Valuing Blockchain: Evidence from Industrial Supply Chain

Caihong Sun, Weili Duan

Abstract—**Blockchain technology is prevalent in healthcare and finance but sparsely integrated within industrial supply chains. This study employs fuzzy-set qualitative comparative analysis to analyze 375 blockchain implementation cases in Chinese industrial enterprises. It investigates the varied driving paths of blockchain-supply chain convergence and their influence on corporate value. Four convergence configurations are identified: collaboration-intensive, efficient-collaboration, technology-driven, and organization-driven types. This study contributes to the literature that 1) no singular indispensable condition exists for dual-chain convergence to yield high enterprise value, but blockchain technology acquisition and government policy support are revealed to play pivotal roles in fostering dual-chain convergence; 2) blockchain primarily serves as a catalyst for improving supply chain efficiency and performance, and its implementation should be customized to fit a company's particular context and strategic objectives. The findings enrich the understanding of the convergence pathways in China's industrial sector, guiding businesses in digital transformation and the pursuit of high-quality growth.**

Index Terms—**Blockchain, Supply chain, Industrial sector, Fuzzy-set Qualitative Comparative Analysis**

I. Introduction

BOTH blockchain adoption and supply chain management optimization exert a profound influence on corporate value creation [1], [2]. The pivotal role of blockchain technology in streamlining supply chain operations and fortifying on-chain data security has been extensively validated in academic literature [3], [4]. Governments worldwide also attach great importance to research on blockchain technology and its supporting infrastructure. In 2019, the U.S. Senate passed the Blockchain Promotion Act. In 2021, the European Commission launched the Digital Europe Program, which is accelerating the European Blockchain Services Infrastructure (EBSI) along with related standards and decentralized digital identities. China designated blockchain as one of the seven key "new infrastructure" areas in 2020. From an enterprise perspective, Industry leaders such as IBM, Maersk, BASF, Lenzing, Circular, EME, Plastic Bank, and Chinese firms, including Dianrong and FnConn (a Foxconn subsidiary), have actively employed blockchain to digitize cross-border supply chains and have already reported promising initial results.

Nevertheless, the penetration of blockchain technology in China's industrial sector remains low. Among the top 50 global blockchain companies listed by Forbes in 2023, all six Chinese companies are from the finance and technology sectors. According to the 164 national blockchain innovation application pilot units announced by the Cyberspace Administration of China and 15 other departments, the proportion of projects in the industrial sector is less than 11%. In the "China Blockchain Innovation Application Case Collection (2023)," the proportion of typical cases in the industrial sector is less than 15%. Collaborative technology, organizational resources, and the policy environment are key elements for achieving dual-chain convergence. However, it remains unclear how industrial enterprises can effectively coordinate to achieve this convergence. Exploring the diverse paths driving dual-chain (blockchain and supply chain) convergence and how these paths can promote high-quality enterprise development has become an urgent research topic in current strategic management.

The efficacy of emerging technologies is not static; instead, it is contingent upon adopter-specific contextual factors [5]. Adopting a configurational perspective and grounding the analysis in the Technology–Organization–Environment (TOE) framework, this study addresses two interrelated research questions:

RQ1: Which combinations of technological capabilities, organizational attributes, and environmental policies enable dual-chain convergence? This study examines how the joint configuration of blockchain maturity, supply chain characteristics, and policy support shapes corporate value.

RQ2: How do the multiple configurations that realize blockchain and supply chain convergence translate into corporate value? This paper identifies the configurational "recipes" associated with high corporate value and compares the divergent pathways underpinning such convergence, focusing on causal asymmetry in value creation mechanisms.

The potential contributions of this study are twofold. First, by adopting a configurational perspective, the research integrates the TOE framework with fuzzy-set Qualitative Comparative Analysis (fsQCA) to identify the critical conditions driving dual-chain convergence and elucidate their interactive effects. Second, through in-depth analyses of

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representative cases, this study identifies multiple equifinal configurations and deciphers the underlying operational mechanisms for achieving deep dual-chain integration and value co-creation, offering actionable strategic guidance to practitioners seeking dual-chain convergence.

The remainder of the paper is organized as follows: Section I introduces the research background and presents the study's questions. Section II reviews the existing literature and develops the theoretical framework. Section III describes the data sources and research methods. Section IV presents the empirical analysis and discusses the findings. Section V summarizes the conclusions, highlighting theoretical and practical implications as well as directions for future research.

II. Review and Analysis Framework

A. Blockchain and Supply Chain Flexibility

Supply chain flexibility refers to the capacity of a supply chain to swiftly adapt and respond efficiently to internal or external changes, disruptions, and various sources of uncertainty [6], [7]. It is generally conceptualized along five dimensions: robust flexibility, reconfiguration flexibility, active flexibility, dormant (or potential) flexibility, and network alignment [8]. As a crucial aspect of supply chain management [4], [9], blockchain technology can enhance flexibility by providing transparent, reliable, and automated coordination mechanisms. Immutable data sharing facilitates real-time monitoring of material flows and allows stakeholders, including suppliers, manufacturers, and distributors, to respond promptly to market fluctuations. Smart contracts automatically execute contractual clauses, reducing latency and opportunistic behavior [5], [9]. Additionally, blockchain's decentralized architecture fosters direct peer-to-peer communication and transactions among nodes [10]. By improving data collection and analytics, blockchain ultimately enables firms to customize products and services to diverse consumer preferences [2], [11].

B. Blockchain and Supply Chain Concentration

Supply chain concentration refers to the proportion of a firm's transactions with its largest trading partners relative to total transaction volume [12], [13]. A higher proportion indicates greater concentration. Increased concentration can lower procurement costs, enhance operational efficiency, and facilitate information sharing [14]. It also allows firms to exercise tighter quality control and cultivate stable, long-term relationships with strategic suppliers, thereby fostering synergistic development at the strategic level [15], [16]. However, the impact of blockchain technology on supply chain concentration is complex. It can either promote or diminish concentration, depending on the specific application approach and the industry environment [5], [13]. On the one hand, blockchain's decentralization, data immutability, robust security, automated reconciliation, and time-stamped metadata can strengthen ties with key suppliers and customers, potentially increasing concentration. Excessive reliance on a few partners may expose firms to risks when major customers demand disclosure of proprietary technologies [11]-[13]. On the other hand, the transparency provided by blockchain can bridge trust gaps between upstream and downstream actors, encouraging firms to diversify their supplier base and limit further increases in supply chain concentration [17].

