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INNOVATION UNDER AN UMBRELLA: HOW CAN BLOCKCHAIN CONTRIBUTE TO CORPORATE INNOVATION IN THE AGE OF GLOBALIZATION

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Abstract. In the age of globalization, enterprises have faced new challenges and opportunities for innovative behavior. Increasing cultural exchanges provide enterprises with a wealth of information and knowledge, but also exacerbate the risk of information loss. Therefore, information security has become an increasingly critical issue. Blockchain technology is an effective guarantee for the success of enterprise innovation in such circumstances. Enterprises can access information across national boundaries and avoid the risk of a cultural clash or a leak of information due to the security and traceability of blockchain technology. In the era of globalization, blockchain technology has become an umbrella for enterprises to exploit cultural diversity. This study presents a DDD model that illustrates how blockchain firms can benefit from cultural diversity to produce innovative products. Specifically, firms that utilize blockchain increase their innovation output by 36.17% compared to those that do not. Additionally, it explores how firms can benefit from the spillover of external knowledge and how traditional models of R&D through equipment purchases give way to new models of bringing in talent for knowledge exchange using blockchain. The model presented in this study provides a novel theoretical perspective on how emerging technologies affect corporate innovation, emphasizing the importance of blockchain technology to corporate innovation in an era of globalization with increasing cultural exchanges. It also provides a new perspective on the application of emerging technologies.

Keywords: blockchain, corporate innovation, cultural diversity, the DDD model.

JEL Classification: D81, F63, O31.

Introduction

Over the past century, the world economy has grown by leaps and bounds, with several countries and regions experiencing significant success. Numerous attempts have been made to determine the reasons behind this success (Noland & Pack, 2003; Dell et al., 2018). The acceleration of globalization, and the resulting increase in cultural exchanges and technologi-

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cal progress is a substantial shift from the past. A brand-new era of technology, including blockchain, IoT (Internet of Things) and artificial intelligence, has given rise to novel directions. Once again, technological advancement has become one of the key drivers of economic growth and social transformation (Grossman & Helpman, 1994; Garcia-Macia et al., 2019).

According to studies, cultural diversity is viewed as a "credit" to technological advancements and a boon to globalization (Ambirajan, 2000; Spring, 2008). Cultural diversity is frequently viewed as a "toolkit" because the richer the culture of the region in which a firm is located, the more diverse its access to information, and the better its perception of the changing external environment, leading to a strong creative capacity (Swidler, 1986). If cultural diversity is considered a coin, each coin has two sides. Cultural diversity within the Organization has its "head" side (Hallett & Ventresca, 2006; Stark, 2011). Other scholars have presented a different view. They argue that communication in different languages and customs can affect the functioning of an organization and increase communication costs. Furthermore, firms may face the risk of innovation leakage since they cannot guarantee that everyone may protect the secrets of the company's innovations when communicating with different racial groups (Corritore et al., 2020). However, cultural diversity can only promote corporate innovation if demanding conditions are met, such as a cultural consensus (Van Knippenberg & Schippers, 2007). It is the "tail" of cultural diversity.

While it is debatable whether cultural exchange resulting from cultural diversity promotes technological innovation, there is a consensus that technological innovation facilitates economic growth and social progress. Specifically, innovation promotes the reorganization of existing resources and the exploitation of new resources in a wide range of areas and sectors of social development and the application of cutting-edge technologies, products and models (Edquist, 2005). It has improved the competitiveness and viability of firms (Fagerberg et al., 2005). However, it has effectively increased the average income of the location and contributed to the region's economic growth (Romer, 1990). The solution to the problem lies in utilizing the "positive" aspects of cultural diversity to support technological innovation. An effective solution to this problem requires an analysis of the advantages and challenges faced by companies subject to technological innovation.

Innovation should be recognized as a risky, and uncertain process. When innovative activities fail, innovators face the dilemma of losing their money, thus discouraging people from undertaking innovative activities (Kline et al., 1986; Fagerberg et al., 2013). Innovative risks have been mitigated in the age of globalization, but different subjects have been adapted to cope with innovation risks to varying degrees. Blockchain, an emerging technology with anonymity, transparency, security, traceability, and efficiency, has changed how data is stored, retrieved, and shared (Milovich et al., 2020). It has been demonstrated that companies can use blockchain technology to gain access to more knowledge and information resources, reduce the risks associated with conducting innovation activities, and thus increase the probability of success (Khan & Salah, 2018). Other literature indicates that innovation agents must have dynamic capabilities due to the more sophisticated external environment and frequent information exchanges in the age of globalization. Otherwise, firms may face innovation risk failure and the dilemma that even if the innovation is successful, it has been lost to the market and cannot be realized due to inadequate timely information collection (Teece, 2014;

Yeow et al., 2018). In light of these analyses, it is evident that the role of cultural diversity is heightened in the digital era and that utilizing cultural diversity to promote corporate innovation can mitigate certain risks. However, failure to leverage cultural diversity effectively can expose one to the risk of being eliminated by the times, even if the innovation succeeds.

In summary, the impact of cultural diversity in the context of globalization and blockchain application has become a hot topic in recent years (Corritore et al., 2020; Liu et al., 2021; Dymek et al., 2022). However, little is known about whether blockchain technology can intervene in the impact of cultural diversity. As blockchain technology rapidly develops and is used in international exchanges, this cannot be ignored. Based on the above analysis, we summarize the research contributions as follows:

First, a theoretical model of blockchain technology influencing innovation in the context of globalization is developed. This is followed by a discussion of how blockchain technology can be used to help enterprises use external information through security and efficiency, thus leading to new business model development in the age of globalization.

Second, the concept of cultural diversity and blockchain technology is explored. An effective model for avoiding the "negative" effects of cultural diversity through blockchain technology is presented and tested using a DDD model.

Additionally, it offers a distinct perspective on applying blockchain technology in the context of globalization. It illustrates how blockchain technology can change the traditional model of corporate investment in R&D, and enable effective corporate innovation through exchanging external knowledge.

This research consists of six parts: the first is the introduction; the second is the literature review and theoretical framework; the third is the empirical methodology and data description; the fourth is the analysis of the empirical results; the fifth is the robustness test; and finally, the conclusion and policy recommendations are provided.

1. Literature review and conceptual framework

1.1. Corporate innovation and risk

In terms of type, innovation can be divided into cumulative and disruptive. A cumulative innovation refers to continuous additions to an original foundation, whereas a disruptive innovation is the development of a new product without the contributions of the original foundation but through the incorporation of some elements (Schumpeter, 2010). Companies may undertake one type of innovation or invest in both depending on the resources and needs of the firm (Acemoglu & Akcigit, 2012; Acemoglu et al., 2018). According to existing research, market size and location are important determinants of a firm's innovation behavior. The firm must anticipate market changes and preferences in advance, its product development must address the needs of the future market. Additionally, since it takes time to transform a firm's innovations into products, firms must understand and evaluate the past market (Acemoglu & Linn, 2004). Furthermore, research indicates that industry plays a significant role in determining innovation differences. There are certain industries that are highly technology-intensive and have exceptionally short product life cycles. Companies in these industries can only survive through continuous innovation (Hitt et al., 2001). In addi-

tion, where a company is in the market is very important. Incumbent companies invest in small improvements to their products, while challenger companies invest in big, disruptive ideas (Acemoglu & Linn, 2004). In a dynamically changing environment, the entry of challenger firms reduces the profitability of incumbent firm innovations. This mechanism may reduce aggregate productivity growth, causing incumbent firms to invest in new innovative creations (Acemoglu & Linn, 2004).

Innovation activities generate revenue for companies, and require significant resource consumption and R&D investment, indicating that companies are exposed to significant risk and uncertainty (Acemoglu et al., 2018). Consequently, government subsidies and industrial policy incentives are particularly important to firms' willingness to innovate. In Europe, governments subsidize large companies because they can better channel subsidies into efficient innovation outcomes. Simultaneously, governments encourage large firms to invest more, increase productivity, and add jobs (Aghion et al., 2015). It encourages companies to innovate while redistributing social resources and promoting economic growth (Acemoglu et al., 2018).

In the age of globalization, corporate innovation faces various risks and uncertainties, including the risks of failure associated with the original innovation and those resulting from changes in the complex external environment, such as the risk that the firm cannot convert its innovation (Fragkandreas, 2013). Businesses must consider rational market expectations and gather more information to develop effective dynamic capabilities rather than just executing their idealized innovations (Eisenhardt & Martin, 2000).

Risks and uncertainties in the globalization era have changed slightly, with more frequent exchanges of information and cultural influences, requiring organizations to face the risk of failure in innovation and changes in the complex external environment, such as the risk that companies cannot realize their innovations even if they do innovate (Fragkandreas, 2013). Firms should engage in rational market expectations and comprehensive information gathering rather than merely implementing their idealized innovations to build good dynamic capabilities (Eisenhardt & Martin, 2000).

