (Agbo et al., 2019). These applications underscore blockchain's role in creating significant operational value across various industries.

The **rarity** of blockchain technology as a resource stems from its relatively recent emergence and the specialized expertise required for its implementation. Early adopters who have developed in-house blockchain capabilities hold a competitive advantage due to the technology's limited penetration in many industries (Tapscott and Tapscott, 2017). The technical knowledge and skills necessary to deploy and manage blockchain solutions are still scarce, making this expertise a rare and valuable asset (Yli-Huumo et al., 2016). Proprietary blockchain solutions tailored to specific business needs also contribute to the rarity of this resource. Custom implementations that address unique operational challenges can create distinct competitive advantages, further enhancing the rarity attribute of blockchain technology (Nofer et al., 2017).

Blockchain's **inimitability** is largely derived from its technical complexity and the depth of organizational integration required for its effective use. The cryptographic foundations and consensus mechanisms intrinsic to blockchain technology present significant barriers to replication (Underwood, 2016). Furthermore, the successful integration of blockchain into existing business processes necessitates a profound understanding of both the technology and the specific operational context, making it difficult for competitors to imitate (Beck et al., 2018). Proprietary blockchain innovations and patented technologies can further protect against imitation, ensuring that competitors cannot easily replicate the unique features and advantages that blockchain provides (Pilkington, 2016). This inimitability secures blockchain's role as a sustainable competitive resource in fostering innovation.

The **non-substitutability** of blockchain technology can be evidenced in its ability to provide decentralized trust and secure, transparent transactions. Unlike traditional centralized databases, blockchain's decentralized nature ensures that no single entity controls the entire ledger, making it a distinct and irreplaceable resource (Tapscott and Tapscott, 2017). The capability of blockchain to facilitate trustless transactions without the need for intermediaries is unparalleled by other technologies (Catalini and Gans, 2020). Smart contracts, which enable automatic and enforceable agreements, further highlight the non-substitutable nature of blockchain. The automation and security provided by smart contracts are not easily replicated by other digital solutions, underscoring blockchain's unique value proposition (Iansiti and Lakhani, 2017).

Applying the VRIO framework to blockchain technology reveals its significant potential as an intangible resource that drives innovation. Blockchain's value, rareness, inimitability, and non-substitutability collectively enable enterprises to achieve sustainable competitive advantages.

2.2. Impact of blockchain technology on innovation

In recognising its potential to significantly transform the operations of various industries, enterprises across different countries have actively embraced blockchain technology in paving their way for international industrial competition with the aim to crown the new wave of industrial innovation (Tseng et al., 2023). At the same time, fostering innovation has been positioned as the focal point for policymakers and entrepreneurs in driving economic development and business growth (Baudier et al., 2022). In order to effectively integrate innovation and consequently enhance competitive edge and sustained growth (Laperche, Burger-Helmchen, 2019), enterprises are required to cultivate flexibility, agility and a culture of change (Dupont, 2019). Functioning as a decentralized and transparent distribution ledger, blockchain can address such needs for more and better innovation through ways such as recording the provenance of digital assets and facilitating access to extensive datasets both within and beyond the traditional organisational boundaries (Baudier et al., 2022), enhancing data security and trust. It can also foster new business models, facilitate efficient and auditable transactions, and promote collaboration through smart contracts, thereby transforming industries and streamlining processes. For instance, blockchain can complement AI by enhancing insight generation, managing model sharing and data usage and contributing to the establishment of a data economy (Casino et al., 2021).

While cryptocurrency might have received the most hype and media attention as one form of blockchain application, today we are witnessing both blockchain products and services, and blockchain-enabled innovation implementation in diverse domains (Morabito, 2019). For instance, in the healthcare sector, blockchain enables the creation of innovative products such as secure patient data management systems and interoperable health information exchanges (Azaria et al., 2016). Blockchain also has the potential to revolutionize innovative products, services and processes by significantly improving how individuals, companies, and governments manage and commercialize intellectual property rights (IPRs) (Gürkaynak et al., 2018). It can develop products that offer immutable and transparent records of ownership and transactions and eliminate barriers to IPR protection and enforcement, encompassing trademarks, patents, copyrights, design rights, database rights, and trade secrets. Moreover, by addressing complex and outdated processes, blockchain has the capacity to elevate the perceived value of IPRs and contribute to a society that is fairer and more innovative (Gürkaynak et al., 2018). Companies like UJO and various IP Offices have already begun work on this area and provided solutions. Digital identity is another example where blockchain facilitates the creation of secure digital identity products. Platforms like uPort and Civic provide individuals with control over their digital identities, ensuring that personal data is securely managed and shared only with authorized parties. These products enhance privacy and security in online transactions and interactions.

Blockchain has also emerged as an unparalleled catalyst and enhancer of innovation in business processes (Aloini et al., 2023) and business models (Oh and Shong, 2017; Nowiński and Kozma, 2017). It enables innovative approaches in organizing economic activities, streamlining processes by minimizing costs and intermediary involvement, and enhancing trust among ecosystem actors (Weking et al., 2020). For instance, there has been a growing body of research looking at blockchain in the healthcare sector in recent years (Abu-Elezz et al., 2020; Tandon et al., 2020) with a particular focus on improving healthcare organizational processes (Spanò et al., 2021; Massaro, 2023). Blockchain may enable both incremental and radical business process innovation (Chang et al., 2019; Secinaro et al., 2021) by tackling some critical issues in the sector, including data security and privacy, lack of trust in information sharing, supply chain control, drug counterfeiting, and cross-institutional data sharing (Aloini et al., 2023). Aloini et al. (2023) also stress that tailored configurations of particular business process management capabilities are needed to enable innovation. Thus, we developed the following hypothesis:

H1. *The application of blockchain positively influences innovation outcomes.*

2.3. Blockchain for operational efficiency and scope expansion

The adoption of blockchain-enabled technologies can influence businesses in multiple dimensions, encompassing their operational arrangements, financing decisions, and organizational structure (Tapscott and Tapscott, 2017). In particular, it has demonstrated its potential to transform enterprises by enhancing operational efficiency (Rico-Peña et al., 2023; Tse et al., 2022). Operational efficiency, often understood as managerial proficiency in converting inputs into outputs, can be seen as a consistent set of effective practices that contribute to enhancing a firm's value by optimizing the utilization of committed resources during the processes of delivering value (Kwon and Lee, 2019). It comprises both cost-based efficiency, linked to factors such as quality costs, engineering changes, manufacturing costs, and time-based efficiency, connected to delivery speed, reliability, manufacturing lead time, and inventory turnover rate (Yeung, 2008). Blockchain-enabled technologies have the capacity to address both aspects (Hasan et al., 2020) by reducing transaction costs, such as negotiation and search costs, along with expenses linked to intermediaries and information technology infrastructures while minimises manual processes involved in aggregating, modifying, and sharing data (Morkunas et al., 2019). For instance, Walmart initiated a blockchain pilot project for supply chain tracking for contamination detection in spinach and lettuce which is anticipated to yield cost savings, thereby enhancing profit potential (Hasan et al., 2020). Manufacturing companies can leverage existing blockchain services or products in the market, connecting with established platforms to integrate inventory, capital, and information flows, resulting in faster processes, reduced costs, improved operational quality and ultimately enhanced efficiency (Pan et al., 2020).