C. Dual-Chain Convergence and Enterprise Value

The dual-chain convergence of blockchain and supply chain management refers to the deep integration of blockchain into supply chain operations, leveraging its unique advantages to mitigate supply chain challenges while utilizing supply chain strengths to offset the limitations of blockchain. This creates a mutually reinforcing system [2]. Researchers have thoroughly examined collaborative management within the context of blockchain in supply chains. On the one hand, the decentralized, immutable, and transparent features of blockchain technology can significantly enhance operational efficiency, reduce operating costs, improve process transparency, minimize opportunistic behaviors among participants, and strengthen mutual trust [18]. In the industrial sector, the effects of blockchain technology on supply chain transparency, concentration, flexibility, and resilience have received significant attention [4], [11]. It allows manufacturers and suppliers to benefit from traceable and secure value chain mapping [9]. In the agricultural sector, the "blockchain and supply chain finance" approach addresses confidentiality issues in agricultural product identification, providing a more effective pathway for agricultural development [19]. On the other hand, the strong logistics and resource integration capabilities of supply chains offer robust support for the practical application of blockchain technology [1], [7]. Moreover, blockchain design can also benefit from the layered modularity of supply chains, enhancing system scalability through side chains or sub-chains [20].

When analyzing how blockchain technology enhances supply chain transparency, flexibility, concentration, and collaboration, existing literature often employs multiple regression methods or normative research to explore the independent value of each element. This methodological bias presents two main limitations: First, it overlooks the interactions and combinatory effects among elements, leading to an insufficient systematic exploration of numerous core components. Second, it neglects the potential high correlation between influencing factors during the process of dual-chain convergence, resulting in inadequate analysis of the differences in factors affecting value co-creation between blockchain and supply chains [10], [16], [18]-[20]. Therefore, in the industrial sector, the interactions between blockchain and supply chains and their convergent value still require further clarification, particularly concerning the "one outcome, multiple causes" phenomenon resulting from the combination of multiple factors, as well as the equivalent results produced by different combinations of antecedent conditions, known as the "Causal Asymmetry" effect. Configuration theory is well-suited to analyze the dual-chain convergence, which involves numerous interwoven factors in complex management issues. It can effectively reveal the intrinsic interactions among these factors and identify multiple driving pathways to achieve efficient dual-chain convergence, thereby enhancing enterprise value.

D. Research Framework

The TOE theoretical framework explains the factors driving complex management phenomena across three dimensions: technology, organization, and environment [21]. It facilitates the exploration of various configurations to achieve efficient dual-chain convergence between blockchain and supply chain.

In the technological dimension, blockchain provides essential value through real-time tracking, secure information sharing, permissioned access control, data integrity, tamper resistance, and identity verification on a distributed ledger, significantly enhancing product traceability and transparency [4], [9]. Additionally, blockchain establishes a peer-to-peer transaction platform that eliminates intermediaries, reducing transaction costs and lead times while improving supply chain flexibility and concentration [4], [22].

In the organizational dimension, supply chain management aims to strengthen multidimensional capabilities. The strategic alignment of efficiency enhances decision-making quality and reduces perceived risks, while tighter governance of partner behavior becomes feasible. This organizational readiness also accelerates blockchain adoption and integration, expanding its role beyond data collection, processing, and sharing to support advanced analytics and smart coordination, thus enhancing dual-chain compatibility [7], [17], [23].

In the environmental dimension, government support is essential for developing the blockchain industry. Policy frameworks and public investments in talent development, data infrastructure, incubation platforms, and testbeds create critical momentum for dual-chain convergence [24].

According to the TOE framework, enhancing value creation requires industrial firms to drive convergence between blockchain and supply chain management through coordinated interactions across technological, organizational, and environmental dimensions [25].

First, technological factors are key drivers for integrating blockchain with supply chains. These factors include the inherent attributes of blockchain technology and the interactive relationships with supply chain partners, featuring critical technical characteristics such as technological capabilities, resources, and collaboration. Xu and Cao measure blockchain adoption by technology maturity, acquisition methods, and attention allocation [26]. Firms with advanced technical capabilities can overcome collaboration barriers and significantly enhance supply chain efficiency.

Secondly, organizational factors emphasize how well upstream and downstream companies coordinate within the supply chain, highlighting key traits like supply chain flexibility, responsiveness, cost, and resources. According to the perspectives presented by Beck et al. [27], the level of supply chain management associated with the adoption of blockchain technology includes structural and efficiency aspects, thereby emphasizing supply chain transparency and collaboration. Therefore, the organizational level of the supply chain is evaluated from two dimensions: supply chain concentration and flexibility. A significant concentration within the supply chain indicates that resources and capabilities, encompassing production, warehousing, logistics, and other domains, are centralized among a limited number of suppliers or partners. This centralized management strategy possesses the potential to reduce coordination costs, enhance management efficiency, and optimize supply chain operations [23]. Supply chain flexibility serves as an indicator of the turnover rate during the flow of the supply chain process, intricately linked to inventory liquidity and the capital invested in inventory. Consequently, the inventory turnover rate is frequently employed as a metric for evaluating supply chain flexibility [6]. An increase in the inventory turnover rate not only ensures continuity in production and operations but also enhances the efficiency of capital utilization [23].

Ultimately, environmental factors consider the significance of policy support in the convergence of blockchain and supply chains. Research by Tan et al. and Liu et al. emphasizes the importance of support from central and local governments for blockchain technology [24], [25]. The government has made significant advancements in talent acquisition, the growth of data infrastructure, the creation of incubation platforms, and the establishment of industry standards by introducing industry norms, providing financial incentives, implementing tax benefits, and funding technological innovation projects. Consequently, these efforts have fostered a supportive environment for converging blockchain technology and supply chains [28].

By employing the TOE framework and adopting a configurational perspective, this study argues that industrial enterprises should systematically synchronize the alignment of technological, organizational, and environmental dimensions to facilitate dual-chain value co-creation. In particular, addressing supply chain concentration and flexibility concurrently enables the seamless integration of blockchain into supply chain operations. Alternatively, firms excelling in a specific supply chain dimension may require targeted strategies, such as optimizing methods for blockchain acquisition and allocating technological resources, to achieve alignment. This paper also identifies distinct pathways for dual-chain value co-creation and examines their varied impacts on enterprise value, providing theoretical foundations and decision support for high-level convergence. For instance, firms with high supply chain concentration tend to adopt blockchain through strategic partnerships or equity investments. In contrast, those with robust in-house R&D (research and development) capabilities can embed blockchain more flexibly within their industrial networks. Ultimately, this study comprehensively examines the key factors driving dual-chain convergence and their distinct impacts on creating enterprise value. Specifically, this evaluation examines supply chain concentration, government policy support, and strategies for acquiring blockchain technology, thus offering theoretical support and guidance for decision-making to promote dual-chain convergence.