1.2. Blockchain and corporate innovation

Blockchain is an emerging technology initially utilized to track debits and credits in a distributed ledger. It records information about the parties and transactions in an encrypted form that can only be viewed by the parties involved as a distributed ledger (Milovich et al., 2020). On a deeper level, blockchain technology offers significant advantages such as anonymity, transparency, security, traceability, and high efficiency of transactions, leading to low transaction costs (Liang et al., 2021). Transparency implies that anyone can view the records of the transaction, which cannot be altered, whereas anonymity implies that the sender and receive identities are hidden. Blockchain is increasingly significant in business innovation due to its unique advantages (Hawlitschek et al., 2018).

The benefit of blockchain is the encryption of confidential information. It addresses the problem that enterprise data and information security cannot be guaranteed due to the proliferation of information and knowledge sharing channels. Furthermore, as the blockchain

platform is decentralized, it reduces the costs associated with information sharing and other transaction forms. It implies that enterprises can significantly improve the efficiency of gathering information, transforming how they invest large sums of money into R&D equipment for innovation, and that enterprises may be more inclined to bring in experts to share knowledge through the blockchain platforms (Milovich et al., 2020). For example, PingAn Group, one of the largest financial organizations in China, has established a supply chain service platform (SAS) through blockchain. Enterprises that are connected to this platform can share vital information. Since the information is encrypted, it cannot be viewed by companies outside the platform, guaranteeing complete information security. Moreover, given the traceability of blockchain, if the information inside the platform is leaked, the source may be immediately identified, allowing this platform to facilitate the sharing of essential technologies that are not patentable. Therefore, the level of corporate innovation has been enhanced further (Guan et al., 2021).

In the age of globalization, the external environment changes rapidly, so a firm's dynamic capabilities are crucial. Enterprise dynamic capability refers to an organization's ability to quickly and effectively adapt to technological changes. It focuses on how businesses adapt their resources, routines, products, and services to a rapidly changing business environment (Teece, 2007). Thus, blockchain technology can enhance the dynamic capabilities of companies and reduce the risk of ineffective innovation. However, most of the blockchain's impact on business innovation research focuses on theoretical models. Few studies have investigated the mechanisms by which blockchain can impact enterprise innovation from an empirical perspective.

1.3. Cultural diversity and corporate innovation

There is a long-standing discussion regarding the impact of cultural diversity on corporate innovation. Several studies have discovered that one important reason for the abundance of innovations among MNCs is that they operate in a different cultural environment and are exposed to more information and knowledge (Maznevski & Athanassiou, 2006). Some scholars support this view.

Multinational corporate groups can contribute to corporate innovation (Harvey & Griffith, 2007). This cultural diversity can provide them with an advantage in terms of information. Since this information is typically translated into various languages, members from diverse cultural backgrounds can offer information from various countries. Additionally, localized teams can generate better and more creative ideas by combining different perspectives (McLeod & Lobel, 1992). Furthermore, people from different cultures can analyze and process information from various cultural contexts with greater depth, allowing them to understand the information better and reveal hidden patterns (Dahlin et al., 2005).

Nevertheless, some scholars have criticized these views. In their view, cultural diversity does not always positively impact business innovation. It is important to note that cultural diversity may result in language barriers and conflicts, which can adversely impact access to information by companies. Furthermore, cultural diversity can lead to conflict in customs and conflicts among team members due to miscommunication between different countries,

decreasing team effectiveness. Additionally, cultural diversity can lead to information advantages and leakage, which impairs the pursuit of corporate innovation (Corritore et al., 2020). Accordingly, firms can only function if they create a sense of cultural identity or belong to a specific organization.

Cultural diversity, like a coin, has both positives and negatives, so these discussions have some validity. The primary advantage of cultural diversity is knowledge and information transfer, while the primary disadvantage is that it reduces business operations efficiency (Stark, 2011). In today's globalized world, cultural diversity plays a larger role, making it relevant to discuss how to harness the positive effects of cultural diversity. Although certain conditions are required to reap the benefits of cultural diversity, little research has been conducted on whether emerging technologies, such as blockchain, can take advantage of cultural diversity. In this area, research has been lacking.

1.4. Theoretical framework and hypothesis

Firms would gain a competitive advantage by implementing innovative technologies. However, innovation is also fraught with risk, as the act of innovation itself may fail, leading to a firm losing all of its R&D investments. Moreover, companies may face the dilemma of not realizing their innovation results due to the complex external environment (Acemoglu et al., 2018).

The frequency of cultural exchanges and the exchange of information have increased with the onset of the globalization period. Cultural diversity provides businesses significant knowledge and growth incentives (Harvey & Griffith, 2007). However, employees from various cultural backgrounds are usually prone to culture conflicts because they interact more frequently and deeply owing to the presence of language barriers, which is particularly damaging to the dissemination and exchange of knowledge. This is one of the harmful consequences of cultural diversity. Furthermore, cultural diversity benefits information while increasing the danger of information leakage (Corritore et al., 2020). Information leakage is a fundamental obstacle to company innovation failure.

As a distributed ledger, blockchain enables the encrypted recording of information and transactions between parties. The parties cannot change the recorded information at will, thereby avoiding information leakage and maximizing the security of the parties' information (Milovich et al., 2020). The detrimental impact of information leakage caused by cultural variety may be minimized by employing blockchain's qualities of anonymity, traceability, and transparency (Liang et al., 2021). Consequently, businesses use cultural diversity expertise and information to reduce the danger of possible information leakage, and the efficiency of information exchange within the organization is considerably boosted, fostering corporate creativity.

In this sense, blockchain can serve as an umbrella for business innovation in the age of globalization. Based on the above analysis, the first hypothesis is proposed:

H1: Companies that utilize blockchain technology can better exploit the knowledge and information resources associated with cultural diversity and are better equipped to engage in corporate innovation than those that do not.

Simultaneously, cultural interactions are becoming common in the age of globalization, and the external environment in which businesses operate is fast changing. Because corporate

innovation is characterized by high risk, high expenditure, and a long return period, rapid changes in the external environment contribute to the unpredictability of corporate innovation success. Furthermore, enterprise innovation necessitates turning innovation results into new products that can be introduced to the market, bringing direct benefits to the enterprise or using new technology to reduce the production cost of original products and improve market competitiveness and market share of products. At this point, businesses urgently need the help of external forces to carry out innovation smoothly. Blockchain technology provides a peer-to-peer and decentralized platform for enterprise information sharing, allowing the quality of knowledge and information sharing to be significantly improved while ensuring the traceability of every information source and significantly lowering the cost of information exchange. This enables businesses to take advantage of innovation possibilities. However, it creates incentives for the commercialization of current technologies. Therefore, businesses may raise their R&D spending and aggressively support the study and use of blockchain technology to enhance their innovation performance. Thus, this research proposes the second hypothesis:

H2: Blockchain-based companies may invest more in R&D to facilitate the commercialization of their innovations.

The increasing frequency of cultural exchanges has led to rapid changes in the external environment, requiring companies to have a stronger dynamic capability to adapt to the complex external environment constantly. The traditional innovation model, which involves purchasing equipment for experimentation, has a relatively long investment cycle and cannot compete in a rapidly changing environment. Therefore, some companies try to change the way they invest in R&D and devote their capital investment to bringing in talents and building digital platforms to gain wider access to external information and knowledge to maintain innovation vitality and achieve innovation with high efficiency. Therefore, the third hypothesis is as follows:

H3: Firms utilizing blockchain technologies alter their R&D investment patterns, with capital investments in R&D giving way to expenditure investments in R&D.

The theoretical framework of this study is shown in Figure 1.

2. Methodology

2.1. Model illustration

The innovative behavior of firms is motivated by various motivations. One of the principal goals of firms is to obtain monopoly rents or market position through patenting (Scotchmer, 1999; Gallini & Scotchmer, 2002). In a previous analysis, it was pointed out that as the outside world gets more complicated, scientific and technological advances may become harder to commercialize or adapt to the market.

Therefore, firms must decide whether to innovate or wait for others to do so and benefit from knowledge spillover. In the next section, we built a model to illustrate how firms decide whether to experiment on their own or wait for others to develop new ideas.

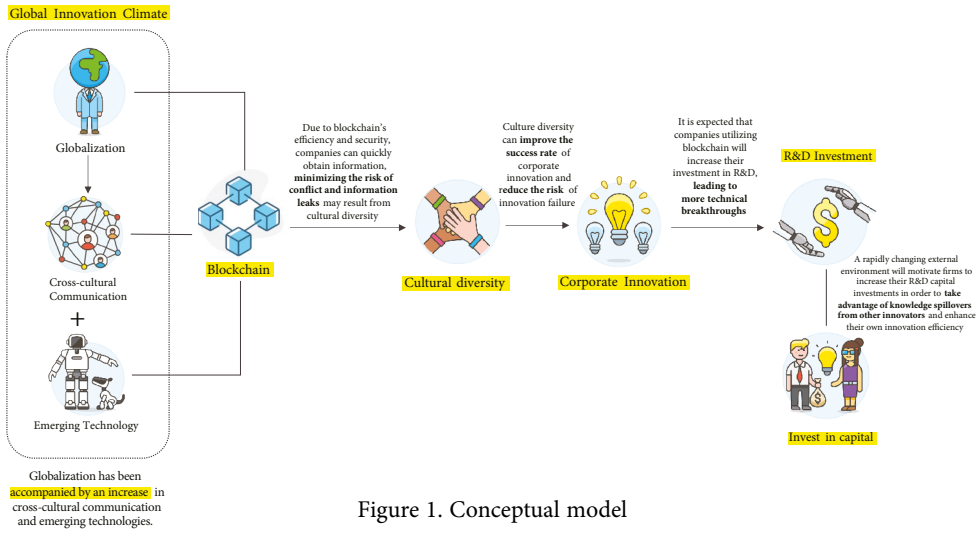

Figure 1. Conceptual model

This study refers to the assumptions underlying the Acemoglu's et al. (2011) model. Assume that there are $N \geq 2$ firms in the market, that time goes on forever, that there is a discount rate $r \geq 0$ for successful future trials by firms, and that each firm can choose to conduct an experiment with a success rate $p \geq 0$.