Prior research has highlighted the role information technology and digital information capabilities played in contributing to firms' operational capabilities by fostering interpersonal and inter-firm relationships (Vaidyanathan and Devaraj, 2008). Properties inherent in blockchain, such as transparency, peer-to-peer networks, low transaction costs, speed and distributed consensus (Nakamoto, 2009), could address the limitations of current asymmetric information systems and lead to effective interpersonal and inter-firm relationships (Hasan et al., 2020) and facilitate seamless collaboration and information sharing across organizational boundaries. In turn, this can expand the operational scope by enabling secure data exchange between stakeholders, including partnerships, suppliers, and collaborators (Shiva et al., 2023). Indeed, a broader operational scope has been observed in areas such as cross-border transactions, supply chain management (Liu and Li, 2020), and data sharing in healthcare (Cerchione et al., 2023).

Operational efficiency and operational scope are also key influencers of innovation outcomes. Enhanced operational efficiency through blockchain technology optimizes resource use and reduces transaction times and costs, freeing up resources for innovation and enabling quicker market responses (Catalini and Gans, 2020; Iansiti and Lakhani, 2017). This efficiency allows organizations to focus more on core activities that drive innovation and enhances organizational agility to adapt swiftly to market changes (Tidd and Bessant, 2020). Expanding operational scope through blockchain encourages collaboration with external partners, leveraging broader resources and fostering a rich innovation ecosystem (Zheng et al., 2017). This collaborative approach enables the cross-pollination of ideas and technologies across industries, further driving innovation (Gomber et al., 2018). Together, operational efficiency and scope create a conducive environment for continuous and sustainable innovation. Thus, the following hypothesis is developed:

H2. *Blockchain influences innovation through operational efficiency and operational scope.*

2.4. Contextual influence on blockchain and innovation

According to the RBV, a firm's fundamental resources include the assets and employees (Tseng et al., 2023). Prior research has revealed a positive correlation between new technology adoption and organizational size where larger companies tend to utilize internet technology more intensively (Del Aguila-Obra and Padilla-Meléndez, 2006) and are more inclined to adopt innovations like cloud technology (Alkhater et al., 2018). It is suggested that the adoption of technologies like blockchain is positively associated with the scale of a company's total assets (Pan et al., 2020). As blockchain technology helps improve enterprise operational capabilities (Pan et al., 2020) and consequently innovation, it is likely that the influence of blockchain on innovation is more pronounced in enterprises with larger assets (i.e. higher capital accumulation).

However, it should also be noted that the scale of enterprise assets may not be the sole driving factor behind blockchain implementation (Pan et al., 2020). Factors like organizational innovativeness and technological intensity, measured by the ratio of R&D expenditures to sales, also play pivotal roles in technology adoption (Tseng et al., 2023). Companies with robust R&D and innovation activities are likely leading in technological progress including blockchain adoption (Tseng et al., 2023). Technological accumulation refers to the process by which a firm or organization enhances its stock of technological knowledge, skills, capabilities, and assets over time. It can be measured by enterprises' total number of active patents and is another critical factor behind blockchain implementation. The relationship between firm size and technological intensity is well-established (Munier, 2006), emphasizing the importance of R&D investment in a company's acceptance of innovation (Frambach and Schillewaert, 2002). Therefore, firms with substantial technological accumulation are believed to be more inclined to adopt new technologies like blockchain, potentially experiencing a more significant influence on innovation. We attempt to confirm the role technological and capital accumulation played in blockchain adoption and innovation outcomes with the following hypothesis:

H3. *Enterprises exhibiting elevated levels of technological and capital accumulation have higher positive influence from blockchain applications on innovation.*

2.5. Unveiling the dynamics on temporality

In recognising the importance of innovation in sustaining organisational performance and growth, it is important to monitor, measure and evaluate it (Gault, 2018). However, as a heavily discussed topic, there is a general lack of consensus on defining, and consequently measuring innovation (Arundel and Huber, 2013; Gault, 2018). The Olso Manual since its first edition published in 1992 has been providing guidelines on defining and measuring innovation statistically in the private sector (OECD/Eurostat, 2018). In general terms, an innovation is defined as "*a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)*." (OECD/Eurostat, 2018, p. 20). The last edition of the Olso Manual has reduced the previous four types of innovations into two main types: product innovations and business process innovations (OECD/Eurostat, 2018).

Although perspectives on the measurements of innovation among individuals remain inclusive among different people, the importance of measuring is acknowledged (Kataria and Nandal, 2020). The Olso Manual (OECD/Eurostat, 2018) highlights measurability as a key selection criterion for innovation. To date, metrics used to measure innovation also vary among different companies and researchers and are determined by the purpose and audience (Andrew et al., 2009; Gault, 2018). In the context of blockchain adoption, we are interested in understanding the temporality aspect of blockchain's impact on innovation. More specifically, we aim to examine the effect of blockchain on innovation speed. In measuring the speed of development and pace of technological innovation progress, technology cycle time, measured as "*the median age of the patents cited on the front page of a patent document*", has been proposed and widely adopted (Kayal, 1999; Rosiello and Maleki, 2021). With properties such as decentralized collaboration to enhance efficiency, utilization of smart contracts for rapid execution, and reduction of administrative overheads and time (Casino et al., 2019), blockchain technology holds the potential to reduce technology cycle time. Thus, the following hypotheses are developed:

H4. *The application of blockchain has stronger promoting effects for faster innovation.*

In summary, Fig. 1 provides a theoretical framework guiding this research.

3. Empirical design

3.1. Model

We design a regression model and examine the effect of blockchain application on enterprise innovation. Based on enterprise-year panel data, the regression model can be described as follows:

$$Innovation_{it} = \beta_0 + \beta_1 Blockchain_{it} + \boldsymbol{\beta_2 X_{it}} + \eta_i + \theta_t + \varepsilon_i$$

i and t indicate enterprise and year respectively. The dependent variable $Innovation_{it}$ is the innovation performance of the enterprise i in year t, measured by the number of patents granted, +1 then taken logarithm. The core independent variable $Blockchain_{it}$ is the blockchain application, measured by identifying the contents of enterprises' annual reports. The vector $\boldsymbol{X_{it}}$ is a series of control variables, including the number of employees, loan of asset ratio, return on equity, the age of enterprises, type of property right, size of the board, cash flow, the growth of sales, and tangible property (Li et al., 2023). The variables η_i and θ_t indicate firm and year fixed effect respectively. The coefficient β_1 represents the effect of blockchain application on enterprise innovation.

3.2. Variables

3.2.1. Dependent variable

In the empirical study of this paper, the dependent variable *Innovation* is the innovation performance of enterprises, which is measured by each enterprise's number of patents granted in each year, +1 then taken logarithm. In China, patents include invention patents, utility model patents and design patents. Invention patents correspond to what is commonly referred to internationally as patents. Therefore, in this article, "patent" refers to "invention patent" in China (Zheng and Li, 2020). Since the values of some samples are zero, we take the values of all samples +1 and take logarithm. In addition to this indicator, we also use the number of enterprises' patent applications as a proxy variable for innovation, thus improving the robustness of the empirical study.