In conclusion, through the application of a configurational approach grounded in the TOE framework, this paper delves into the characteristics associated with the implementation of blockchain technology, the organization and effectiveness of the supply chain, as well as the role of governmental policy support in facilitating the convergence of dual chains. Specifically, this analysis examines how the synergistic effects of these dimensions create various configurations aimed at achieving higher enterprise value through dual-chain convergence. Furthermore, the manuscript delineates essential strategies for the effective convergence of dual chains and analyzes how diverse combinations of conditions variably impact enterprise value, thereby identifying the most advantageous configurations for fostering high-quality enterprise development. The resultant theoretical framework is illustrated in Fig. 1.

III. Research Methods and Data

A. *Mixed Methods of FsQCA and Correlation Analysis*

This study employs a hybrid research approach that combines fsQCA with correlation analysis, driven by three considerations:

Firstly, the fsQCA method proficiently captures the intricate, simultaneous, and asymmetric relationships among technological, organizational, and environmental variables, while elucidating the interactive matching effect between blockchain technology and supply chain management. This effect significantly deviates from the singular causal linear assumption characteristic of traditional multiple regression analysis methods [21]. Dual-chain convergence is not the result of a singular factor, rather, it is a “one outcome, multiple causes” effect from combining multiple factors. From a configurational perspective, it is imperative to delineate how various combinations of antecedent conditions equivalently yield specific outcomes, commonly referred to as the “Causal Asymmetry” effect [29].

Secondly, fsQCA identifies and contrasts distinct configurations of cases, thereby facilitating comparative analyses regarding the methods through which firms attain efficient dual-chain convergence [29]. For instance, certain enterprises may depend on established blockchain technology combined with high supply chain flexibility to achieve convergence, whereas others may primarily rely on technical support from their partners and government policy assistance.

Lastly, the flexibility inherent in fsQCA enables it to be augmented by correlation analysis, thereby ensuring that antecedent conditions are not assumed to possess symmetric causal relationships with outcomes before the configurational analysis [21], [30]. This integrated approach mitigates reliance on pairwise correlations and establishes a more robust foundation for uncovering multi-factor convergence configurations.

B. *Data Sources*

The subjects of this research paper comprise publicly listed companies within the industrial sector that utilize blockchain technology. The procedure for selecting the research subjects is delineated as follows:

i) Identification of blockchain adopters: All publicly listed companies reporting the implementation of blockchain applications were sourced from the Tonghuashun Financial Data Terminal (iFinD) database.

ii) Industry classification: Industrial enterprises were identified utilizing the Wind financial terminal in accordance with the Shenwan industry classification standard. As of June 2024, the iFinD database indicated that 232 listed companies employed blockchain technology, of which 82 were categorized within the industrial sector, representing 35.19%.

iii) Data cleaning: Companies that had incomplete or missing data were excluded, resulting in a final panel of 82 listed industrial firms.

Subsequently, we have compiled annual observations for each firm from 2018 to 2022. Considering each firm year as an independent case within a comprehensive qualitative comparative analysis, the resultant dataset comprises 375 observations.

The data sources utilized in this study are detailed as follows. The outcome variable data were compiled from the SinoFin-CCER Standard Database, a collaborative development between SinoFin Information Service Co., Ltd. and the China Center for Economic Research (CCER) at Peking University, utilizing quarterly reports from the Shanghai and Shenzhen Stock Exchanges. Data pertaining to technological conditions were procured from the China Research Data Service Platform (CNRDS), which consolidates information from a variety of public sources, including corporate annual reports, technology application cases, investor question and answer (Q&A) sessions, and

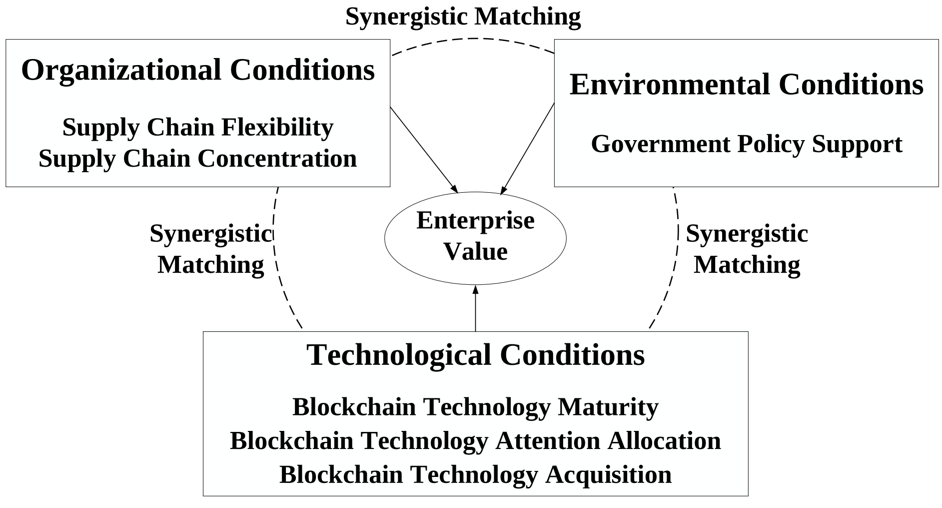

Fig. 1. Theoretical Framework for Analyzing High Enterprise Value in Dual-Chain Convergence.

news reports. Preeminent sources include company websites, the Shenzhen Stock Exchange, Cninfo, and other prominent financial information platforms. Data regarding organizational conditions were predominantly sourced from corporate annual reports and disclosures available on the Cninfo website, as well as extracted from the Supply Chain Research Database of the China Stock Market & Accounting Research (CSMAR) platform. Environmental condition data were acquired from the State Council Policy Document Database, encompassing policy releases from the central government and 34 provincial-level governments via their official websites.