Companies have several options. At time t, a firm can choose to gain monopoly profits by conducting its own experiments to achieve technology advances. Alternatively, the firm can pay a fee to use the information gathered from others. This fee is to improve its product or business model.

Assume that the profit that each firm can bring from its own innovation or from observing the innovative behavior of others is α_n and that the profit of each firm can be discounted as Q_n. The equation is as follows:

$$Q_n = \frac{\alpha_n}{r}. \tag{1}$$

In cases where several firms complete an experiment simultaneously, they would share the profits equally. Based on Acemoglu's et al. (2011) assumptions, there are only two firms, and each firm receives 50% of the profit.

$$\alpha_1 > \alpha_2 > p\alpha_1. \tag{2}$$

If $\beta = \frac{Q_2}{Q_1}$ is defined, then $\beta > p$.

On this basis, this study discusses asymmetric pure strategy equilibrium. Suppose there are two environments: one with a high level of cultural diversity where information is disseminated more quickly and the cost of obtaining information for the firm is zero. The other is a low cultural diversity environment where information is disseminated slower and the cost of obtaining information for the firm is $k(t, c)$. In an environment where information is spread more rapidly,

$$\frac{Q_N}{Q_1} > p. \tag{3}$$

Since knowledge spreads rapidly and at no cost, when one business succeeds, other businesses prefer to pay for its information to be promptly produced. When one firm's innovation fails, other enterprises have the option to experiment immediately. One could alternatively argue that purchasing the knowledge of others is inexpensive, or that a business only needs to know that others have succeeded.

When businesses operate in an environment with sluggish information distribution, they must pay a high-cost *k*, including time and money, to receive knowledge from others. When this cost is high enough, businesses prefer to undertake their own experiments than observing the behavior of others. This makes the whole market pretty chaotic, which is also called "market failure due to information asymmetry" because resources are squandered and social welfare declines.

The discussion of firm strategies in the case of symmetric equilibrium continues below. Acemoglu's et al. (2011) hypothesis is brought up again to learn more about how the spread of information affects company innovation:

$$\text{when } n \geq 2,\ Q_n = Q_2. \tag{4}$$

From moment t_0 on, we define experimentation speed as φ_n. There are currently n firms that have not conducted an experiment. In the case where the value from ongoing experiments is $v_n(t)$, then the value a firm can obtain by choosing to conduct an experiment at moment t_{0+t} is

$$v_n(t) = \int_{t_0}^{t_{0+t}} \phi_n(n-1) e^{-\phi_n(n-1)(z-t_0)} \left[pQ_2 + (1-p) v_{n-1} \right] dz + e^{-\phi_n(n-1)t} e^{-rt} pQ_2. \tag{5}$$

Specifically, since information transfer costs are negligible and cultural diversity is high, other firms would be able to observe the results of a successful experiment at no cost in $z \in (t_0, t_{0+t})$. Other firms will follow this firm or replicate its results, and the value that each firm will be able to extract is $e^{-r(z-t_0)}Q_2$. In the event that a firm does not succeed in its experiment, there will be n-1 remaining firms. Suppose a firm decides to experiment at this point. The value that may be obtained is $e^{-rt}pQ_2$. At this point, $1 - \int_{t_0}^{t_0+t} \phi_n(n-1) e^{-\phi_n(n-1)(z-t_0)} dz = e^{-\phi_n(n-1)t}$ is the probability that this event would occur. It can be simplified as follows:

$$\phi_n(n-1)\left[pQ_2 + (1-p) v_{n-1} \right] = \left(\phi_n(n-1) + r \right) pQ_2. \tag{6}$$

As indicated in the previous hypothesis, $v_n = pQ_2$, $n \geq 2$ implies that firms are able to receive information at no cost, and firms do not take any risks by experimenting. No matter if the company waits for the results of others or carries out its own experiments, its value remains the same. Therefore, it can be concluded that:

$$\phi_n = \frac{rQ_2}{(1-p)(n-1)Q_1}. \tag{7}$$

At this point, ϕ_n indicates the speed of the mixed experiment for the firm, and that after one firm's experiment fails and the information dissemination is optimal, the most prudent

course of action for the other firms is to speed up the mixed experiment. Furthermore, this equilibrium changes when the cost of dissemination of information is k. Then, we have $v_n = p(Q_2 + k)$. Firms are only motivated to experiment if the benefits they obtain and the costs they incur equal the first discounted value. Thus, we have Equation (8) as follow.

$$\phi_n = \frac{r(Q_2 + k)}{(1-p)(n-1)Q_1}. \tag{8}$$

The results suggested that when firms' experiments fail due to poor information conditions, other firms may accelerate their experiments rapidly. Experiment speedup varies according to the cost of obtaining information for different firms. The discussion of k here is limited, and a speedup coupled with information asymmetry could lead to resource waste and a reduction in social welfare.

Overall, external knowledge and information play an instrumental role in enterprise innovation and influence enterprises' decisions regarding innovation strategy. The better the external information environment, the slower the competitive environment and the faster the pace of experimentation conducted by enterprises, the greater the social welfare and the less wasteful it is. Otherwise, companies may only pursue a single-minded pursuit of speed, resulting in ineffective innovation and decreased efficiency. A similar innovation environment can be observed in the implementation of blockchain technology, where the security and efficiency of the technology allow companies to exchange information, reduces inefficient competition among companies, and increases the overall efficiency of business innovation.

2.2. Empirical model

The preceding analysis explained the research background and research questions. We proposed the hypothesis that blockchain can be applied to facilitate corporate innovation by exploiting the positive aspects of cultural diversity through logical deduction. Particularly, companies can gain knowledge and information advantages from diverse cultures that can facilitate innovation using blockchain. We also utilize a theoretical model to illustrate the impact of blockchain technology on business innovation based on the exchange of information.

The Difference in Difference in Difference (DDD) model was proposed to assess the impact of the introduction of the 2016 blockchain white paper to test the hypotheses and perform logical consistency econometric tests on them. In the subsequent section, robustness tests were performed using the generalized DID model.

The 2016 was utilized as the year of the national White Paper on Blockchain Technology and Applications in China (China Academy of Information and Communications Technology, 2016) to examine the impact of blockchain use on corporate innovation after legalization. The sample was selected from listed enterprises, excluding delisted enterprises, ST enterprises[1], and missing data, and the panel was constructed from 2013 to 2020. Organizations used blockchain at varying times since some enterprises may begin using blockchain in 2017 after the publication of the white paper. A multi-period DDD model was constructed that considers the heterochrony of enterprises' use of blockchain. Based on previous research by Li et al.

[1] ST enterprises (Special Treatment enterprises) are listed companies whose financial or other conditions are abnormal and are at risk of delisting. According to the regulations of the China Stock Exchange, the stock code must be preceded by the "ST" as a warning to the market.

(2016), this study employed a "two-way fixed effects model", which accounts for "individual fixed effects" and "time fixed effects". The DDD model is set up as indicated in equation (9):

$$Y_{it} = \alpha_1 + \beta_1 \text{treat}_i \times \text{culture}_i \times \text{post}_t + \beta_2 \text{culture}_i \times \text{post}_t + \beta_3 \text{treat}_i \times \text{post}_t + \delta Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \quad (9)$$

2.2.1. Dependent variables

In the model above, the dependent variable Y_{it} corresponds to the number of patents filed by each firm for independent innovation, denoted by *Invia*, representing the difference between the firm's innovation outcomes (Acemoglu et al., 2011; Wan et al., 2022). Treat_I is a dummy variable that distinguishes between the experimental and the control groups. If the firm uses blockchain technology, it belongs to the experimental group, and the variable has a value of 1; if the firm does not use blockchain technology, it belongs to the control group, and the variable has a value of 0. Additionally, cultural diversity is another important criterion for classifying groups. A region's cultural diversity can be explained by its linguistic diversity. According to Xu et al. (2015), the dialect index was calculated. Because the language index belongs to the interval, it was set to 1 when it was higher than the mean of the language index, and it was set to 0 when it was lower than the mean and considered as the experimental group. Post_t is a time dummy variable, when $\text{post}_t = 1$, it indicates the year t is the year of policy shock occurrence. The Chinese white paper on blockchain was issued in 2016, but some companies may lag in using blockchain technology (Li et al., 2016). Thus 2016 was chosen as the year of the policy shock event, but the heterochronous DDD model was adopted for enterprises applying blockchain technology after that time. Z_{it} indicates a set of control variables that are described in detail below. μ_I denotes an individual fixed effect; λ_t denotes a time fixed effect; and ε_{it} is a random error term.