3.2.2. Core independent variable

The core independent variable in this paper is *Blockchain*, measuring the degree of each enterprise's blockchain application. *Blockchain* is measured by identifying the contents of enterprises' annual reports about blockchain application, then calculating the degree of blockchain application (Li et al., 2022).

First, we construct the information pool of all the enterprise annual report content. We use the Python crawler function to organize the enterprise annual reports, then based on the Jieba Chinese word separation function for the enterprise annual reports, we conduct word separation and statistics to construct the information pool of all the enterprise annual report content. Next, we identify keywords related to blockchain application in enterprise annual reports. We identify keywords related to blockchain application based on important policies and research reports, which contain four aspects: blockchain core technology, blockchain assistive technology, blockchain derivative technology and blockchain technology carriers. Finally, we calculate the blockchain application index for each annual report. We statistic the occurrences of the keywords in the information pool of all the enterprise annual report content and aggregate them to get the blockchain application index of each annual report.

3.2.3. Control variables

In the empirical study, we include a series of control variables that reflect enterprise characteristics, including enterprise fixed effects and year fixed effects. The control variables include: *Employee*, the number of employees, measured by the total number of employees, taken logarithm; *LOAR*, loan of asset ratio, measured by the ratio of total liabilities to total assets of enterprises; *ROE*, return on equity, measured by the ratio of net profit to net assets of enterprises; *SOE*, type of property right, 1 for state-owned enterprises and 0 for private enterprises; *Age*, the age of enterprises, measured by the time from the year of listing, taken logarithm; *Board*, size of the board, measured by the number of board members, taken logarithm; *CF*, cash flow, measured by the ratio of net cash flow to total assets; *Growth*, the growth of sales, measured by the ratio of the growth of main business income to the previous year's main business income; *Tangible*, tangible property, measured by the ratio of fixed assets to total assets.

3.3. Data

In the empirical study, we match the data from 3 aspects to obtain the enterprise-level panel data from 2007 to 2020. The sample used for the empirical analysis of this paper includes all enterprises listed on the Chinese A-shares, including both Shanghai and Shenzhen exchanges. We organize the data of enterprise annual reports, enterprise financial data and patent micro data for the empirical study.

Specifically, the enterprise annual report data is obtained through Python crawler; the enterprise financial data are obtained through China Stock Market & Accounting Research (CSMAR) and Wind database; the patent micro data are compiled by China's State Intellectual Property Office, with data sources from the Institute for Contemporary China Studies of Tsinghua University and Shenzhen Tekglory Technology Co.

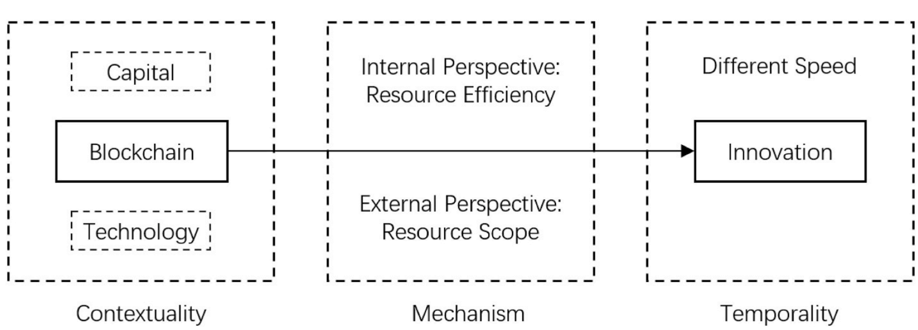

Fig. 1. Theoretical framework.

Ltd. To obtain more accurate results on the basis of referencing existing literature (Huang et al., 2023a; Li et al., 2022), we exclude the enterprises classified as special treatment, which indicates abnormal financial or operating conditions; exclude enterprises in the information transmission, software and information technology service industry that blockchain technology belongs to; and perform a 1% tail shrinkage process, to reduce the influence of outliers. The patent micro data are patent-level data, in which we match the "applicant" information with the annual report data and financial data of enterprises to obtain the panel data at the enterprise level from 2007 to 2020. Due to the availability and completeness of the data, we set the sample start period at 2007. To exclude the outliers influenced by the Covid-19, we set the end of the sample at 2020. Also, we use different sample period for robustness test and report the results in Appendix 2.

The descriptive statistics of the main variables in the empirical study are shown in Table 1. The correlation coefficients are shown in Appendix 1.

4. Results

4.1. Basic results

First, we analyse the effect of enterprise's blockchain application on innovation based on the regression model. Table 2 reports the basic regression results, showing that blockchain application can promote innovation significantly. In column (1), the coefficient of blockchain application is 0.106 and significant at the 1% level, without the inclusion of control variables and fixed effects. In column (2), the coefficient of blockchain application remains significantly positive after adding a series of control variables. On this basis, the coefficient of blockchain application remains significantly positive at the 1% level in column (3) with the inclusion of enterprise and year fixed effects. Thus, the basic regression results suggest that enterprise's blockchain application has a positive effect on innovation.

4.2. Robustness tests

Next, to improve the robustness of the empirical analysis, we conduct robustness tests in 3 aspects and report the results in Table 3. In column (1), we change the measure for enterprises' blockchain application by further expanding the keyword pool to cover a wider range of blockchain application. Column (1) still uses innovation as the dependent variable, and the regression results show that blockchain application has a positive effect on innovation and is significant at the 1% level. In column (2), we identify and exclude the 10% sample that may have an abnormal number of disclosures, considering the possibility of exaggerated disclosures by enterprises. We first estimate the number of possible disclosures for each enterprise in each year, and then remove the samples above the 90% quantile of the residuals and conduct the regression with the remaining samples. Column (2) shows that the regression results after excluding outliers are still positively significant, so blockchain application can significantly promote innovation. In column (3), we change the core independent variable to the lagged one period considering the possible simultaneity and time lag. The coefficient of the core independent variable in column (3) is also positively significant. In addition, we test for different sample period as well as multicollinearity, and the results are reported in Appendix 2 and Appendix 3. Thus, the results of the robustness tests indicate that the findings of the empirical analysis are robust. Therefore, Hypothesis 1 is validated.

Table 1
Descriptive statistics.

Variables	(1) Obs.	(2) Mean	(3) Std. Dev.	(4) Min	(5) Max
Innovation	15716	1.033	1.281	0.000	4.942
Blockchain	15716	1.181	0.975	0.000	3.884
Employee	15716	7.702	1.134	2.944	12.211
LOAR	15716	0.447	0.223	0.046	0.988
ROE	15716	0.071	0.127	−0.627	0.416
SOE	15716	0.569	0.493	0.000	1.000
Age	15716	1.981	0.931	0.000	3.229
Board	15716	2.155	0.201	1.609	2.709
CF	15716	0.046	0.075	−0.180	0.257
Growth	15716	0.162	0.331	−0.562	1.771
Tangible	15716	0.278	0.191	0.003	0.801
Asset turnover ratio	15716	0.696	0.471	0.076	2.705
Cost ratio	15716	0.724	0.172	0.201	1.015
Supplier distribution	15716	0.103	0.053	0.000	0.608
Cooperator distribution	15716	0.128	0.106	0.000	0.715
Technological accumulation	15716	3.874	3.619	0.000	11.156
Capital accumulation	15716	21.751	1.299	19.372	25.893
TCT	15716	1.028	0.654	0.000	3.178

Table 2
Blockchain's effect on innovation.