C. Variable Measurement and Calibration

1) Outcome Variable

This paper examines the implications of the convergence of blockchain and supply chain on enterprise value. In research pertaining to blockchain and supply chain management, owing to the paperless nature of blockchain technology, the majority of scholars employ outcome variables such as green supply chain management and sustainability [31], [32]. Additionally, other studies utilize financial metrics, including corporate performance indicators and stock prices, to assess outcomes [24]. Among the various financial metrics, asset multiples—defined as the ratio of market value to book value of assets—offer a more accurate and less biased estimation compared to corporate performance metrics, stock price, sales multiples, and profitability ratios such as return on assets (ROA) and Tobin's Market Value to Replacement Cost Ratio (Tobin's Q) [33]. Consequently, this study adopts the enterprise value multiple as its outcome variable, which is calculated as follows:

$$EVM = TVM / \alpha \tag{1}$$

$$TVM = A\varepsilon_A + B\varepsilon_B\nu_B + H\varepsilon_H\nu_H + \beta\left(T - A - B - H\right) \tag{2}$$

EVM denotes the Enterprise Value Multiplier; TVM denotes Total Market Value; α denotes Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA); letters A, B, H, and T denote the number of A, B, H, and T shares at year-end; ε_i denotes the stock prices of each share; ν_i denotes the closing price of each share at year-end; and β denotes the Net Asset Value per share.

2) Condition Variables

Blockchain Technology Maturity: To assess the maturity of blockchain technology within the context of our research, it has been classified into three phases: preparation (score of 1), completion (score of 2), and application (score of 3). This taxonomy was established through manual data collection supported by Python packages such as Jieba and Pandas. The specific criteria differentiating each phase are as follows: during the preparation phase, the technology remains in an initial exploratory stage, with foundational conceptual principles outlined but lacking practical application examples; in the completion phase, the infrastructure and theoretical framework are developed, along with experiments and proof-of-concept demonstrations; in the application phase, the technology has been widely adopted across various sectors, featuring mature solutions and market recognition.

Blockchain Technology Attention Allocation: This study assesses the extent of attention allocated to blockchain technology by analyzing the frequency of references to blockchain-related concepts in investor Q&A sessions, news reports, and corporate annual reports. To ensure accuracy, unanswered questions, as well as irrelevant and invalid information, were excluded.

Blockchain Technology Acquisition: This study assesses how enterprises acquire blockchain technology by utilizing a binary coding system for classification purposes. The methodologies are categorized based on descriptions of corporate blockchain applications obtained from the CNRDS blockchain section, investor Q&A sessions, news articles, corporate annual reports, and the iFind database. Platform technologies (e.g., collaborations, shareholdings, acquisitions) are assigned as code 0, whereas internally developed technologies are designated as code 1.

Supply Chain Concentration: This is assessed by the proportion of procurement from major suppliers and the percentage of sales attributable to major customers. The calculation methodology is delineated as follows:

$$SCC = \left(P_{\sup pliers}^{T5} + P_{sales}^{T5}\right) / 2 \tag{3}$$

SCC denotes the Supply Chain Concentration; P_i^{T5} denotes the proportion of purchases from the top 5 suppliers and sales to the top 5 customers.

Supply Chain Flexibility: Assessed by the inventory turnover rate. The calculation formula is as follows:

$$ITO = C / \left[\left(Inv_{begin} + Inv_{end}\right) / 2\right] \tag{4}$$

ITO denotes the inventory turnover ratio; C denotes the cost of goods sold; Inv_i denotes the beginning and ending Inventory.

Government Policy Support: The extent of governmental policy support is assessed by counting the number of blockchain-related policies issued by both central and local authorities. An initial search identified 272 policies, which were subsequently refined to 262 unique policies following the removal of duplicates. These policies were categorized according to the province in which the enterprise operates. Specific variable indicators are delineated in Table I.

TABLE I
VARIABLES ABBREVIATION

Variables	Abbreviation
Enterprise Value Multiplier	EVM
Blockchain Technology Maturity	LoBT
Blockchain Technology Attention Allocation	NoC
Blockchain Technology Acquisition	ACQ
Supply Chain Concentration	SCC
Supply Chain Flexibility	ITO
Government Policy Support	POL

TABLE II
CALIBRATION POINTS

Variables	Fuzzy set calibration		
	Fully in	Intermediate	Fully out
NoC	33.850	4.000	0.000
LoBT	3.000	2.000	1.000
ACQ	1.000	\	0.000
SCC	55.189	31.475	11.328
ITO	21.386	3.215	1.277
POL	17.000	7.000	2.000
EVM	99.185	17.807	-44.879

In selecting calibrated thresholds, this paper adopts the methodology of prior research, establishing the quantiles for fully in, intermediate, and fully out members of a fuzzy set at 0.95, 0.50, and 0.05, respectively. For binary coding, we employ 0 and 1 as a definitive set without calibration [29]. Additionally, a value of 0.001 is incorporated into the calibrated 0.5 to mitigate difficulties associated with the crossover point while preserving valid cases [30]. The selection of anchor points for relevant variables is presented in Table II.

IV. DATA ANALYSIS AND EMPIRICAL RESULTS

A. *Descriptive Statistics and Correlation Analysis Results*

This study employs the fsQCA method to investigate the configurational effects of multiple factors on the outcome variable. Additionally, it examines the linear relationships between individual factors and the outcome variable through correlation analysis. Descriptive statistics and correlation analysis were performed using STATA 15.0 software. The data were categorized based on how enterprises acquire blockchain technology: the “ACQ 0” group refers to companies adopting platform-based technologies (including collaboration, equity investment, acquisition, etc.), while the “ACQ 1” group includes those pursuing in-house R&D. The results are presented in Table III.

TABLE III
DESCRIPTIVE STATISTICS(N=375)

Category	Variables	N	Mean	Sd	Min	Max
ACQ 0	NoC	175	10.02	14.96	0.000	86.00
	LoBT	175	1.829	0.812	1.000	3.000
	SCC	175	35.63	15.12	8.060	94.15
	ITO	175	10.07	30.24	0.334	282.3
	POL	175	7.691	4.560	2.000	24.00
	EVM	175	24.67	68.78	-304.6	526.2
ACQ 1	NoC	200	8.830	14.51	0.000	109.0
	LoBT	200	1.875	0.844	1.000	3.000
	SCC	200	29.69	13.60	6.960	72.02
	ITO	200	4.105	3.719	0.463	22.61
	POL	200	7.310	4.286	2.000	24.00
	EVM	200	13.70	93.02	-1,083	253.4

TABLE IV
CORRELATIONS OF LATENT VARIABLES

Variables	EVM	NoC	LoBT	SCC	ITO	ACQ	POL
EVM	1						
NoC	-0.086	1					
LoBT	-0.039	0.039	1				
SCC	0.132	-0.030	-0.154	1			
ITO	0.062	0.063	0.037	0.222	1		
ACQ	-0.067	-0.040	0.028	-0.203	-0.141	1	
POL	-0.034	0.224	0.020	-0.008	0.071	-0.043	1

Prior to calibration, this study conducted a correlation analysis on the raw data to assess whether the independent variables from the technological, organizational, and environmental dimensions are correlated with the value generated by dual-chain convergence, while also addressing potential multicollinearity issues. As shown in Table IV, the results indicate that the six antecedent variables of industrial listed companies exhibit either no significant correlation or only weak correlations with the outcome variable.