The model setting of this study requires additional comments. In this study, the sample comprised listed companies headquartered in different cities within China[2]. For example, Pingan Bank of China has its headquarters in Shenzhen. This study also included a measurement of differences in cultural diversity at the level of the city. Since Chinese listed companies are inherently centralized, the headquarters of listed companies frequently serve as R&D and financial centers, resulting in corporate R&D being primarily performed at headquarters. Nevertheless, it is imperative to acknowledge that different subsidiary compositions may significantly impact corporate cultural exchange. In the heterogeneity analysis section, this study discusses the presence and absence of multinational subsidiaries, and in its final section, it highlights the potential limitations of measuring cultural diversity.

2.2.2. Independent variables

In our DDD model $t = \beta_1 \text{treat}_i \times \text{culture}_i \times \text{post}_i$ is our DDD term. β_1 is the DDD term and is the core explanatory variable. Whether blockchain technology significantly impacts organizational cultural diversity was examined to gain knowledge and information advantages and affects innovation.

[2] In the sample selected for this study, there are more than two thousand eight hundred listed enterprises. These companies have their headquarters in most prefecture-level cities, including Shenzhen, Zhuhai, Anyang, Anqing, Datong, and other.

2.2.3. Control variables

Z_{it} is the control variable. (1) firm-level characteristics including the firm size (lnsize), the proportion of executive shareholding (GmShrRat), the proportion of management shareholding (MShrRat), and the proportion of shareholding of the first largest shareholder (LrgHldRt) (Acemoglu & Cao, 2015; Wan et al., 2022); (2) the characteristics of the firm's executive team, which have been documented to influence the behavior of the firm's innovation decisions (Miller et al., 1986), and gender of the firm's CEO (Gender) was added; (3) the firm's financial position and growth capability, including total liabilities (lnliability) and net profit (NetProfit) (Acemoglu et al., 2011). Table 1 shows the descriptive statistics of the variables.

Table 1. Descriptive statistics of variables

Variables	Index	Mean	Standard deviation	Minimum	Maximum
Invia	Inventions independently filed by companies	98.6299	0.0000	5,495.0000	98.6299
lnsize	Logarithm of total assets of listed companies	1.4873	14.9416	31.0359	1.4873
Gender	Gender of chairman of listed companies	0.2320	1.0000	2.0000	0.2320
GmShrRat	Shareholding ratio of senior management of listed companies	18.6037	0.0000	99.4496	18.6037
LrgHldRt	Shareholding ratio of top shareholders of listed companies	14.9247	0.2900	89.9900	14.9247
ROTA	Return on assets of listed companies	0.1390	–2.1947	10.6160	0.1390
ROE	Return on net assets of listed companies	1.2743	–174.8947	8.7150	1.2743
liability	Logarithm of total liabilities of listed companies	1.8487	11.6019	31.0466	1.8487
NetProfit	Net profit of listed companies	9.1800e+09	–4.0500e+10	3.1800e+11	9.1800e+09
Edu	Education level of chairman of listed companies	0.8750	1.0000	7.0000	0.8750
InDrcNum	Number of independent directors of listed Companies	1.4555	0.0000	13.0000	1.4555
lnGDP	Logarithm of GDP of listed companies' cities	0.7259	6.7040	11.5868	0.7259
expend	Total R&D Expenditures of listed companies	155,000.0000	0.0009	2190000.0000	155,000.0000
fee	R&D Expenses of listed companies	1.3700e+09	0.0000	2.9400e+10	1.3700e+09
capital	R&D Capital of listed companies	1.5400e+08	–3.2500e+07	6.1400e+09	1.5400e+08
lnpay	Percentage of management shareholding of listed companies	0.4927	16.0374	18.9687	0.4927

Note: The descriptive statistics of the data are raw, and the data are standardized in the latter.

2.3. Data sources

In this study, data were compiled and merged from multiple databases. The explanatory variable was derived using data from the China Research Data Service Platform (CNRDS) (Invia). After cleaning and matching these data, excluding ST companies, delisted companies, and missing samples, the sample contained more than 2,800 listed companies.

According to Acemoglu et al. (2011) and Wan et al. (2022), the number of patents filed by firms was used as a variable to measure the innovation outcomes of firms. The use of blockchain technology by the firm distinguished the experimental and control groups. Based on the "Blockchain Investments" database provided by the China Research Data Service Platform (CNRDS), manual collation and data cleaning were carried out to ensure that the enterprises that use blockchain were listed correctly. Additionally, the annual reports of companies were checked against information provided by companies using several platforms, such as Cinifo.com, one of the most widely used platforms for statutory disclosures in China, to ensure that the companies included information on the use of blockchain technology. The experimental group was separated from the control group based on the linguistic diversity of the city where the company is located. A range of 0 to 1 was established by calculating a dialect index, where 1 corresponded to companies with high cultural diversity and 0 to locations with low cultural diversity if the index was above the mean. Data on linguistic diversity were also obtained from the China Research Data Service (CNRDS). Table 2 outlines the data sources and descriptions of the other variables included in this study.

Table 2. Data sources

Variables	Index	Source
lnsize	Logarithm of total assets of listed companies	CNRDS CSMAR
Gender	Gender of chairman of listed companies	CNRDS CSMAR
GmShrRat	Shareholding ratio of senior management of listed companies	CNRDS CSMAR
LrgHldRt	Shareholding ratio of top shareholders of listed companies	CNRDS CSMAR
ROTA	Return on assets of listed companies	CNRDS CSMAR
ROE	Return on net assets of listed companies	CNRDS CSMAR
liability	Logarithm of total liabilities of listed companies	CNRDS CSMAR
lnprofit	Net profit of listed companies	CNRDS CSMAR
Edu	Education level of chairman of listed companies	CNRDS
InDrcNum	Number of independent directors of listed Companies	CNRDS CSMAR
lnGDP	Logarithm of GDP of listed companies' cities	CSMAR STATS
expend	Total R&D Expenditures of listed companies	CNRDS CSMAR
fee	R&D Expenses of listed companies	CNRDS CSMAR
capital	R&D Capital of listed companies	CNRDS CSMAR
lnpay	Logarithm of the general budget expenditure of the city where the listed company is located	CSMAR STATS

3. Empirical analysis and results

3.1. Baseline regression results

This study used DDD based on two-way fixed effects to explore whether blockchain can assist companies in taking advantage of cultural diversity's knowledge and information benefits and promote corporate innovation. We gradually add control variables and two-way fixed effects to the regressions using a DDD model. Table 3 depicts the regression results. Column 1 displays simple regression results with the primary variables without including two-way fixed effects. Column 2 presents the results after adding control variables such as firm-level attributes, factors influencing innovation decisions, and CEO personal characteristics. Column 3 illustrates the regression results after considering the firm's growth capacity and dynamic equilibrium.

The results are significant but less explanatory without controlling for two-way fixed effects from columns (1) to (3). Adding control variables gradually increased the model's explanatory power without affecting its coefficients. In columns (4) to (6), we employ two-way fixed effects by adding control variables, such as firm-level characteristics, executive team characteristics, firm financial status, and firm growth capability. The DDD regression results demonstrate that the difference in innovation outcomes between firms using blockchain compared to other firms is positively correlated with the use of blockchain or not after 2016, and the results are significant. After the inclusion of control variables, the explanatory strength of the model increased, although the coefficient of influence decreased from 37.65% to 35.73%. The regression coefficients remain significant with the inclusion of individual effects and time fixed effects in columns (4), (5), and (6). Moreover, we use clustering robust standard errors to increase the credibility of the results and avoid problems, such as between-group heteroskedasticity. We standardized the Z-Scores for the primary variables to increase the reliability of regression results by removing the influence of variable units. As a result of the release of the first Chinese blockchain white paper in 2016, companies that have implemented blockchain can obtain knowledge and information advantages through cultural diversity to promote corporate innovation, which is consistent with the hypotheses.

3.2. Omitted variables

This study incorporated some variables that may affect the behavior of firms in conducting corporate innovation, including the characteristics of the internal executive team and the firm's external environment, to protect the estimation results from being biased by the omission of some variables and to eliminate the influence of other unobservable variables (Acemoglu et al., 2016).

3.2.1. Educational background of executives

According to the executive ladder theory, executives, as central figures in corporate operations, significantly contribute to corporate innovation (Hambrick & Mason, 1984). In one sense, the social connections of executives can provide resources to drive innovation. However, executives may make different decisions on corporate innovation due to differences in their educational backgrounds and other factors (Peng & Mao, 2017).