Variables	(1) Patent granted	(2) Patent granted	(3) Patent granted
Blockchain	0.106***	0.093***	0.087***
	(0.012)	(0.013)	(0.015)
Controls		Yes	Yes
Year dummy			Yes
Enterprise dummy			Yes
Observations	15716	15716	15716
R-squared	0.086	0.619	0.670

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

Table 3
Robustness tests.

Variables	(1) Blockchain measure	(2) Eliminating exaggeration	(3) Lagged one period
Blockchain	0.077***	0.061***	0.072***
	(0.014)	(0.015)	(0.012)
Controls	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Enterprise dummy	Yes	Yes	Yes
Observations	15716	14228	14589
R-squared	0.632	0.625	0.629

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

5. Mechanism

5.1. Internal perspective: operational efficiency

From the internal perspective, we analyse whether operational efficiency is the mechanism through which enterprises' blockchain application promotes innovation. Operational efficiency is an important factor in promoting enterprise innovation (Huang et al., 2023b). Table 4 shows that enterprises' blockchain application can reduce operational cost and improve operational efficiency. In column (1), we use enterprises' asset turnover ratio as the dependent variable, measured by the ratio of total turnover to total assets (Li et al., 2022). The results in column (1) show that enterprises' blockchain application can improve the asset turnover ratio and is significant at the 1% level. In column (2), we use enterprises' cost ratio as the dependent variable, measured by the ratio of total cost to total income. The results in column (2) show that enterprises' blockchain application can significantly reduce the cost ratio. As robustness tests, we obtained similar results using the Tobit

Table 4
Blockchain's effect on operational efficiency.

Variables	(1)	(2)
	Asset turnover ratio	Cost ratio
Blockchain	0.023*** (0.002)	−0.030*** (0.003)
Controls	Yes	Yes
Year dummy	Yes	Yes
Enterprise dummy	Yes	Yes
Observations	15716	15716
R-squared	0.662	0.651

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

model (see Appendix 4). Blockchain application facilitates more efficient use of resources and optimizes decision making through digital technology, thereby reducing operational cost and improving operational efficiency.

5.2. External perspective: operational scope

From the external perspective, we analyse whether operational scope is the mechanism through which enterprises' blockchain application promotes innovation. Table 5 shows that enterprises' blockchain application can promote different types of operational scope. In column (1), we use enterprises' supplier distribution as the dependent variable, measured by 1 - supplier concentration ratio. Supplier concentration means the share of purchases of the 10 suppliers with the largest purchases (with enterprise i in year t) out of the total purchases (of enterprise i in year t). 1 subtracts this value can measure the extent of the distribution of suppliers. The results in column (1) show that enterprises' blockchain application can increase supplier distribution and is significant at the 1% level. In column (2), we use the enterprises' cooperator distribution as the dependent variable, measured by 1 - cooperator concentration ratio. Cooperator distribution means the share of cooperating patents granted number of the 3 cooperators with the most cooperating patents granted number (with enterprise i in year t) out of the total cooperating patents granted number (of enterprise i in year t). 1 subtracts this value can measure the extent of the distribution of cooperators. The results in column (2) show that enterprises' blockchain application can significantly increase cooperator distribution. As robustness tests, we obtained similar results using the Tobit model (see Appendix 5). Blockchain application facilitates innovation by improving operational scope and matching more suppliers and cooperators. Therefore, Hypothesis 2 is validated.

6. Heterogeneity

6.1. Contextuality

Further, we conduct the heterogeneity analysis for the impact

Table 5
Blockchain's effect on operational scope.

Variables	(1)	(2)
	Supplier distribution	Cooperator distribution
Blockchain	0.018*** (0.002)	0.012*** (0.002)
Controls	Yes	Yes
Year Dummy	Yes	Yes
Enterprise Dummy	Yes	Yes
Observations	15716	15716
R-squared	0.575	0.553

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

Table 6
Blockchain application's contextuality.

Variables	(1)	(2)
	Patent granted	Patent granted
Blockchain × *Technological accumulation*	0.044*** (0.009)	
Blockchain × *Capital accumulation*		0.038*** (0.008)
Blockchain	0.053*** (0.010)	0.059*** (0.012)
Technological accumulation	0.719*** (0.018)	
Capital accumulation		0.635*** (0.017)
Controls	Yes	Yes
Year dummy	Yes	Yes
Enterprise dummy	Yes	Yes
Observations	15716	15716
R-squared	0.681	0.677

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

blockchain application in different contexts and report the results in Table 6. We use enterprises' total number of active patents (taken logarithm) to measure technological accumulation, and enterprises' total asset (taken logarithm) to measure capital accumulation. In column (1), the coefficient of the interaction term between blockchain application and technological accumulation is 0.044 and significant at the 1% level, showing that enterprises exhibiting elevated levels of technological accumulation experience higher positive influence from blockchain applications on innovation. In column (2), the coefficient of the interaction term between blockchain application and capital accumulation is 0.038 and significant at the 1% level, showing that enterprises exhibiting elevated levels of capital accumulation experience higher positive influence from blockchain applications on innovation. These results analyse the contextual influence of blockchain application and their effects on innovation. Therefore, Hypothesis 3 is validated.

6.2. Temporality

Then, we conduct the heterogeneity analysis for innovation's temporality and report the results in Table 7. We focus on the patents' Technology Cycle Time (TCT), measured by the average age of patents' cited patents (OECD, 2009) taken logarithm. We calculate the average patent Technology Cycle Time of each enterprise in each year, then divide them into three groups by quartiles. The group with the largest average TCT is Group Slow, and the group with the smallest average TCT is Group Fast. Comparing Columns 1 to 3 of Table 7 shows that blockchain application is a facilitator for different speeds of innovation and is significant at the 1% level. Relatively, blockchain application has the strongest facilitating effect on fast innovation with a coefficient of 0.103, and the weakest facilitating effect on slow innovation with a coefficient of 0.078. For Group Medium, the coefficient of blockchain application is 0.085. Therefore, Hypothesis 4 is validated.

Table 7
Innovation's temporality.

Variables	(1)	(2)	(3)
	Slow	Medium	Fast
Blockchain	0.078*** (0.014)	0.085*** (0.014)	0.103*** (0.016)
Controls	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Enterprise dummy	Yes	Yes	Yes
Observations	5239	5239	5238
R-squared	0.666	0.668	0.673

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

7. Discussion and conclusion

This paper tackles the still under-researched area of the impact of blockchain application on innovation by investigating what impact are observed, how is this impact realised, and the contextual influences of the results. By drawing large scale empirical evidence from Chinese listed companies spanning from 2007 to 2020, the findings revealed nuanced insights on the multifaceted relationship between blockchain and innovation within the dynamic business landscape. As the analysis shows that enterprises' adoption of blockchain applications has a significant positive impact on their innovation performances. Looking more closely, we revealed that the positive impact was achieved through two key mechanisms: the improvement of operational efficiency and the broadening of operational scope. Blockchain's inherent characteristics, such as decentralization, transparency, and immutability, contribute to streamlined and more efficient business processes (Weking et al., 2020). The distributed ledger system can reduce the need for intermediaries, minimise errors, and accelerate transaction processing (Casino et al., 2019). The transparency and traceability offered by blockchain technology enable enterprises to extend their operation reach (Hasan et al., 2020). Such expansion can go beyond the traditional boundaries, and facilitate collaborations, partnerships, and interactions across diverse stakeholders (Shiva et al., 2023). Enterprises can access new markets, engage in novel chains, and leverage a broader spectrum of resources. Consequently, the efficiency gain can allow the enterprise to redirect resources towards innovation endeavours and improve productivity; the broadened operational scope can foster innovation by exposing the enterprise to new perspectives, ideas and opportunities that were previously inaccessible.