B. *Necessity Analysis*

To investigate asymmetric and complex relationships, it is essential to perform a necessity analysis for each variable prior to conducting the configuration analysis. As demonstrated in Table V, irrespective of whether the value produced by dual-chain convergence is high or low, the consistency of the tested necessary conditions did not meet the threshold of 0.9 [29]. This indicates that the value obtained from dual-chain convergence is not solely dependent on any individual variable but rather results from the interplay among technological, organizational, and environmental factors. Consequently, a holistic evaluation of enterprise value should account for the synergistic interactions across these three domains.

TABLE V
RESULTS OF THE NECESSITY TEST FOR INDIVIDUAL VARIABLES

Variables	Outcome variable: EVM		Outcome variable: ~EVM	
	Consistency	Coverage	Consistency	Coverage
ACQ	0.596	0.514	0.550	0.573
~ACQ	0.504	0.481	0.533	0.615
NoC	0.594	0.620	0.600	0.757
~NoC	0.767	0.613	0.698	0.675
LoBT	0.518	0.554	0.559	0.722
~LoBT	0.741	0.581	0.655	0.621
SCC	0.706	0.663	0.602	0.684
~SCC	0.663	0.580	0.704	0.743
ITO	0.617	0.656	0.616	0.793
~ITO	0.805	0.635	0.733	0.698
POL	0.881	0.632	0.855	0.741
~POL	0.639	0.785	0.575	0.854

~ indicates the absence of the condition.

TABLE VI
CONFIGURATIONS FOR ACHIEVING HIGH ENTERPRISE VALUE

Variables	1	2	3	4	5	6	7	8
NoC		⨂		●	⊗	●	⨂	
LoBT	⨂	⨂	⨂	⨂	⨂	●	●	⨂
SCC	●	•	●		⊗	⨂	⊗	
ITO	•	⊗	⨂	•	•	⊗	•	●
ACQ	●	•	●	●	●	●	●	⨂
POL			•		⊗	•	●	•
Consistency	0.831	0.897	0.896	0.865	0.911	0.890	0.909	0.885
Raw coverage	0.266	0.233	0.217	0.221	0.183	0.181	0.147	0.241
Unique coverage	0.017	0.028	0.020	0.006	0.024	0.037	0.015	0.004
Solution consistency	0.829							
Solution coverage	0.604							

Black circles (●) indicate the presence of a condition, and circles with "x" (⊗) indicate its absence. Large circles indicate core conditions; small ones, peripheral conditions. Blank spaces indicate "don't care".

C. *Configurational Analysis*

The analysis of conditional configurations effectively reveals the impacts of the interactive matching of various factors. In accordance with Ragin's recommendation [34], this study primarily employs the intermediate solution as the foundation for analysis, complemented by the configuration presentation of the parsimonious solution. According to the standards governing configuration analysis, a model is considered valid when the overall consistency exceeds 0.8 and all raw consistencies are greater than 0.75. For samples comprising fewer than 100 cases, the frequency threshold is typically set at one due to the limited sample size. For larger datasets exceeding 100 cases, a threshold of 2 or 3 is recommended. Since this study involves 375 cases, the frequency threshold was established at 3 [29]. Consequently, the consistency threshold for the truth table was set at 0.89.

The results of the conditional configuration analysis demonstrate that the model meets these criteria: the overall consistency is 0.89, surpassing the required 0.8 threshold, and all raw consistencies exceed 0.75. Core conditions appear in both the parsimonious and intermediate solutions, whereas non-core conditions are only present in the intermediate solution [35]. The study identifies eight configurations facilitating dual-chain convergence and enhancing enterprise value. These configurations exhibit an overall consistency of 0.829 and a coverage of 0.604, indicating that they explain over 60% of the high-value enterprise cases. The detailed results are presented in Table VI. Subsequent sections provide an in-depth analysis of each configuration leading to dual-chain convergence and high enterprise value, along with representative case studies for each configuration.

1) *Collaboration-Intensive Type*

This encompasses configurations 1, 2, and 3, involving fifty cases. These configurations integrate blockchain technology via platform technology (ACQ 0) and exhibit a relatively high SCC, with an average value of 43.52. By engaging in collaborative research and development or participating in blockchain platforms, enterprises can efficiently adopt advanced technologies, share associated costs and risks, and enhance their competitiveness. In environments characterized by highly concentrated supply chains, enterprises can effectively integrate resources, manage collaborations, control risks, and foster innovation. The attributes of blockchain technology complement these advantages, thereby augmenting the potential for value creation. For instance, Changshan Beiming, a provider of IT architecture solutions, became a participant in Zhixin Chain, a blockchain initiative collaboratively launched by Tencent, China Cybersecurity, and Beiming Software. The company's supplier concentration exceeds 45.11%, with Huawei being the predominant supplier, supplying goods valued at over 1.5 billion yuan annually to Beiming, which accounts for 16.23% of the company's yearly supply. Through collaboration with prominent technology corporations such as Huawei and Tencent, Changshan Beiming actively engages in projects within sectors such as Big Data +, AI +, and Blockchain +, attaining leading positions in smart cities, social governance, and the industrial internet. Similarly, Shenzhen Sea Star Group, a company specializing in the production and sales of smart hardware, has joined UniteData, an open community for big data ecosystems. The group's customer concentration averages over 64.53%, with Philips Electronics being its primary customer, purchasing goods from Sea Star that account for over 60.23% of Shenzhen Sea Star's annual sales. By utilizing blockchain technology, Shenzhen Sea Star can achieve end-to-end tracking of products from sourcing, production, and transportation to delivery, thereby optimizing inventory management and enhancing operational efficiency.