Table 3. Baseline regression model

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Invia	Invia	Invia	Invia	Invia	Invia
t*treat* culture	0.3916**	0.4059**	0.3989**	0.3765**	0.3794**	0.3573**
	(0.1723)	(0.1752)	(0.1670)	(0.1726)	(0.1748)	(0.1637)
t*treat	–0.0031	–0.0357**	–0.0399**	0.0156	0.0153	0.0073
	(0.0040)	(0.0161)	(0.0200)	(0.0151)	(0.0132)	(0.0234)
culture*treated	0.0685	0.0180	–0.2920			
	(0.0772)	(0.0837)	(0.2686)			
lnsize		0.0479***	0.0331**		0.0075	0.0092
		(0.0152)	(0.0134)		(0.0078)	(0.0107)
Gender		0.0094	0.0100		–0.0167	–0.0183
		(0.0361)	(0.0378)		(0.0160)	(0.0164)
GmShrRat		–0.0003	–0.0004		–0.0004	–0.0005
		(0.0003)	(0.0003)		(0.0003)	(0.0003)
MShrRat		0.0011***	0.0010***		–0.0002	–0.0003
		(0.0003)	(0.0003)		(0.0004)	(0.0004)
LrgHldRt		0.0001	–0.0002		0.0008*	0.0008
		(0.0007)	(0.0007)		(0.0005)	(0.0005)
ROTA			0.0465			–0.0281
			(0.0298)			(0.1057)
ROE			–0.0003*			–0.0005*
			(0.0002)			(0.0003)
liability			0.0045			–0.0062
			(0.0039)			(0.0042)
NetProfit			0.0000*			0.0000
			(0.0000)			(0.0000)
Constant	–0.0054	–1.0851***	–0.8554***	–0.0308***	–0.1991	–0.1128
	(0.0168)	(0.3420)	(0.2842)	(0.0106)	(0.1654)	(0.2370)
Observations	17,011	16,798	16,229	17,011	16,798	16,229
R-squared	0.0012	0.0010	0.0030	0.0040	0.0041	0.0066
Company FE	NO	NO	NO	YES	YES	YES
Year FE	NO	NO	NO	YES	YES	YES

Notes: ① The clustering robustness standard errors are in parentheses; ② *** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here.

In subsequent studies, scholars discovered that differences in the academic backgrounds of executives might be reflected in their approaches to organizational innovation. Those with a stronger academic background understand the potential value of innovation investment opportunities and can better manage innovation resources (Hirshleifer et al., 2013). These individuals can allocate better and mobilize physical resources and human capital to achieve

the firm's innovative behavior, improving its innovation efficiency. Furthermore, executives with a higher level of academic achievement may foster an environment that tolerates minor failures in innovative behavior, thereby creating a better team climate (Manso, 2011). Thus, firms with highly qualified management teams may attract more skilled inventors to work for them, increasing their capacity to innovate.

Following Chemmanur and Paeglis (2005) and Chemmanur et al. (2011), we regress the executive's educational level, i.e., the executive's educational attainment (Edu), as the control variable in a two-way fixed effects model, and Table 4 displays the results in Column (1). The model's coefficient increased slightly after including the executive's educational background, but it is still significant at the 5% confidence level, supporting the hypotheses.

3.2.2. A company's proportion of independent directors

Independent directors are essential to an organization's management team and stakeholders in implementing innovative business practices (Bebchuk & Hamdani, 2017). Firms with a higher percentage of independent directors are subject to stronger regulation. Firms can share information more efficiently with the outside world due to more effective regulation and governance, and corporate decisions are made with a keen eye toward long-term objectives.

Although firm growth is a complex and dynamic process involving several economic, social, and cultural factors (Delmar et al., 2003; Wong et al., 2005), a firm's innovative behavior undoubtedly contributes to its future success. Specifically, the innovative behavior of an organization may change the composition of its productive resources and increase the firm's output and market share (Coad & Rao, 2008). However, this success is not common to all firms. Demirel and Mazzucato (2012) examined the role of innovation in firm growth during the period from 1950 to 2008 and discovered that it was highly dependent on a combination of factors, such as firm size, patents, and patent duration, and that the long-term impact of innovation on firms could not be achieved without additional factors.

Therefore, while corporate innovation may be beneficial to firmsm, in the long run, it depends on the judgment and decisions of corporate stakeholders. Companies with more independent directors have better information exchange and stronger external regulation. Therefore, the model included the number of independent directors (InDrcNum) as a control variable. Column (2) reveals that the results are still significant even after controlling for the number of independent directors.

3.2.3. Level of regional economic development

There is strong support for Schumpeter's central claim (Fagerberg, 2003) that innovation significantly impacts firms' products and business models and is a major driver of regional economic development (Romer, 1990; Aghion & Howitt, 1992; Castellacci, 2007). Furthermore, innovation improved firms' market leadership, competitiveness, and viability, transforming them into market leaders, and driving local employment levels and per capita income. Thus, the external environment also affects firm innovation behavior.

Arrow (1962) argued that knowledge could have strong externalities, and flow from the firm that creates it and other regional firms (Acs et al., 2013). Nevertheless, firms cannot continue to survive in some environments if the external environment is unfavorable or if the

firm is less resistant to external risks (Liu & Laperche, 2015). If a company cannot convert its innovative behavior into business value, its competitors may overtake it (Van der Panne et al., 2003), and the external environment also influences this conversion.

Firms with a better external environment have easier access to knowledge, and their innovations are readily converted into commercial value, which promotes innovation. Therefore, we added the level of regional economic development (lnGDP) to the model, presented in column (3). It can be concluded that the coefficients have not changed, and the results are still significantly positive, reiterating the hypotheses.

3.3. Endogeneity problem

The possibility of mutual causality between the control and explanatory variables must be considered to ensure a higher accuracy. Endogeneity is discussed further. We lagged the explanatory variables by two to three periods, whereas the explanatory variables were lagged by one period and included in the GMM model for regression (Yao & Song, 2021). For clustering firms, robust standard errors have also been employed to overcome the effects of heteroskedasticity between groups. Furthermore, we conducted Sargan and Hansen tests to ensure that the results were robust and free of problems, such as weak instrumental variables. The model passed the test, and column (4) of Table 4 displays the regression results. The data in column (4) indicates that the results are positively significant, representing that firms utilizing blockchains gain insight from cultural diversity, can exchange information effectively, and encourage innovation within their organizations. In short, the GMM regression results support the hypotheses.

3.4. Validity test of the DDD model

In addition to indicating the reliability of the estimation results, a series of validity tests were conducted, primarily through parallel trend tests. The prerequisite assumption of the DDD model is that trends in the control and treatment groups are the same before applying the policy. Hence, we have established the following equation:

$$Y_{it} = \beta_k \sum_{k\geq -4}^{4} \text{treat}_i \times \text{culture}_i \times \text{year}_{2016+k} + \delta Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}.$$

The model setup was based on Liu and Qiu (2016), who discovered no significant trend difference between the experimental and control groups before the initiation of the policy. If the trend for each year before 2016 is insignificant, then the parallel trend hypothesis is satisfied.

Figure 2 displays an analysis of trends for the years before and after the publication of the 2016 blockchain white paper. According to the results of this study, the trend of change in the treatment and control groups before the introduction of the 2016 blockchain white paper is consistent, and none of the interaction coefficients are significant. Nevertheless, there was a significant difference between the treatment and the control groups after the publication of the blockchain white paper in 2016. The trend of innovation results for the treatment group was significantly higher than that of the control group, indicating that the sample passed the parallel trend test.

Table 4. Omitted variables and GMM

VARIABLES	(1)	(2)	(3)	(4)
	Invia	Invia	Invia	Invia
t*treat* culture	0.3624**	0.3617**	0.3617**	3.8856*
	(0.1635)	(0.1636)	(0.1636)	(1.9929)
t*treat	0.0039	0.0046	0.0046	0.5568
	(0.0245)	(0.0241)	(0.0242)	(4.8213)
lnsize	0.0097	0.0094	0.0094	0.4847**
	(0.0113)	(0.0114)	(0.0115)	(0.2232)
Gender	−0.0087	−0.0083	−0.0082	−0.3461
	(0.0133)	(0.0133)	(0.0133)	(0.3502)
GmShrRat	−0.0005	−0.0005	−0.0005	−0.0006
	(0.0003)	(0.0003)	(0.0003)	(0.0012)
MShrRat	−0.0003	−0.0003	−0.0003	0.0002
	(0.0004)	(0.0004)	(0.0004)	(0.0010)
LrgHldRt	0.0007	0.0007	0.0007	0.0003
	(0.0005)	(0.0005)	(0.0005)	(0.0059)
ROTA	−0.0292	−0.0293	−0.0293	1.8146
	(0.1054)	(0.1055)	(0.1053)	(1.1098)
ROE	−0.0005*	−0.0005*	−0.0005*	−0.0485
	(0.0003)	(0.0003)	(0.0003)	(0.0566)
liability	−0.0064	−0.0063	−0.0063	−0.2366**
	(0.0043)	(0.0043)	(0.0044)	(0.1093)
NetProfit	0.0000	0.0000	0.0000	−0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Edu	−0.0053	−0.0053	−0.0053	−0.0305**
	(0.0046)	(0.0046)	(0.0045)	(0.0134)
InDrcNum		0.0036	0.0036	−0.0292**
		(0.0047)	(0.0047)	(0.0127)
lnGDP			0.0040	−0.5311
			(0.0579)	(0.5134)
Constant	−0.1078	−0.1162	−0.1567	
	(0.2402)	(0.2374)	(0.4778)	
Observations	15,811	15,811	15,803	11,096
R-squared	0.0065	0.0066	0.0066	
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Sargan				0.000
Hansen				0.961

Notes: ① The clustering robustness standard errors are in parentheses; ② *** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here.