Our empirical results also evidenced contextual differences where enterprises with heightened levels of technological and capital accumulation experience a more pronounced positive influence from blockchain applications on innovation. As a fast-emerging technology, the inherent complexities of blockchain integration often require a sophisticated technological infrastructure and financial commitment for effective adoption (Pan et al., 2020). Thus, enterprises with more resources are better positioned to strategically leverage blockchain applications for innovation.

The results also show that the adoption of blockchain applications expedites technology development cycles, evidencing its role in accelerating innovation processes. This can be achieved through the automation of processes and the potential elimination of intermediaries, which can, in turn, streamline workflows and reduce delays. For instance, smart contracts can automate agreements, ensuring quick and accurate transactions without manual intervention (Zou et al., 2019). The transparent and immutable nature of blockchain records can enhance trust and reducing time spent on verification and reconciliation (Gomaa et al., 2023). Consequently, enterprises can bring new products and services to market quicker and responding to the market more timely, demonstrating how blockchain makes innovation faster.

7.1. Theoretical contributions

In regard to theoretical contributions, this paper proposes a framework for understanding dynamic and complex relationships between blockchain and innovation. The RBV offers a holistic framework for understanding the competitive advantage, emphasizing the role of unique and valuable resources in driving sustained enterprise performance (Freeman et al., 2021). By employing the RBV as a theoretical lens, it enriches the understanding of blockchain as an intangible resource, highlighting its value, rareness, inimitability, and non-substitutability (VRIO) and their influence on innovation outcomes. Our study establishes a clear theoretical link between operational efficiency, enhanced through blockchain, and its positive impact on innovation, underscoring how efficient resource utilization and reduced operational costs facilitate greater innovative capabilities.

Additionally, the research extends theoretical knowledge by showing how blockchain expands operational scope, enabling new business models and market opportunities, fostering a broader innovation ecosystem. It differentiates the impact of blockchain on enterprises with varying levels of capital and technological accumulation. While firms with high accumulation levels benefit more, those with lower levels can leverage blockchain for cost reduction, improved data security, and market expansion. By providing robust empirical evidence from a large dataset of Chinese listed companies, the study validates theoretical models linking blockchain adoption to enhanced innovation outcomes, thereby strengthening the theoretical arguments and providing a foundation for future research.

7.2. Managerial implications

From a practical perspective, this paper encourages enterprises who are actively seeking innovation to view blockchain applications as a catalyst for innovation, and therefore more proactively explore and adopt blockchain technology to its full potential. At the same time, we also acknowledge the initial costs of implementing blockchain. However, this study highlights that after establishing the initial implementation structure, the marginal costs of continued use are lowered. Moreover, as the enterprises grow, the average costs fall. Therefore, this research particularly encourages enterprises with strong technological and capital accumulation to leverage blockchain technology effectively. Additionally, for enterprises with less capital and technological accumulation, blockchain can still offer substantial benefits. Blockchain's ability to reduce operational costs through automation and eliminate intermediaries can be particularly advantageous for smaller enterprises (Catalini and Gans, 2020). Access to decentralized financial services provides easier and more affordable financing options, and secure, transparent cross-border transactions enable market expansion without significant capital investment (Tapscott and Tapscott, 2017). Blockchain also enhances data security, crucial for enterprises lacking extensive IT infrastructure, and fosters collaborations by providing secure platforms for partnerships (Zheng et al., 2017). Lastly, blockchain simplifies regulatory compliance, reducing the burden on smaller firms (Pilkington, 2016).

Lastly, this research also revealed that the adoption of blockchain applications can effectively enhance enterprises' operational efficiency and scope levels. This finding encourages enterprises that are aspiring to improve these aspects to proactively harness the potential of blockchain applications. Queiroz and Wamba (2019) point out that one of the significant barriers hindering enterprises from adopting blockchain technology lies in their insufficient comprehension of its value. Thus, we believe our results can contribute to addressing this barrier.

From a policy perspective, our findings can also contribute to policy makers' decision-making in regard to blockchain development. For governments, the economic and social impact of blockchain technology requires greater attention. The paper suggests exploring policies that can lead to better utilization of blockchain technology and leverage its positive effects.

7.3. Limitations and future research

While we acknowledge the substantial contributions this paper has made to the existing literature, we do also recognize the presence of limitations that require further attention and refinement in future research endeavours. When measuring enterprises' blockchain applications, our methodology relies on collecting the annual reports of each enterprise and measuring the degree through analysing the textual content within the annual reports. While this methodology has been adopted in recent years for its relevance, there may be some concerns about its accuracy and reliability, which need to be further validated. There are potential risks for companies to exaggerate their achievements in blockchain adoption in these reports. Some similar concepts - such as blockchain consideration, blockchain investment, blockchain implementation - are not easily distinguished by this approach.

Future research in this domain could explore alternative pathways for measuring blockchain applications and their impact on innovation. As an emerging technology, blockchain is still rapidly evolving and continued attention on its impact is required in the future. A more qualitative approach can complement this by highlighting specific challenges in linking blockchain applications with innovation from an organizational behaviour perspective. Enterprises may encounter various hurdles in navigating this transformative landscape. Concerns such as investment scope, security, interoperability, standardization, cultural and management shift all present obstacles that demand further attention. Thus, a more thorough exploration of the limitations and challenges associated with the adoption of blockchain applications, coupled with an in-depth investigation into the identification of best practices that facilitate the effective utilization of blockchain for enterprises, would provide practical value.

CRediT authorship contribution statement

Zhaochen Li: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zimu Xu:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization.

Declarations of interest

None.

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Appendix 1. Correlation Coefficients

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Innovation	1.000								
Blockchain	0.121	1.000							
Employee	0.302	0.182	1.000						
LOAR	−0.101	−0.117	−1.921	1.000					
ROE	0.207	0.164	0.051	0.041	1.000				
SOE	−0.091	−0.110	0.090	0.169	0.059	1.000			
Age	0.176	0.090	−0.117	−0.088	−0.130	−0.428	1.000		
Board	0.078	0.047	0.007	−0.095	0.023	−0.283	0.109	1.000	
CF	0.094	0.078	0.040	−0.006	0.256	−0.030	−0.014	0.060	1.000
Growth	0.217	0.104	0.028	0.064	0.230	0.106	−0.101	−0.026	0.016
Tangible	−0.091	−0.081	−0.047	−0.264	−0.118	−0.227	0.123	0.175	0.230
Asset turnover ratio	0.109	0.042	0.043	0.018	0.178	−0.058	−0.028	0.041	0.126
Cost ratio	0.098	0.103	−0.037	−0.155	−0.290	−0.215	0.208	0.059	−0.214
Supplier distribution	0.041	0.053	0.011	0.019	0.102	−0.201	0.102	0.101	0.102
Cooperator distribution	0.030	0.051	0.010	0.103	0.122	−0.192	0.117	0.099	0.098
Technological accumulation	0.074	0.061	0.205	0.112	0.139	0.187	0.124	0.105	0.161
Capital accumulation	0.067	0.066	0.229	0.102	0.131	0.160	0.090	0.069	−0.333
TCT	−0.043	−0.102	0.017	0.038	0.192	0.165	0.024	0.089	−0.102