2) Efficiency-Collaboration Type

This encompasses configurations 4 and 5, involving 35 cases. It emphasizes acquiring technology via collaborative R&D or joining blockchain platforms, while sustaining a high level of supply chain flexibility (mean value of 8.09, exceeding the overall mean of 6.02). This model highlights the importance of technological collaboration and strategic planning, enabling enterprises to access the latest blockchain technology, improve supply chain transparency and traceability, and effectively manage the supply chain. On the other hand, a high inventory turnover rate ensures efficient flow and allocation of resources, enhances technological innovation and operational efficiency, and attracts more investors and partners. For example, as a leading digital solution provider in China, Digital China jointly launched the FISCO BCOS open-source project with WeBank, Tencent, Huawei, and other companies, improving operational efficiency and achieving a supply chain flexibility of 9.42. Its product, Digital China KunTai, leads in sales. Another example is LIFESENSE, which focuses on the R&D and production of medical-grade smart products. In this industry, timely delivery is just as crucial as product quality. LIFESENSE established a blockchain research laboratory in collaboration with BAIC (Beijing) Blockchain to promote the application of blockchain technology in supply chain management. Through the digital transformation and upgrading of the supply chain, LIFESENSE reduced external communication and information transfer, improved order collaboration efficiency between supply and demand, achieved cost reduction and efficiency gains, and further enhanced the company's profitability.

3) Technology-Driven Type

This encompasses configurations 6 and 7, totaling seven cases. The characteristic shared by these configurations is that the method of acquiring blockchain technology, technological maturity, and policy environment support synergistically and dynamically collaborate to enhance the capacity for dual-chain value co-creation. This synergy transpires when technological maturity is elevated and the policy environment is both conducive and advantageous, with each element augmenting the other: technological maturity offers a robust foundation for practice, while policy support establishes favorable external conditions, thereby mitigating risks associated with technological implementation and policy modifications. The distinction between the two lies in that Configuration 6 emphasizes the importance of blockchain technology attention allocation, whereas Configuration 7 concentrates on the release of blockchain-related policies. For instance, Nantian Information in Configuration 7 closely follows the national development trend of blockchain technology and actively invests in blockchain R&D and applications in 2021. The company disseminated 58 news reports and strategic plans pertaining to blockchain technology. Its internally developed "Blockchain Basic Service Application Platform (NBaaS)" has been successfully implemented across multiple sectors, including anticounterfeiting traceability, financial insurance, fund management, and cross-border trade. By leveraging digital technology, the security and efficiency of the company's internal management processes have been markedly enhanced. These initiatives have not only bolstered the company's market competitiveness but also substantially augmented its value through ecosystem collaboration and value sharing.

4) Organization-Driven Type

This encompasses configuration 8, involving 19 cases. In configuration 8, the level of blockchain technology development is not high; however, the supply chain flexibility is notably robust, with a mean value of 8.79, exceeding the overall mean of 6.02. Furthermore, government policy support is regarded as a peripheral condition. This indicates that organizations that integrate supply chain improvements with blockchain technology possess the capacity to innovate,

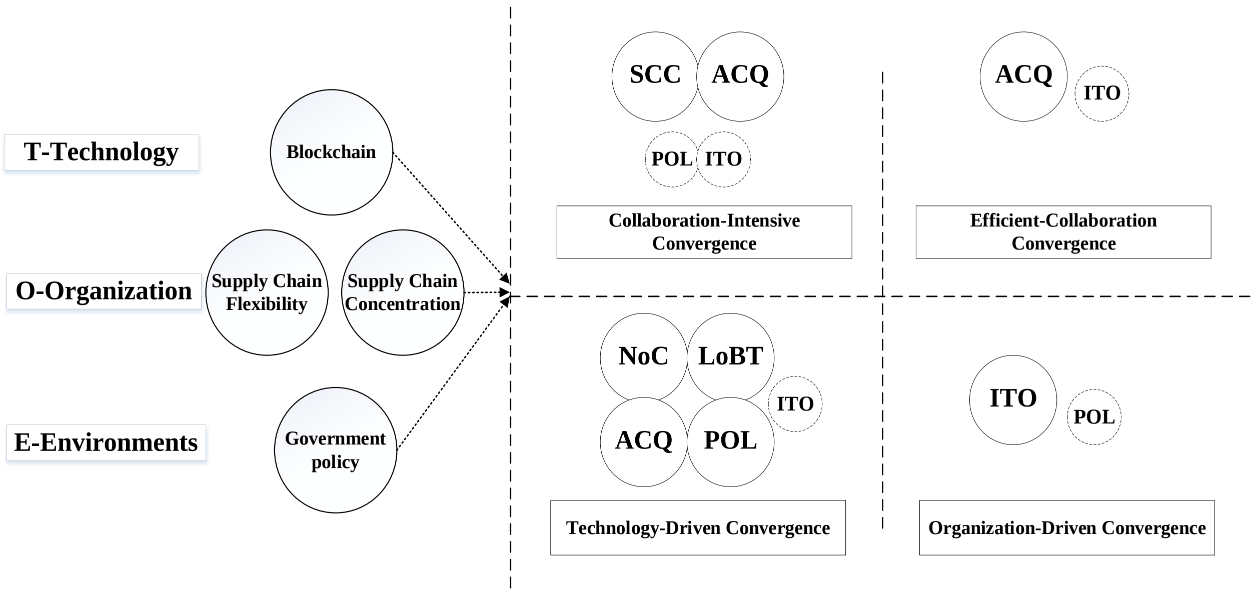

Fig. 2. Ecological construction of dual-chain convergence: A TOE-dimension perspective.