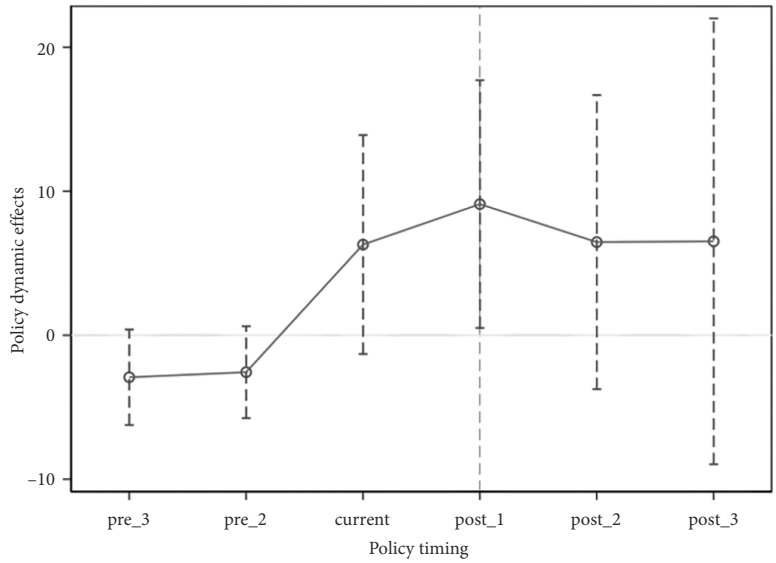

Figure 2. Parallel trend tests

3.5. Heterogeneity analysis

Many factors affect corporate innovation behavio, and the possibility of heterogeneous behavior exists on several levels (Acemoglu et al., 2011). Discussing heterogeneous factors can help us understand blockchain technology's impact on corporate innovation and whether this behavior varies across conditions. These differences may have multiple aspects, including the internal and external environment and information transparency.

3.5.1. Serving as both Chairman and CEO

The top management team of a company may influence the company's long-term success. The top management team makes decisions regarding R&D investments and innovation planning, which can positively or negatively impact the company's long-term financial health. A high-quality executive team may invest in value-enhancing long-term projects (Chemmanur & Jiao, 2012). Innovative projects are undoubtedly desirable projects that positively impact the company's future development (Hirshleifer et al., 2013), and investing in innovative projects is advantageous for the transformation and sustained-term growth of the company.

Nevertheless, the reality of the business environment is complex and volatile, requiring companies' ability to respond to changes in the environment while enhancing performance. Additionally, companies must be able to respond to unexpected events using strategies such as R&D investment jumps. In companies where the chairman also serves as CEO, the executive team has a heightened concentration of power, facilitating quick decisions in response to changing market conditions. Comparatively, corporate power is more diffuse in companies where the chairman and CEO are not the same person, allowing for greater checks and balances of power and access to more information. The executive team's characteristics significantly impact the company's innovation behavior (Galasso & Simcoe, 2011). Table 5

represents that Separate regression analyses are conducted for firms with and without two concurrent positions.

There is a positive correlation between firms with dual occupancy in column (1) and firms without dual occupancy in column (2). Accordingly, a higher degree of power concentration is required when using emerging technologies, such as blockchains, to promote corporate innovation to make rapid decisions in response to complex environmental changes. The higher the level of power concentration, the more effective the use of blockchain technology.

Table 5. Dual-occupancy vs. non-dual-occupancy

VARIABLES	(1)	(2)
	Invia	Invia
t*treat* culture	0.5088***	0.3457**
	(0.0944)	(0.1615)
t*treat	0.0710	0.0061
	(0.0711)	(0.0279)
Constant	–2.2812	–0.1144
	(2.3252)	(0.4934)
Observations	3,251	12,552
R-squared	0.0208	0.0067
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.5.2. Eastern coastal and inland areas

In China, the development of coastal and inland regions differs depending on resource endowments and other factors. The degree of development also influences factors, such as the building of the regional institutional environment, affecting the business environment and the degree of marketization. Economically developed regions may have a better institutional environment (Acemoglu et al., 2014), and the external environment may impact the choice of firm development.

Innovation is a behavior that has the potential to benefit business and regional development. However, innovation entails certain risks. It involves a significant investment of resources. The resources and funds required to promote innovative behavior may be unavailable in relatively less developed regions (Oughton et al., 2002). However, devoting significant resources to innovative behavior may also lead to regional development problems due to the failure of innovation (Fragkandreas, 2013). As a general rule, firms' innovative behavior is influenced by the external environment, and firms that can utilize superior external resources for sustained innovation are more likely to achieve superior results. Though the eastern

coastal region has a higher level of development than the inland region, blockchain technology can facilitate information exchange between different regions and address the problems caused by regional differences. Table 6 contains the specific results of the regression analysis.

According to the regression analysis of the eastern coastal region in column (1), the results are positively significant, while in the regression of the inland region in column (2), the results are negatively insignificant, indicating that blockchain has a substantial impact on the eastern coastal region. The external environment has a positive effect on the development of enterprise innovation, whereas the external environment in the inland region is relatively poor, and the use of blockchain has no significant effect on enterprise innovation.

Table 6. Eastern coastal and inland area

VARIABLES	(1)	(2)
	Invia	Invia
t*treat* culture	0.3876**	–0.0805
	(0.1713)	(0.0736)
t*treat	0.0059	0.0039
	(0.0278)	(0.0235)
Constant	–0.3627	0.3657
	(0.6528)	(0.8718)
Observations	11,047	4,756
R-squared	0.0076	0.0086
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.5.3. Differences in information transparency

As we approach the age of globalization, new technologies are emerging. Knowledge and information transfer development may impact all aspects of society, including the environment consisting of scientists, research institutions, private firms, or government agencies. Corporate innovation agents are influenced by the emergence of overall innovation networks (Wuchty et al., 2007; Furman & Stern, 2011). The level of transparency in corporate information can influence the dissemination of knowledge and information, as well as the creditworthiness and performance of firms due to the variety of industries and economic firms.

Technologies, such as blockchains, have contributed to change in how and through which information is disseminated in the age of globalization (Milovich et al., 2020). The extent to which emerging technologies are used in different economic formations also varied. Literature demonstrated that the speed and timing of knowledge transfer, the closeness of firm linkages, and application tadiffer between different economic formations, with profound

implications for innovation networks and enterprise dominance (Acemoglu et al., 2016). Particularly, the impact of the original firm's creditworthiness may be weakened because this new technology, which does not rely on third parties, enables firms to collaborate in new ways, negating the importance of credit endorsements.

Therefore, this study conducted separate regression analyses for high and low information transparency samples. Table 7, column (1), demonstrates that the impact of blockchain technology is positively insignificant for firms with high information transparency, while it is positively significant for firms with low information transparency. Due to its decentralization and security, blockchain technology provides new ways for enterprises to collaborate in the age of globalization, reducing the influence of credit endorsement under the traditional model and reflecting the advantages of emerging technology.

Table 7. Differences in information transparency

VARIABLES	(1)	(2)
	Invia	Invia
t*treat* culture	1.7000	0.3717**
	(1.2914)	(0.1765)
t*treat	0.0145	0.0026
	(0.2326)	(0.0279)
Constant	–3.3303	–0.1663
	(4.0336)	(0.4786)
Observations	330	15,472
R-squared	0.1795	0.0065
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.5.4 Multinational and non-multinational companies

Multinational corporations (MNCs) are influential in corporate innovation and beneficiaries of cultural diversity. MNCs may benefit from a larger scope: although knowledge is created at the firm's headquarters, knowledge acquisition may occur worldwide (Almeida et al., 2002). This process involves knowledge transfer within the MNC to avoid transaction costs associated with knowledge assets.

However, further research has discovered that not all MNCs benefit from overseas exchanges because effective knowledge transfer between knowledge senders and receivers requires absorptive capacity. While multinational corporations are often considered knowledge receivers and transferors, their absorption capacity differs due to corporate concerns about risks such as information leakage and organizational differences (Song, 2014). Based on the

analysis in the previous section, this study tested the validity of this finding in MNCs and non-MNCs separately. The results are shown in Table 8 below.

Column (1) demonstrates that the impact of the use of blockchain technology is positively insignificant for MNCs, while Column (2) is positively significant for non-MNCs. Blockchain's security and traceability features enable companies to creatively take advantage of cultural diversity. However, this study primarily reflects this impact on local Chinese companies. A possible explanation can be provided in the limitations section of this study, which discusses the choice of cultural diversity measures.

Table 8. Multinational and non-multinational companies

VARIABLES	(1)	(2)
	Invia	Invia
t×treat×culture	0.1582	1.6517***
	(0.1335)	(0.1221)
t×treat	0.0224	0.0984
	(0.0167)	(0.0689)
t×culture	0.0048	–0.0148
	(0.0401)	(0.0269)
Constant	–0.1238	0.0786
	(0.7903)	(0.7219)
Observations	7,234	8,569
R-squared	0.0176	0.0436
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.5.5. Technology-intensive and non-technology-intensive enterprises

According to researchers, the development of industries has also resulted in significant differences due to the advent of globalization and the further acceleration of economic development. Some industries have observed faster innovation, shorter technology, product lifecycles, and significant volatility in sales and profits compared to traditional development models. In contrast, other industries have not changed from the traditional model, and researchers have discovered that these firms have become increasingly technology-intensive (Hitt et al., 2001).

