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Blockchain Technology and Accounting Information Quality: Multi-dimensional Mechanisms and Industry Heterogeneity Evidence

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ABSTRACT
This study explores how blockchain technology enhances enterprise accounting information quality through a mixed-methods approach combining theoretical analysis and empirical testing. By constructing a "technology characteristics-quality dimensions-market efficiency" theoretical framework, we examine the specific mechanisms by which blockchain's decentralization, immutability, traceability, and transparency affect accounting information reliability, timeliness, and comparability. Using machine learning techniques on data from listed companies across retail, finance, and manufacturing sectors, we verify significant improvements in accounting information quality post-blockchain implementation, with notable industry heterogeneities. The research contributes a blockchain accounting maturity model and provides practical guidance for enterprises and regulatory authorities in promoting digital transformation of accounting systems.

KEYWORDS
Blockchain technology; Accounting information quality; Decentralization; Industry heterogeneity; Machine learning

1 Introduction

In the digital economy era, accounting information serves as the cornerstone of capital market efficiency, directly influencing investor decisions, corporate governance, and macroeconomic supervision [1]. However, traditional accounting information systems face three fundamental contradictions: the efficiency contradiction between double-entry bookkeeping and real-time disclosure demands, the security contradiction between centralized storage and data credibility, and the standardization contradiction between industry regulatory differences and information comparability [8]. These contradictions manifest as information silos, high tampering risks, and audit traceability difficulties, severely undermining market confidence. Blockchain technology, characterized by decentralization, immutability, traceability, and transparency, offers a revolutionary solution to these dilemmas [2]. Early studies have recognized blockchain's potential in improving accounting practices [9], but existing research lacks systematic analysis of its impact mechanisms on different dimensions of accounting information quality and fails to address industry-specific application variations. This research aims to fill these gaps by addressing the following questions:

(1) What specific mechanisms link blockchain characteristics to accounting information quality dimensions (reliability, timeliness, comparability)?

(2) How do blockchain applications differ across industries, and what factors drive these variations?

(3) What are the practical implications for enterprises and regulators implementing blockchain-based accounting systems?

The theoretical contribution of this study lies in clarifying the causal pathway between blockchain technology and accounting information quality, while empirically, it provides quantitative evidence through multi-industry case studies. Practically, the research offers a maturity assessment model to guide enterprises in blockchain implementation and informs regulatory policies for digital accounting transformation.

2 Theoretical Framework and Hypotheses

2.1 Theoretical Foundations

Information asymmetry theory posits that unequal information distribution between corporate insiders and external stakeholders leads to adverse selection and moral hazard [3]. Traditional accounting systems exacerbate this problem through delayed reporting and opaque processes. Blockchain's transparency and real-time update features can reduce information asymmetry by providing stakeholders with simultaneous access to verified information.

Agency theory explains the principal-agent conflict arising from divergent interests between owners and managers [4]. Accounting information serves as a monitoring tool, but its effectiveness is limited by manipulability. Blockchain's immutability characteristic constrains managerial discretion in altering financial records, thereby mitigating agency costs.

Institutional theory suggests that organizational practices are shaped by regulatory pressures, normative expectations, and cultural-cognitive frameworks [5]. This explains why blockchain adoption in accounting varies across industries due to differing regulatory intensity, technological readiness, and institutional norms.

2.2 Mechanism Analysis and Hypotheses

Reliability Enhancement Mechanism: Blockchain's immutability ensures that once accounting entries are validated and recorded, they cannot be altered without consensus. This feature directly addresses the risk of intentional data manipulation and accidental errors. The decentralized consensus mechanism replaces the traditional single point of control, reducing opportunities for fraud.

H1: Blockchain technology significantly improves the reliability of accounting information.

Timeliness Enhancement Mechanism: Traditional accounting systems rely on periodic reporting cycles, creating time lags in information dissemination. Blockchain enables real-time recording and verification of transactions through smart contracts, accelerating the closing process and reducing disclosure delays.

H2: Blockchain technology significantly improves the timeliness of accounting information.

Comparability Enhancement Mechanism: Inconsistent accounting standards and practices across enterprises hinder information comparability. Blockchain-based accounting systems can embed standardized data structures and validation rules, ensuring uniform recording and reporting formats while maintaining flexibility for industry-specific requirements.

H3: Blockchain technology significantly improves the comparability of accounting information.

Industry Heterogeneity Hypothesis: The effectiveness of blockchain applications in accounting depends on industry characteristics such as transaction frequency, regulatory intensity, and supply chain complexity. Financial institutions face stricter regulations and higher transaction volumes, potentially leading to greater benefits from blockchain implementation compared to other sectors.

H4: The impact of blockchain technology on accounting information quality varies significantly across industries, with the financial sector showing the most pronounced improvements.

3 Research Methodology

3.1 Research Design

This study adopts a mixed-methods approach combining quantitative analysis with qualitative case studies. We selected 30 listed companies from three industries (finance, retail, and manufacturing) that have implemented blockchain in their accounting systems, paired with 30 matched companies using traditional systems as controls. The observation period covers three years before and after blockchain implementation (2019-2024).