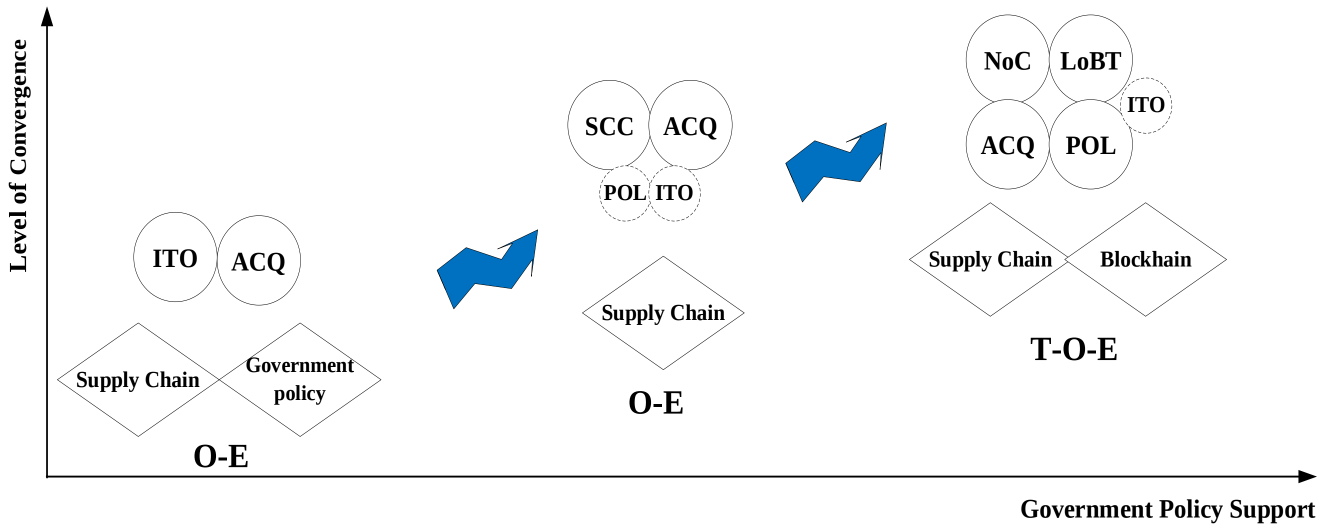

Fig. 3. Leap of dual-chain convergence configurations under government policy support.

augment value, and attain a competitive edge. Nevertheless, it is not imperative for all firms to implement this technology immediately, as the adoption process necessitates a careful evaluation of costs, complexity, and operational compatibility. Some organizations may continue to perform effectively through proficient supply chain management alone. This highlights that fundamental supply chain management and optimization remain the most essential and critical components for enterprises. For instance, in configuration 8, the average maturity of blockchain technology for Leo Group is 1, which is lower than the overall mean of 1.84. The average attention allocation for blockchain technology is 5.5, below the overall mean of 9.21. However, the average supply chain flexibility (ITO) is as high as 30.66, significantly surpassing the overall mean of 6.02. Leo Group's subsidiary, MediaV, has joined the "Marketing Data Chain" platform launched by Xiaomi and completed the initial joint testing and debugging phases. By leveraging supply chain advantages, it has conducted a series of tests and experiments with Xiaomi and various partners, addressing issues encountered in the exchange and utilization of programmatic advertising data, thereby enhancing value creation. Although blockchain technology has not yet attained an optimal level of maturity and remains relatively limited within corporate settings, a high degree of supply chain flexibility can nonetheless serve as a valuable asset for organizations. This adaptability enables enterprises to respond swiftly to market fluctuations and customer requirements, consequently augmenting operational efficiency and competitive advantage. Therefore, even in scenarios where blockchain technology is not fully mature, organizations can still achieve commendable performance through optimizing supply chain management.

D. Discussion

Following the analysis of conditional configurations, Fig. 2 illustrates the relationships among technological, organizational, and environmental conditions across various configurations. It emphasizes the effects of interactive alignment and elucidates the fundamental roles of supply chain conditions, blockchain technology, and environmental factors in each configuration.

Furthermore, this research emphasizes the pivotal role of ACQ in facilitating dual-chain convergence to augment enterprise value. In 77.8% of configurations 1-7, ACQ is recognized as a fundamental condition. Notably, in-house R&D was present in 200 instances, whereas platform-based technology was present in 175 instances, highlighting the strategic significance of choosing an appropriate acquisition approach for dual-chain convergence. In-house R&D enhances corporate control over data security and privacy, fostering trust throughout the supply chain. Conversely, platform technology supports rapid deployment, cost reduction, and increased operational efficiency, especially in large-scale implementation scenarios.

Through comparative analysis, this study finds that government policy support assumes a crucial role in shaping the environmental conditions necessary for dual-chain convergence. Incentives such as tax reductions, financial subsidies, and research and development grants serve to motivate enterprises to explore and adopt blockchain technology. The development of standards and regulatory frameworks provides explicit guidance for their application in supply chain management. Furthermore, the promotion of cross-industry and cross-sector collaboration facilitates the creation of exchange platforms that accelerate the widespread implementation of blockchain technology within supply chains. Throughout the evolution of various configurations, including organization-driven, efficiency-collaborative, collaboration-intensive, and technology-driven types, the significance of POL has progressively increased, transitioning from a supplementary role to a central condition. These findings clearly demonstrate that government policy not only promotes technological collaboration among industrial enterprises but also improves the overall operational efficiency of supply chains. Fig. 3 illustrates the evolution of

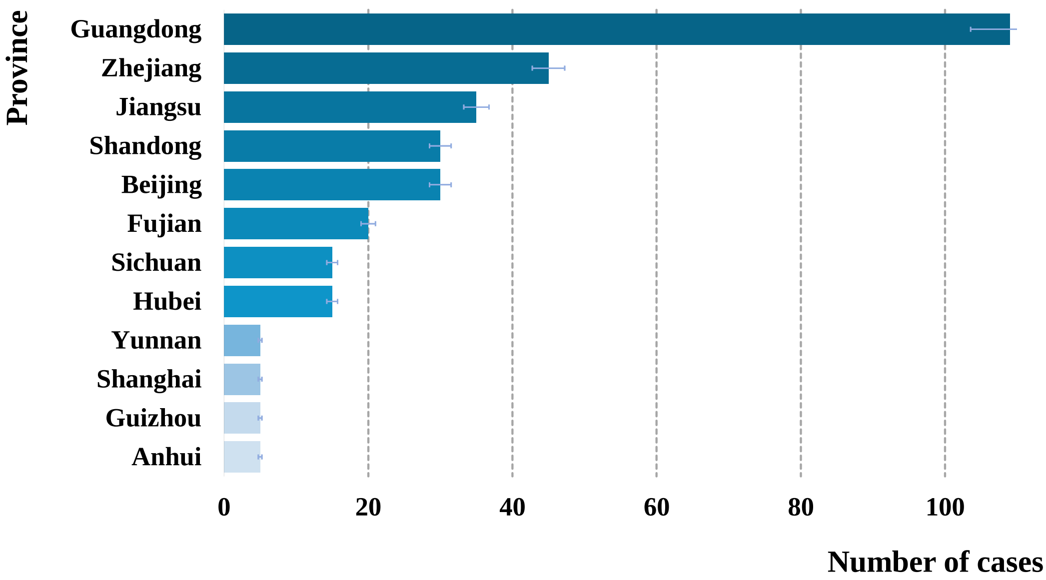

Fig. 4. Regional distribution of Chinese industrial enterprises involved in blockchain technology.

dual-chain convergence configurations under governmental leadership.