In a competitive market, technology-intensive firms require dynamic capabilities, and their viability may fluctuate. When it comes to firms, volatility in the environment and unstable performance may ultimately lead to failure, so firms must innovate continuously to remain competitive (Vaaler & McNamara, 2010). Among the technology-intensive are the

computer software, biomedical, and aerospace industries (Acemoglu et al., 2016). We divided the sample of enterprises based on the industries in which they are listed in China into technology-intensive and non-technology-intensive companies for regression analysis to determine whether the differences in enterprises' original innovation capabilities affect this study's findings. Table 9 provides specific results.

In Column (1), the regression for technology-intensive enterprises is negatively insignificant, indicating that blockchain technology does not significantly promote enterprise innovation in technology-intensive industries. For non-technology-intensive firms, the regression of Column (2) is positively significant, indicating that blockchain technology assists non-technology-intensive firms in absorbing information and knowledge and encouraging innovation. This study demonstrated that firms do not invest in blockchain technology to promote innovation because they are more innovative, but rather that blockchain technology can help non-technology-intensive firms to leverage external information to innovate, which may help to reduce the innovation gap between different industries.

Table 9. Technology-intensive and non-technology-intensive enterprises

VARIABLES	(1)	(2)
	Invia	Invia
t×treat×culture	0.0927	1.2726**
	(0.1114)	(0.6164)
t×treat	0.0241	0.0389
	(0.0222)	(0.0348)
t×culture	0.0041	–0.0099
	(0.0372)	(0.0233)
Constant	0.4530	0.6000
	(0.8717)	(0.8320)
Observations	7,685	8,118
R-squared	0.0535	0.0179
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.5.6. High-tech and non-high-tech enterprises

Considering the increasing mobility of people and knowledge in the era of globalization, the mobility of employees between firms promotes corporate communication and innovation. A common feature of the mobility of professional engineers and technicians is the transfer of skills, experience, and knowledge between firms in the same industry, which can enhance a firm's innovative capacity (Inkpen & Wang, 2006).

Generally, firms are classified as high-tech or non-tech based on this circumstance. Firms in the high-tech sector tend to possess extensive industry knowledge and a dense network of contacts, and the presence of highly skilled personnel increases the firm's human capital and increases its innovation capacity (Liu et al., 2010). Since the division by industry is not precise enough and the division by technology-intensive enterprises is too coarse, this paper reviews the Chinese recognition standards for high-tech enterprises and matches the list of high-tech companies available for recognition. Table 10 displays the specific results of a regression analysis carried out on high-tech and non-tech enterprises.

In Table 10, it can be found that the regression coefficient for high-tech enterprises in model (1) is positively insignificant, which indicates that blockchain technology does not appear to promote enterprise innovation in high-tech companies. In contrast, the regression in model (2) for non-high-tech enterprises is positively significant, suggesting that blockchain technology supports non-high-tech enterprises in acquiring knowledge and promoting enterprise innovation. Furthermore, blockchain technology makes it easier for companies with low levels of innovative ability to achieve technological advances, helping to close the gap between companies.

Table 10. High-tech and non-high-tech enterprises

VARIABLES	(1)	(2)
	Invia	Invia
t×treat×culture	0.1007	1.9663**
	(0.0952)	(0.8010)
t×treat	0.0310*	0.0593
	(0.0180)	(0.0582)
t×culture	0.0057	–0.0388
	(0.0299)	(0.0276)
Constant	0.3105	–0.5872
	(0.5526)	(0.7859)
Observations	12,769	3,034
Number of id	2,146	478
R-squared	0.0199	0.0704
Company FE	YES	YES
Year FE	YES	YES
Based Control	YES	YES
Added Control	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

3.6. Mechanism analysis

3.6.1. Overall investment in R&D

It is necessary to increase its R&D expenditures for a firm to increase its innovation capabilities. Yet, firms decide how much to invest in R&D based on the external environment and their own strategic choices due to the complex environment and opportunity costs associated with firm innovation (Fabrizio & Tsolmon, 2014).

The demand-matching theory provides a comprehensive description of R&D investment and the organizational structure of a firm's strategic activity. Firms prefer to realize their innovations during high demand periods, representing that they discount the future returns of the innovation and aim to take advantage of the highest potential revenue in the current period (Barlevy, 2007). In light of this consideration, firms often make rational expectations because of the delay between their investment in R&D expenditures and the output of innovation; they invest in R&D during periods of low demand to achieve successful corporate R&D during periods of high demand.

However, firms often confront a dilemma since knowledge has a spillover effect, and it takes time for R&D results to be applied to patents and products, indicating that other firms may have time to imitate or surpass the first mover's innovations, resulting in the first mover losing a portion of its profits (Barlevy, 2007). When a company can keep its R&D results confidential by some means, it may gain profits by investing in R&D. Otherwise, companies may only invest in R&D in non-competitive industries (Fabrizio & Tsolmon, 2014). Blockchains can avoid this dilemma by reducing the risk of leakage of innovations by firms with their cryptographic features. This study conducted regression analysis using corporate R&D (expend) data, and Table 11 presents the results.

According to the regression results in column (1), companies that use blockchain technology experience a rise in R&D expenditures, as they are less exposed to risks, such as leakage of ideas, leading to a rise in overall innovation and a further expansion of the advantages brought by emerging technologies.

3.6.2. R&D expenses and R&D capital

Companies invest in R&D vary; for example, there is R&D capital for buying equipment for experiments. In contrast, there are R&D expenses for strategies, such as hiring talent and implementing technology. This difference is attributable to the strategic positioning of the firm and its operating environment (Acemoglu et al., 2011).

Companies must decide whether to innovate to become industry leaders or reinvent to become followers by bringing in talent and technology (Acemoglu et al., 2011). During a short product life cycle, choosing the right innovation behavior becomes more critical than completing an innovation in the competitive environment of an industry. Because if the market does not require this innovation, then the firm's innovation cannot be realized (Fabrizio & Tsolmon, 2014). Therefore, firms have chosen to be followers rather than leaders.

This study collected the costs (fees) and capital (capital) that firms invest in R&D for regression analysis to examine how blockchain technology influences firms' innovation behavior. The findings indicate that the mechanism by which firms increase their innovation

behavior by increasing their R&D expenditures in column (2) in Table 11 is positively significant, while the mechanism by which firms promote innovation by increasing their R&D capital in column (3) in Table 11 is not significant. This illustrates that enterprises have greater resources to innovate with the method of information and knowledge exchange provided by the blockchain platform, particularly in a period of rapid external change. Companies can imitate innovation easily, and increase their investment in R&D expenses rather than R&D capital by taking advantage of the knowledge spillover from other innovators. This is also compatible with the external environment in this era of globalization and demonstrates that firms possess strong dynamic capabilities.

Table 11. R&D investment

VARIABLES	(1)	(2)	(3)
	expend	fee	capital
t*treat* culture	0.2548***	0.4160**	0.1805
	(0.0749)	(0.1633)	(0.1662)
t*treat	–0.498***	–0.3103**	0.0006
	(0.0566)	(0.1369)	(0.0685)
t*culture	0.0538	0.0451	–0.0153
	(0.0414)	(0.0392)	(0.0394)
Constant	–5.2580***	–5.2899***	–1.6699
	(1.5658)	(1.1536)	(1.0668)
Observations	3,416	3,933	9,887
R-squared	0.1099	0.1948	0.0253
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Based Control	YES	YES	YES
Added Control	YES	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

4. Robustness tests

4.1. Applying the generalized DID model

We refer to Dai et al. (2020) to test the robustness of the findings by constructing a generalized DID model. Particularly, the regional dialect index is used to measure cultural diversity as a basis for differences, and the threshold has been eliminated. This approach ensures the rigor of the model estimation in different cases and prevents information loss. We re-estimated using a two-way fixed effects model, as column (1) in Table 12 demonstrates. The parameters estimated by the generalized DID model are still positive, indicating the robustness of the regression results and supporting the hypothesis presented in this study.

4.2. Excluding regulated industries such as insurance

There is considerable variation among industries in terms of the innovative behavior of firms as various factors influence it. Several industries are subject to substantial knowledge spillovers and have a natural advantage in innovation (Acemoglu et al., 2011). However, certain firms face heightened risks when investing in R&D due to specific factors (Liu & Laperche, 2015). Previous studies have indicated differences in innovation behavior in some industries, such as insurance, due to government regulation. The regression analysis excluded the insurance industry from the other financial industries. Column (2) in Table 12 presents the results.

Excluding the regulated industries, the regression results are still positive and significant at the 5% confidence level, indicating that the analysis is rigorous.

4.3. Adding city fixed effects

It should be noted that the sample includes multiple firms located in different regions and exposed to different external environments, so controlling only for time fixed and firm fixed effects may miss the unobservable factors at the city level. Therefore, we have added city fixed effects to column (3) in Table 12 for analysis, and the results are still positive, demonstrating the validity of the research.