Variables	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Innovation									
Blockchain									
Employee									
LOAR									
ROE									
SOE									
Age									
Board									
CF									
Growth	1.000								
Tangible	−0.108	1.000							
Asset turnover ratio	0.123	−0.056	1.000						
Cost ratio	−0.100	0.175	0.374	1.000					
Supplier distribution	0.088	0.115	0.102	0.119	1.000				
Cooperator distribution	0.-79	0.131	0.102	0.110	0.161	1.000			
Technological accumulation	0.041	−0.131	0.263	0.012	0.101	0.073	1.000		
Capital accumulation	0.366	0.245	0.042	0.031	0.124	0.038	0.141	1.000	
TCT	−0.093	0.066	0.037	−0.029	0.067	0.051	−0.047	0.033	1.000

Appendix 2. Robustness test for different sample period (2012–2020)

Variables	(1)	(2)	(3)
	Patent granted	Patent granted	Patent granted
Blockchain	0.097***	0.085***	0.078***
	(0.014)	(0.015)	(0.017)
Controls		Yes	Yes
Year dummy			Yes

(*continued on next page*)

(*continued*)

Variables	(1)	(2)	(3)
	Patent granted	Patent granted	Patent granted
Enterprise dummy			Yes
Observations	10102	10102	10102
R-squared	0.525	0.603	0.656

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

Appendix 3. Robustness test for multicollinearity

Variables	(1) VIF	(2) 1/VIF
SOE	1.30	0.77
Age	1.26	0.79
Blockchain	1.25	0.80
Tangible	1.22	0.82
LOAR	1.20	0.83
Employee	1.19	0.84
ROE	1.17	0.85
CF	1.15	0.87
Board	1.13	0.88
Growth	1.08	0.93

Appendix 4. Robustness tests using Tobit model: blockchain's effect on operational efficiency

Variables	(1)	(2)
	Asset turnover ratio	Cost ratio
Blockchain	0.020***	−0.026***
	(0.002)	(0.003)
Controls	Yes	Yes
Year dummy	Yes	Yes
Enterprise dummy	Yes	Yes
Observations	15716	15716
R-squared	0.831	0.816

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

Appendix 5. Robustness tests using Tobit model: blockchain's effect on operational scope

Variables	(1)	(2)
	Supplier distribution	Cooperator distribution
Blockchain	0.015***	0.009***
	(0.002)	(0.002)
Controls	Yes	Yes
Year Dummy	Yes	Yes
Enterprise Dummy	Yes	Yes
Observations	15716	15716
R-squared	0.752	0.738

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Robust standard errors in parentheses.

Data availability

Data will be made available on request.

References

Abu-Elezz, I., Hassan, A., Nazeemudeen, A., Househ, M., Abd-Alrazaq, A., 2020. The benefits and threats of blockchain technology in healthcare: a scoping review. Int. J. Med. Inf. 142, 104246.

Abril, C., Gimenez-Fernandez, E.M., 2024. Using gamification to overcome innovation process challenges: a literature review and future agenda. Technovation 133, 103020.

Agbo, C.C., Mahmoud, Q.H., Eklund, J.M., 2019. Blockchain technology in healthcare: a systematic review. Healthcare 7 (2). https://doi.org/10.3390/healthcare7020056.

Allen, D.W.E., Berg, C., Markey-Towler, B., Novak, M., Potts, J., 2020. Blockchain and the evolution of institutional technologies: Implications for innovation policy. Research Policy 49 (1), 103865.

Alkhater, N., Walters, R., Wills, G., 2018. An empirical study of factors influencing cloud adoption among private sector organisations. Telematics Inf. 35 (1), 38–54.

Aloini, D., Benevento, E., Stefanini, A., Zerbino, P., 2023. Transforming healthcare ecosystems through blockchain: opportunities and capabilities for business process innovation. Technovation 119, 102557. https://doi.org/10.1016/j.technovation.2022.102557.

Anderson, N., Potočnik, K., Zhou, J., 2014. Innovation and creativity in organizations: a state-of-the-science review, prospective commentary, and guiding framework. J. Manag. 40 (5), 1297–1333. https://doi.org/10.1177/0149206314527128.

Andrew, J.P., Haanaes, K., Michael, D.C., Sirkin, H.L., Taylor, A., 2009. Measuring Innovation 2009: the Need for Action, A BCG Senior Management Survey. The Boston Consulting Group, Inc.

Anthony, S.D., Johnson, M.W., Sinfield, J.V., 2008. Institutionalizing Innovation. MIT Sloan Management Review. https://sloanreview.mit.edu/article/institutionalizing-innovation/.

Arundel, A., Huber, D., 2013. From too little to too much innovation? Issues in measuring innovation in the public sector. Struct. Change Econ. Dynam. 27, 146–159. https://doi.org/10.1016/j.strueco.2013.06.009.

Aslam, J., Saleem, A., Kim, Y.B., 2023. Blockchain-enabled supply chain management: integrated impact on firm performance and robustness capabilities. Bus. Process Manag. J. 29 (6), 1680–1705.

Azaria, A., Ekblaw, A., Vieira, T., Lippman, A., 2016. Medrec: using blockchain for medical data access and permission management. In: 2016 2nd International Conference on Open and Big Data (OBD). IEEE, pp. 25–30.

Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17 (1), 99–120. https://doi.org/10.1177/014920639101700108.

Baudier, P., Chang, V., Arami, M., 2022. The impacts of blockchain on innovation management: sectoral experiments. Journal of Innovation Economics & Management 37 (1), 1–8. Scopus.

Böhmecke-Schwafert, M., Moreno, E.G., 2023. Exploring blockchain-based innovations for economic and sustainable development in the global south: a mixed-method approach based on web mining and topic modeling. Technol. Forecast. Soc. Change 191, 122446.

Brunnermeier, M., 2018. Blockchain economics. https://markus.scholar.princeton.edu/publications/blockchain-economics.

Carmona-Lavado, A., Gimenez-Fernandez, E.M., Vlaisavljevic, V., Cabello-Medina, C., 2023. Cross-industry innovation: a systematic literature review. Technovation 124, 102743.

Casino, F., Dasaklis, T.K., Patsakis, C., 2019. A systematic literature review of blockchain-based applications: current status, classification and open issues. Telematics Inf. 36, 55–81. https://doi.org/10.1016/j.tele.2018.11.006.

Catalini, C., Gans, J.S., 2020. Some simple economics of the blockchain. Commun. ACM 63 (7), 80–90.

Cerchione, R., Centobelli, P., Riccio, E., Abbate, S., Oropallo, E., 2023. Blockchain's Coming to Hospital to Digitalize Healthcare Services: Designing a Distributed Electronic Health Record Ecosystem.