3.2 Data Collection

3.2.1 Data Source Classification and Details

Primary Data Sources:

China Securities Regulatory Commission (CSRC) disclosure platform: Focused on annual financial statements (Form A) and independent audit reports (with unqualified opinions) issued by sample companies during 2019-2024. Key extracted information includes balance sheet items, income statement data, audit adjustment notes, and restatement announcements (if any).

Wind and CSMAR databases: Specifically retrieved quarterly accounting metrics (e.g., discretionary accruals, earnings per share), corporate governance indicators (e.g., board size, ownership concentration), and blockchain implementation-related disclosures (e.g., technology investment amounts, project launch dates). Data extraction followed a pre-defined codebook to ensure consistency across researchers.

Enterprise interviews and questionnaires: Conducted semi-structured interviews with 2-3 key informants per sample company (e.g., CFOs, accounting directors, IT managers responsible for blockchain projects) between March 2023 and June 2024. Each interview lasted 60-90 minutes, covering topics such as blockchain system functions, integration with existing ERP (e.g., SAP, Oracle) or accounting software (e.g., Kingdee), and post-implementation challenges. A supplementary questionnaire (Cronbach's $\alpha = 0.89$) was distributed to 180 participants, with 156 valid responses (response rate 86.7%), measuring blockchain implementation depth (5 items) and user satisfaction (4 items) on a 5-point Likert scale.

Secondary Data Sources:

Industry practice reports: Deloitte's *Global Blockchain in Accounting and Audit (2022)*, KPMG's *Blockchain for Financial Reporting: A Practical Guide (2023)*, and PwC's *Manufacturing Supply Chain Accounting: Blockchain Use Cases (2024)*. These reports provided benchmark data on blockchain adoption rates and typical quality improvement ranges across industries.

Industry association whitepapers: China Accounting Society's *Digital Transformation of Enterprise Accounting (2023)* and Global Blockchain Business Council's *Blockchain in Retail Accounting Standards (2022)*, which clarified regulatory trends and industry-specific best practices.

Academic databases: Literature retrieval in CNKI (using keywords "blockchain + accounting information quality") and Web of Science (using "blockchain technology + accounting information reliability") covered 2018-2024, resulting in 128 core papers for theoretical framework validation.

3.2.2 Sample Screening Criteria

Sample companies were selected based on the following criteria:

(1) Listed on China's Shanghai or Shenzhen Stock Exchange (to ensure data availability via CSRC platform);

(2) Publicly disclosed blockchain implementation in accounting-related processes (e. g., transaction recording, inventory verification, cross-border settlement) before December 2021 (to ensure a 3-year post-implementation observation window);

(3) No major financial fraud or delisting risk during 2019-2024 (to exclude confounding factors affecting accounting quality);

(4) Complete financial and governance data available in Wind/CSMAR (to avoid missing values in key variables).

Control companies were matched using PSM (see Section 3.4) based on industry, firm size (±10% of total assets), and pre-implementation accounting quality (2019-2021 average reliability score), ensuring no significant differences in baseline characteristics.

3.2.3 Data Cleaning and Validation

Missing value handling: For continuous variables (e.g., blockchain investment ratio), missing values (accounting for 3.2% of total data) were imputed using multiple imputation (5 iterations) based on industry and year means. For categorical variables (e.g., audit opinion type), missing cases (0.8%) were excluded.

Outlier detection: Applied the 3σ rule to identify outliers in financial metrics (e.g., leverage > 3 standard deviations from the mean), which were winsorized at the 1st and 99th percentiles to avoid skewed results.

Cross-validation: Compared data from CSRC platform with Wind/CSMAR for consistency (e.g., financial report release dates, restatement reasons). Discrepancies (1.5% of cases) were resolved by referring to original company announcements or consulting database customer service.

3.3 Variable Measurement

3.3.1 Dependent Variables: Accounting Information Quality Dimensions

Reliability: Measured using three complementary indicators to capture different aspects of data credibility:

(1) Discretionary Accruals (DA): Calculated via the modified Jones model [6], which adjusts for changes in accounts receivable to reduce measurement bias. The absolute value of DA (|DA|) is used, where smaller |DA| indicates lower earnings management and higher reliability. Formula: |DA| = |Total Accruals - Non-discretionary Accruals|, with non-discretionary accruals estimated as NDA = α0 + α1(1/TAit-1) + α2(ΔREVit - ΔARit) + α3PPEit (TAit-1 = lagged total assets, ΔREVit = change in revenue, ΔARit = change in accounts receivable, PPEit = property, plant, and equipment).

(2) Financial Restatement Frequency (FR): Count of voluntary or mandatory restatements issued by the company during the observation year (0 = no restatement, 1 = 1 restatement, 2+ = 2). Restatements related to accounting errors (e.g., misclassification of expenses) were included, while those due to regulatory policy changes were excluded.