4.4. Considering macro-fiscal factors

It may not be sufficient to take into account only the external market environment and the degree of marketization when assessing the innovative behavior of firms, so we include a control variable here, namely government expenditure spending (Deschryvere, 2014). Local economic models influenced the government-enterprise relationship, the region's growth, and the choice of corporate innovative behavior, with firms in regions with higher government taxes and subsidies likely to face increased government assistance. Column (4) in Table 12 displays the results after including the fiscal expenditure of the city where the firm is located. At the 5% confidence level, the results are still positive and significant, supporting the hypotheses.

Table 12. Robustness tests

VARIABLES	(1)	(2)	(3)	(4)
	Invia	Invia	Invia	Invia
t*treat*culture	0.6523**	0.3529**	0.3568**	0.3558**
	(0.3153)	(0.1716)	(0.1721)	(0.1728)
t*treat	0.0301	0.0063	0.0062	0.0074
	(0.0397)	(0.0199)	(0.0186)	(0.0181)
t*culture	0.0004	0.0052	0.0051	0.0047
	(0.0913)	(0.0284)	(0.0283)	(0.0278)
				0.0632
				(0.1057)

End of Table 12

VARIABLES	(1)	(2)	(3)	(4)
	Invia	Invia	Invia	Invia
Constant	–0.1613 (0.5299)	–0.1614 (0.4847)	–0.1579 (0.4813)	–1.0187 (1.7492)
Observations	15,803	15,681	15,803	15,803
R-squared	0.0062	0.0067	0.0066	0.0066
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Based Control	YES	YES	YES	YES
Added Control	YES	YES	YES	YES
City FE	No	No	YES	YES

Notes: ①The clustering robustness standard errors are in parentheses; ②*** represents $p < 0.01$, ** represents $p < 0.05$, * represents $p < 0.10$; ③ Z-Score normalization is used here; ④ Based Control in order for the control variables in Table 3; ⑤ Added Control in order for the control variables in Table 4.

5. Discussion

This study provides a comprehensive analysis of the central topic of cultural diversity and technological innovation in the period of globalization, evaluates the influence of cultural diversity and emerging technologies on corporate innovation in the current setting of frequent cultural exchanges, and offers a fresh viewpoint on the use of blockchain technology. This research is a valuable contribution to the existing literature.

This study presents a detailed discussion of cultural diversity and technological innovation as an influential topic in the era of globalization. Specifically, we explore the impact of cultural diversity and emerging technologies on business innovation in the globalization era, provide a novel perspective on the application of blockchain technology, and contribute to the existing literature.

First, we must recognize that cultural diversity is leading to increased exchanges of information and resources (Hallett & Ventresca, 2006; Stark, 2011) and that these exchanges can either contribute to innovation (Corritore et al., 2020) or hinder it due to risks of interpersonal conflicts and information loss. Undoubtedly, these debates demonstrate the importance of effectively utilizing cultural diversity internationally. We present a new perspective on how blockchain technology can harness the "positives" of cultural diversity as an "umbrella" for business innovation. This could represent a breakthrough in the cultural diversity study.

Second, emerging technologies have recently been a hot topic of discussion. The main focus of these studies is whether emerging technologies meet people's expectations and how blockchain technology can improve supply chain management (Liu et al., 2021; Dymek et al., 2022). Besides, limited research has been conducted on whether blockchain technology can further drive scientific progress. We should leverage the advantages of developing technologies to spur innovation further rather than focus on developing cutting-edge technologies. This study offers a comprehensive perspective on the application of disruptive technologies

to foster enterprise innovation, thereby making an invaluable contribution to the literature on emerging technologies.

Third, it is widely agreed that technological innovation drives economic growth (Romer, 1990), but how to drive enterprise innovation in the era of globalization has prompted considerable discussion among scholars. In the future, as information and knowledge exchange accelerate, firms may be exposed to new opportunities and challenges, and the failure to use information and resources wisely can result in heightened risks (Teece, 2014; Yeow et al., 2018). We discuss the innovation model for corporations in the age of globalization from the perspective of cultural diversity and blockchain technology. We also discuss how to benefit from external knowledge spillovers. Companies can eliminate the traditional model of investing in fixed assets for R&D and provide robust support for literature on corporate innovation in the globalization age by bringing in talent and building platforms.

Overall, this study theoretically enriches the literature regarding cultural diversity and presents fresh perspectives on emerging technologies and corporate innovation in the era of globalization. Globalization is an inevitable megatrend, due to an increasing number of cultural exchanges and the rapid development of emerging technology. The study also provided new theoretical guidance for enterprise innovation by emphasizing how emerging technologies and cultural diversity can be effectively utilized. This study examined the concept of corporate innovation in the age of globalization through the lens of cultural diversity and blockchain technology. Specifically, the role of external knowledge spillover, benefiting from outside assistance by bringing in talent and constructing platforms, also replaces the traditional model of investing in fixed assets for R&D, providing new evidence for the literature on corporate innovation in the era of globalization.

This study offers a novel viewpoint on the use of emerging technologies and business innovation in the era of globalization. Globalization is an inevitable mega-trend from a practical standpoint, with increasingly frequent cultural exchanges and the rapid development of emerging technologies. How to successfully employ emerging technology and cultural diversity is an additional important aspect of this research. It also offers fresh theoretical advice for business innovation in practice.

Conclusions

Numerous discussions and controversies have been generated regarding cultural diversity and emerging technologies due to globalization, which has boosted international exchanges and technological developments. In this study, we examined how blockchain can serve as an umbrella for corporate innovation in the age of globalization by constructing a proprietary dataset on corporate innovation. A DDD model is also applied to analyze how blockchain may assist companies in accessing cultural diversity's knowledge and information advantages and facilitating corporate innovation.

This study presented that advanced technologies in the digital economy contribute to variations in the innovation capabilities of firms. As the external environment continues to undergo rapid changes, enterprises are faced with the risk of innovation failure and the dilemma of not being equipped to realize their innovation results. Enterprises must analyze

information resources securely through blockchain to avoid information leakage and thus make the right innovation decision. The release of the 2016 blockchain white paper presents companies with an opportunity to utilize blockchain technologies. Businesses have accelerated their innovation output by 35.66% for each standard deviation in coefficients by constructing federated chains to gain information advantages through blockchain.

Additionally, the study developed a theoretical model to simulate the operating environment in which blockchain technology is utilized, emphasizing that blockchain technology can decrease ineffective resource investment and enhance the efficiency of corporate innovation. Furthermore, the study discovers that the use of emerging technologies to capitalize on cultural diversity is affected by external conditions, with variations in the efficiency of their use across different characteristics of firms and external situations. Although the characteristics of the executive team had a minimal impact on the efficiency of utilizing blockchain technology, the transparency of information and the external environment significantly impacted the use of blockchain by companies. Simultaneously, promoting blockchain technology for corporate innovation is significant in non-MNCs. Compared to high-tech enterprises, blockchain technology is useful to non-high-tech enterprises and has contributed to narrowing the gap between enterprises.

In terms of mechanisms, the R&D environment faced by companies has changed in the globalization era. Blockchain users consolidate their existing advantages by investing in R&D, moving from capitalized investments, such as equipment purchases, to expenditure investments, such as recruiting talent. The shift also represents a change in the pattern of corporate R&D investments.

Limitations and future directions

This study proposes a theoretical hypothesis of how blockchain technology can be an "umbrella" to protect corporate innovation in the age of globalization through logical deduction. We illustrate how blockchain technology can help companies leverage "positive" aspects of cultural diversity to promote corporate innovation, through theoretical and empirical models. However, there are still limitations in this research.

– First, this study analyzes the impact of cultural diversity, mainly using linguistic diversity as a proxy variable for cultural diversity, while other measures of cultural diversity may exist. Meanwhile, this study measures the impact of regional cultural diversity on firm innovation, and the analysis of possible transnational cultural exchanges is insufficient.

– Secondly, this research analyzes the differences between enterprises using blockchain technology and those not using blockchain technology. It also conducts a comparative analysis between different industries and different external environments. However, it cannot analyze the differences between enterprises using blockchain technology.

– Third, since blockchain technology has a certain threshold, this study's sample for analysis and discussion is listed enterprises. The listed enterprises have advantages in scale and market position, and the conclusion may not apply to SMEs at this stage.

In summary, the innovation behavior of enterprises in the age of globalization is still a key topic of academic interest. In addition to blockchain technology, other emerging tech-

nologies, such as the IoT and artificial intelligence, had an important impact on corporate innovation. Future research must address the impact of different emerging technologies on innovation behavior. Simultaneously, there may be multiple dimensions of the impact of cultural diversity on firms' innovative behavior, and the use of linguistic factors as a measure has certain limitations. Future research can further consider the impact of cultural diversity on firms' innovative behavior from different perspectives and provide new support to existing studies. Future research could consider the impact of cultural diversity on corporate innovation from different perspectives, integrating cross-cultural exchanges into the analysis using new indicators to provide evidence to support existing research.

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Author contributions

Runze Zhang and Xi Chen were responsible for the idea and first draft of this research. Zhijun Li and Peiyang Qiu were responsible for data collection and analysis.

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