Chang, S.E., Chen, Y.C., Wu, T.C., 2019. Exploring blockchain technology in international trade: business process re-engineering for letter of credit. Ind. Manag. Data Syst. 119 (8), 1712–1733.

Chin, T., Wang, W., Yang, M., Duan, Y., Chen, Y., 2021. The moderating effect of managerial discretion on blockchain technology and the firms' innovation quality: evidence from Chinese manufacturing firms. Int. J. Prod. Econ. 240, 108219. https://doi.org/10.1016/j.ijpe.2021.108219.

Chod, J., Trichakis, N., Tsoukalas, G., Aspegren, H., Weber, M., 2020. On the financing benefits of supply chain transparency and blockchain adoption. Manag. Sci. 66 (10), 4378–4396. https://doi.org/10.1287/mnsc.2019.3434.

Christidis, K., Devetsikiotis, M., 2016. Blockchains and smart contracts for the internet of things. IEEE Access 4, 2292–2303. https://doi.org/10.1109/ACCESS.2016.2566339.

Del Aguila-Obra, A.R., Padilla-Meléndez, A., 2006. Organizational factors affecting Internet technology adoption. Internet Res. 16 (1), 94–110.

Frambach, R.T., Schillewaert, N., 2002. Organizational Innovation Adoption: A Multi-Level Framework of.

Freeman, R.E., Dmytriyev, S.D., Phillips, R.A., 2021. Stakeholder theory and the resource-based view of the firm. J. Manag. 47 (7), 1757–1770.

Gault, F., 2018. Defining and measuring innovation in all sectors of the economy. Res. Pol. 47 (3), 617–622. https://doi.org/10.1016/j.respol.2018.01.007.

Gomber, P., Kauffman, R.J., Parker, C., Weber, B.W., 2018. On the fintech revolution: interpreting the forces of innovation, disruption, and transformation in financial services. J. Manag. Inf. Syst. 35 (1), 220–265.

Gomaa, A.A., Gomaa, M.I., Boumediene, S.L., Farag, M.S., 2023. The creation of one truth: single-ledger entries for multiple stakeholders using blockchain technology to address the reconciliation problem. J. Emerg. Technol. Account. 20 (1), 59–75.

Gong, Y., 2020. Blockchain Trend Report Da Ling Think Tank (2019).

Gupta, C., Gupta, V., Fernandez-Crehuet, J.M., 2023. A blockchain-enabled solution to improve intra-inter organizational innovation processes in software small medium enterprises. Engineering Reports 5 (7), e12674. https://doi.org/10.1002/eng2.12674.

Gupta, P., 2006. Institutionalizing innovation for growth and profitability. J. Private Equity 9 (2), 57–62.

Gürkaynak, G., Yılmaz, İ., Yeşilaltay, B., Bengi, B., 2018. Intellectual property law and practice in the blockchain realm. Comput. Law Secur. Rep. 34 (4), 847–862. https://doi.org/10.1016/j.clsr.2018.05.027.

Hasan, M.R., Shiming, D., Islam, M.A., Hossain, M.Z., 2020. Operational efficiency effects of blockchain technology implementation in firms. Review of International Business and Strategy 30 (2), 163–181. https://doi.org/10.1108/RIBS-05-2019-0069.

Hileman, 2017. Forward. In: Morabito, V. (Ed.), Business Innovation through Blockchain. Springer p.v.

Huang, B., Li, H., Liu, J., Lei, J., 2023a. Digital technology innovation and the high-quality development of Chinese enterprises: evidence from Enterprise's digital patents. Econ. Res. J. 58 (3), 97–115.

Huang, X., Wang, H., Sun, Y., Yu, L., 2023b. Digital Technology and the Upgrade of Export Quality:Evidence from patent text with machine learning. Journal of Quantitative & Technological Economics 40 (12), 69–89. https://doi.org/10.13653/j.cnki.jqte.20231018.002.

Iansiti, M., Lakhani, K.R., 2017. The truth about blockchain. Harv. Bus. Rev.

Jiang, N., Liu, X., Xu, M., 2021. Evaluating blockchain technology and related policies in China and the USA. Sci. Publ. Pol. 48 (4), 562–575. https://doi.org/10.1093/scipol/scab032.

Joseph, C., Norizan, S., Enggong, T.S., Rahmat, M., Nyet, C.A., 2022. Realizing sustainable development goals via entrepreneurial digital mindset: resource-based view perspective. Int. J. Account. 7 (42).

Kant, N., 2021. Blockchain: a strategic resource to attain and sustain competitive advantage. Int. J. Innovat. Sci. 13 (4), 520–538.

Kant, N., Anjali, K., 2020. Can blockchain be a strategic resource for ODL?: a study. Asian Assoc. Open Univ. J. 15 (3), 395–410.

Kataria, A., Nandal, N., 2020. Measuring innovation: challenges and best practices. International Journal of Advanced Science and Technology 29.

Kayal, A., 1999. Measuring the pace of technological progress: implications for technological forecasting. Technol. Forecast. Soc. Change 60 (3), 237–245. https://doi.org/10.1016/S0040-1625(98)00030-4.

Kwon, H.B., Lee, J., 2019. Exploring the differential impact of environmental sustainability, operational efficiency, and corporate reputation on market valuation in high-tech-oriented firms. Int. J. Prod. Econ. 211, 1–14.

Li, W., Pan, W., Yuan, K., 2022. Enterprise digital transformation and the development of China's real economy. Journal of Quantitative & Technological Economics 39 (9), 5–25. https://doi.org/10.13653/j.cnki.jqte.20230418.001.

Liu, Z., Li, Z., 2020. A blockchain-based framework of cross-border e-commerce supply chain. Int. J. Inf. Manag. 52, 102059. https://doi.org/10.1016/j.ijinfomgt.2019.102059.

Li, Z., Xu, Z., Sukumar, A., 2023. Digital resilience and firm internationalization: a study of Chinese listed companies. J. Enterprise Inf. Manag. https://doi.org/10.1108/JEIM-02-2023-0095.

Madhani, P.M., 2010. The resource - based view (RBV): issues and perspectives. PACE, A Journal of Research of Prestige Institute of Management 1 (1), 43–55. January 2010.

Massaro, M., 2023. Digital transformation in the healthcare sector through blockchain technology. Insights from Academic Research and Business Developments.

Morabito, V., 2019. Business Innovation through Blockchain: the B3 Perspective. Springer, *Cham*. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85111257807&partnerID=40&md5=f53c9bac8090ae9531099e8e2defcba7.

Morkunas, V.J., Paschen, J., Boon, E., 2019. How blockchain technologies impact your business model. Bus. Horiz. 62 (3), 295–306.

Munier, F., 2006. Firm size, technological intensity of sector and relational competencies to innovate: evidence from French industrial innovating firms. Econ. Innovat. N. Technol. 15 (4–5), 493–505.

Nakamoto, S., 2009. Bitcoin: a peer-to-peer electronic cash system. available at: https://bitcoin.org/bitcoin.pdf. (Accessed 9 December 2017).

Nofer, M., Gomber, P., Hinz, O., Schiereck, D., 2017. Blockchain. Business & information systems engineering 59, 183–187.

Nowiński, W., Kozma, M., 2017. How Can Blockchain Technology Disrupt the Existing Business Models?.