Fig. 4 illustrates the regional distribution of industry cases involving blockchain technology across China. The data reveals considerable disparities across provinces in blockchain adoption. Guangdong Province stands out with over 100 cases, a reflection of its strong technological infrastructure and advantageous policy environment. As the central region within the Guangdong-Hong Kong-Macao Greater Bay Area, Guangdong has successfully attracted numerous high-tech enterprises. By 2024, the province hosted more than 77,000 high-tech firms, accounting for 35.8% of the national total, according to a Nanfang Daily report published on January 26, 2025. Beijing and Zhejiang follow, each with approximately 30 blockchain application cases. These regions benefit from concentrated technological resources and vibrant innovation ecosystems. Overall, the regional distribution underscores the influence of local economic development, governmental support, and industrial foundations on adopting emerging technologies such as blockchain.

E. Robustness Test

To ensure the robustness of the conclusions, the following tests were conducted within this paper: First, the configuration for high enterprise value was examined by adjusting the case threshold and consistency level. The case number threshold was reduced to 2 and 1, resulting in eight and seven configurations, respectively, identical or similar to the original, with minimal parameter modifications. Subsequently, the consistency level decreased from 0.890 to 0.800, and the overall coverage diminished from 0.604 to 0.595, aligning with the original conclusion. Second, to address the issue of sample data, only firms with continuous data availability throughout the period were retained, and continuous variables were subjected to shrinkage at the 1% significance level to eliminate outlier effects, all of which serve to confirm the robustness of the conclusions presented in this study.

V. Conclusion

A. Research Conclusions

At the end of 2023, the Ministry of Industry and Information Technology, along with other relevant departments, released the Guidelines for the Construction of Blockchain and Distributed Ledger Technology Standard Systems, initiating the comprehensive promotion of the New Industry Standardization Leading Project Implementation Plan (2023–2035). This initiative emphasizes the importance of enhancing the top-level design of blockchain standardization and advancing the high-quality development of the blockchain industry. These policy measures establish new expectations for the application of blockchain technology within industrial supply chains. In light of this policy context, this study concentrates on publicly listed industrial enterprises implementing blockchain technology. By integrating conventional correlation analysis with fsQCA, the research investigates multiple conditions and causal configurations that contribute to elevated enterprise value through blockchain-enabled supply chain practices. The findings delineate four effective configuration types that facilitate advanced dual-chain convergence and value creation: collaboration-intensive, efficiency-collaboration, technology-driven, and organization-driven.

This study draws the following conclusions. First, multiple configurations can achieve high-level blockchain and supply chain convergence, exhibiting “Multiple Concurrency” and “Causal Asymmetry” characteristics. Second, no single condition is necessary to attain dual-chain convergence and substantial enterprise value; however, ACQ and POL play critical roles in enabling such convergence. Third, specific conditions demonstrate a substitutive relationship.

For instance, under specific scenarios, LoBT and SCC can function interchangeably to enhance value creation jointly. Fourth, under enabling factors such as policy support, supply chain management capabilities can also significantly boost enterprise value. In other words, not all enterprises need to adopt blockchain technology immediately. Considerations such as cost, implementation complexity, and compatibility with existing operations should guide the decision-making process. Blockchain serves as a catalyst for improving supply chain efficiency and performance. Whether and how a firm integrates blockchain technology into its supply chain should depend on its unique circumstances and strategic objectives.

B. Theoretical and Managerial Implications

The theoretical contribution of this study resides in the integration of the TOE framework with a configurational perspective, presenting an innovative approach to the examination of the convergence between blockchain technology and supply chains. This integration reveals the complex and diverse causal configurations that drive dual-chain convergence. While preceding research has examined the benefits of blockchain technology and its applications within supply chain management [10], [36]-[40], they frequently neglect to address the significant influence of dual-chain convergence on enterprise value. By adopting a systemic perspective grounded in the TOE framework, this study progresses beyond the analysis of individual factors to emphasize the interaction and alignment among multiple dimensions. It systematically examines the synergistic effects of blockchain technology conditions, supply chain organizational capabilities, and government policy support on dual-chain convergence. The findings not only offer a new perspective for understanding the complexity of dual-chain convergence but also provide empirical validation of the multiple configurations that can enhance enterprise value.

The findings of this study offer meaningful practical implications for the advancement of dual-chain convergence and the promotion of high-quality enterprise development. Firstly, enterprise-level and blockchain technological maturity are crucial for achieving dual-chain integration. Organizations should improve strategic planning and increase internal awareness of the potential of blockchain technology. Secondly, entities characterized by high supply chain concentration, low structural complexity, and strong operational flexibility are better equipped to adopt blockchain solutions, facilitating more efficient dual-chain convergence and enhancing enterprise value. Thirdly, given the significant complexity and cost associated with blockchain research and development, participation in high-tech enterprise consortia or forming strategic partnerships with blockchain laboratories can accelerate technological progress and application. Finally, government policy support plays an essential role in promoting dual-chain convergence. Policy incentives significantly strengthen industrial collaboration and improve overall supply chain efficiency. In conclusion, to achieve effective dual-chain convergence and generate enterprise value, industrial enterprises should focus on enhancing blockchain capabilities, establishing resilient strategic alliances, actively engaging with government initiatives, and fostering cross-functional collaboration within the supply chain.

C. Limitations and Future Outlook

This study also presents several limitations. First, the measurement of blockchain technology attention allocation requires further refinement. In this study, attention was assessed by counting the frequency of investor Q&A sessions and news reports. Future research could employ advanced techniques such as natural language processing and Transformer-based multi-head attention mechanisms to evaluate contextual relevance and enhance measurement precision. Second, the research sample comprises listed companies in the industrial sector that have adopted blockchain technology. As a result, the original sample size is relatively limited, which may constrain the observable degree of variation in the data. Finally, future studies could utilize the entropy weight method to evaluate indicators related to supply chain and blockchain outcomes comprehensively. Furthermore, R&D investment and firm size, as representative variables of technological application, may serve as important mediating factors in future research. Expanding the research scope to include the entire industry would further enrich the generalizability of the findings.

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