Noonan, L., 2018. China Leads Blockchain Patent Applications. Financial Times. https://www.ft.com/content/197db4c8-2e92-11e8-9b4b-bc4b9f08f381.

OECD, 2009. OECD Patent Statistics Manual. OECD Publishing, Paris.

OECD/Eurostat, 2018. *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation*. In: The Measurement of Scientific, Technological and Innovation Activities, 4th Edition. OECD Publishing, Paris. https://doi.org/10.1787/9789264304604-en.

Oh, D.-S., Phillips, F., Park, S., Lee, E., 2016. Innovation ecosystems: a critical examination. Technovation 54, 1–6. https://doi.org/10.1016/j.technovation.2016.02.004.

Oh, J., Shong, I., 2017. A case study on business model innovations using Blockchain: focusing on financial institutions. Asia Pacific Journal of Innovation and Entrepreneurship 11 (3), 335–344. Scopus.

Pan, X., Pan, X., Song, M., Ai, B., Ming, Y., 2020. Blockchain technology and enterprise operational capabilities: an empirical test. Int. J. Inf. Manag. 52, 101946. https://doi.org/10.1016/j.ijinfomgt.2019.05.002.

Parolin, G., McAloone, T.C., Pigosso, D.C., 2024. How can technology assessment tools support sustainable innovation? A systematic literature review and synthesis. Technovation 129, 102881.

Pilkington, M., 2016. Blockchain technology: principles and applications. In: Research Handbook on Digital Transformations. Edward Elgar Publishing, pp. 225–253.

Queiroz, M.M., Wamba, S.F., 2019. Blockchain adoption challenges in supply chain: an empirical investigation of the main drivers in India and the USA. Int. J. Inf. Manag. 46, 70–82.

Rico-Peña, J.J., Arguedas-Sanz, R., López-Martin, C., 2023. Models used to characterise blockchain features. A systematic literature review and bibliometric analysis. Technovation 123, 102711. https://doi.org/10.1016/j.technovation.2023.102711.

Rosiello, A., Maleki, A., 2021. A dynamic multi-sector analysis of technological catch-up: the impact of technology cycle times, knowledge base complexity and variety. Res. Pol. 50 (3), 104194.

Saberi, S., Kouhizadeh, M., Sarkis, J., Shen, L., 2019. Blockchain technology and its relationships to sustainable supply chain management. Int. J. Prod. Res. 57 (7), 2117–2135.

Schmitz, J., Leoni, G., 2019. Accounting and auditing at the time of blockchain technology: a research agenda. Aust. Account. Rev. 29 (2), 331–342. https://doi.org/10.1111/auar.12286.

Secinaro, S., Calandra, D., Secinaro, A., Muthurangu, V., Biancone, P., 2021. The role of artificial intelligence in healthcare: a structured literature review. BMC Med. Inf. Decis. Making 21, 1–23.

Shiva, et al., 2023. https://golab.bsg.ox.ac.uk/documents/exploring-blockchain-technologies-for-collaboration-and-partnerships.pdf.

Spanò et al. Spanò, R., Massaro, M., Iacuzzi, S., 2021. Blockchain for Value Creation in the Healthcare Sector Technovation, vol. 2021, 102440. https://doi.org/10.1016/j.technovation.2021.102440.
Statista. https://www.statista.com/statistics/1285636/china-blockchain-market-size/, 2023.
Stroh, T., Mention, A.L., Duff, C., 2023. The impact of evolved psychological mechanisms on innovation and adoption: a systematic literature review. Technovation 125, 102759.
Tapscott, D., Tapscott, A., 2017. How blockchain will change organizations. MIT Sloan Manag. Rev. 58 (2), 10.
Tandon, A., Dhir, A., Islam, A.N., Mäntymäki, M., 2020. Blockchain in healthcare: a systematic literature review, synthesizing framework and future research agenda. Comput. Ind. 122, 103290.
Tidd, J., Bessant, J.R., 2020. Managing Innovation: Integrating Technological, Market and Organizational Change. John Wiley & Sons.
Tse, Y.K., Wang, S., Liu, X., Wu, C.H., 2022. Untangling operational performance implication of ambidextrous blockchain initiatives: an empirical investigation of Chinese manufacturers. Ind. Manag. Data Syst. 123 (2), 556–577. https://doi.org/10.1108/IMDS-05-2022-0298.
Tseng, F.-M., Liang, C.-W., Nguyen, N.B., 2023. Blockchain technology adoption and business performance in large enterprises: a comparison of the United States and China. Technol. Soc. 73, 102230. https://doi.org/10.1016/j.techsoc.2023.102230.
Turró, A., Urbano, D., Peris-Ortiz, M., 2014. Culture and innovation: the moderating effect of cultural values on corporate entrepreneurship. Technol. Forecast. Soc. Change 88, 360–369. https://doi.org/10.1016/j.techfore.2013.10.004.
Underwood, S., 2016. Blockchain beyond bitcoin. Commun. ACM 59 (11), 15–17.
Upadhyay, A., Mukhuty, S., Kumar, V., Kazancoglu, Y., 2021. Blockchain technology and the circular economy: implications for sustainability and social responsibility. J. Clean. Prod. 293, 126130.
Vaidyanathan, G., Devaraj, S., 2008. The role of quality in e-procurement performance: an empirical analysis. J. Oper. Manag. 26 (3), 407–425.
Walport, M., 2016. Distributed Ledger Technology: beyond Block Chain. Government Office for Science. https://www.gov.uk/government/publications/distributed-ledger-technology-blackett-review.
Wang, Q., Su, M., Li, R., 2020. Is China the world's blockchain leader? Evidence, evolution and outlook of China's blockchain research. J. Clean. Prod. 264, 121742. https://doi.org/10.1016/j.jclepro.2020.121742.
Weking, J., Mandalenakis, M., Hein, A., Hermes, S., Böhm, M., Krcmar, H., 2020. The impact of blockchain technology on business models – a taxonomy and archetypal patterns. Electron. Mark. 30 (2), 285–305. https://doi.org/10.1007/s12525-019-00386-3.
Xiao, L., Xu, X., Xue, W., 2024. Blockchain mania without bitcoins: evidence from the Chinese stock market. Res. Int. Bus. Finance 67, 102141. https://doi.org/10.1016/j.ribaf.2023.102141.
Yeung, A.C.L., 2008. Strategic supply management, quality initiatives, and organizational performance. J. Oper. Manag. 26 (4), 490–502.
Yli-Huumo, J., Ko, D., Choi, S., Park, S., Smolander, K., 2016. Where is current research on blockchain technology?—a systematic review. PLoS One 11 (10), e0163477.
Zheng, S., Li, Z., 2020. Pilot governance and the rise of China's innovation. China Econ. Rev. 63, 101521. https://doi.org/10.1016/j.chieco.2020.101521.
Zheng, Z., Xie, S., Dai, H., Chen, X., Wang, H., 2017. An overview of blockchain technology: architecture, consensus, and future trends. In: 2017 IEEE International Congress on Big Data (BigData Congress), pp. 557–564.
Zou, W., Lo, D., Kochhar, P.S., Le, X.B.D., Xia, X., Feng, Y., et al., 2019. Smart contract development: challenges and opportunities. IEEE Trans. Software Eng. 47 (10), 2084–2106.