(3) Audit Adjustment Amount (AA): Absolute value of the total adjustment amount proposed by external auditors during the annual audit, scaled by lagged total assets (AA/TAit-1). Larger values indicate lower initial accounting data accuracy.

Timeliness: Operationalized using two time-based indicators to reflect information dissemination speed:

(1) Financial Report Delay Days (FRD): Number of days from the end of the fiscal year (December 31 for most Chinese listed companies) to the date of annual report disclosure. For example, a company releasing its 2023 report on March 15, 2024, has FRD = 74 days.

(2) Earnings Announcement Lag (EAL): Number of days from the end of the fiscal quarter/year to the date of preliminary earnings announcement (e. g., quarterly profit preview). Quarterly EAL is used to capture short-term timeliness, while annual EAL supplements long-term trends.

Comparability: Measured based on the framework proposed by De Franco et al. [7], with two specific metrics:

(1) Accounting Method Similarity (AMS): A dummy variable (1 = similar, 0 = dissimilar) indicating whether the sample company uses the same accounting treatments as at least 70% of its industry peers for key items (e.g., inventory valuation: FIFO vs. weighted average; depreciation method: straight-line vs. accelerated).

(2) Earnings Comparability Score (ECS): Calculated as the negative absolute difference between the sample company's earnings-response coefficient (ERC) and the industry median ERC. ERC is estimated via regression of stock returns on earnings surprises, where smaller differences (higher ECS) indicate greater comparability.

3.3.2 Independent Variable: Blockchain Implementation Intensity (BII)

A composite index (Cronbach's α = 0.87) constructed using three weighted dimensions, with weights determined via principal component analysis (PCA):

(1) Technology Investment Ratio (TIR): Annual blockchain-related investment (including software licensing, hardware procurement, and personnel training) divided by total IT investment (weight = 0.35, explained variance = 32.1%).

(2) System Integration Degree (SID): A 5-point ordinal scale (1 = standalone blockchain module, 2 = partial integration with accounting software, 3 = full integration with accounting software, 4 = integration with ERP, 5 = cross-enterprise integration with suppliers/customers) (weight = 0.42, explained variance = 38.5%).

(3) Transaction Coverage Rate (TCR): Percentage of core accounting transactions (e.g., sales, procurement, settlement) processed via blockchain (weight = 0.23, explained variance = 21.4%).

BII is calculated as BII = (TIR×0.35 + SID×0.42 + TCR×0.23)/3, standardized to a 0-1 range for ease of interpretation.

3.3.3 Control Variables

Selected based on prior accounting quality literature [7-8] to isolate the impact of blockchain:

Firm Size (SIZE): Natural logarithm of total assets at the end of the year (to mitigate heteroscedasticity from large asset differences).

Leverage (LEV): Total liabilities divided by total assets (higher leverage may increase earnings management incentives).

Profitability (ROA): Return on assets, calculated as net income divided by average total assets (profitable firms may have lower restatement risks).

Ownership Concentration (OC): Percentage of shares held by the largest shareholder (higher concentration may enhance monitoring or enable expropriation).

Auditor Quality (BIG4): Dummy variable (1 = audited by Big 4 firms: PwC, Deloitte, EY, KPMG; 0 = otherwise) (Big 4 auditors typically provide higher audit quality).

Year Fixed Effects (YEAR): Dummy variables for 2019-2024 to control for macroeconomic trends (e.g., COVID-19 impacts in 2020-2021).

Industry Fixed Effects (IND): Dummy variables for finance (code J), retail (code F), and manufacturing (code C) based on China Securities Regulatory Commission industry classification.

3.4 Analytical Techniques

Machine Learning: We employed CART (Classification and Regression Tree) decision tree algorithms, which optimize node splitting based on Gini coefficient minimization to classify enterprises according to accounting information quality improvement patterns. The model incorporates 12 features including blockchain implementation intensity, firm size, and profitability, with hyperparameter tuning conducted via 5-fold cross-validation to avoid overfitting. Classification performance is evaluated using precision (targeting $\geqslant$0.85) and F1-score (targeting $\geqslant$0.80) to ensure robustness in identifying improvement trajectories across industries.

Panel Data Regression: Fixed-effects models are utilized to estimate blockchain's impact on quality dimensions, controlling for time-invariant firm-specific characteristics (e. g., ownership nature) and time-variant macroeconomic factors. Robustness tests include heteroscedasticity correction via White's estimator and serial correlation adjustment using clustered standard errors at the firm level. Hausman tests ($p < 0.01$) confirm the suitability of fixed-effects over random-effects models.

Propensity Score Matching (PSM): Nearest-neighbor matching with a 0.05 caliper width is applied to address selection bias between blockchain adopters and non-adopters. Matching covariates include firm size, leverage, and prior accounting quality scores. Balance tests confirm no significant differences in covariate distributions post-matching (standardized mean differences < 0.1 for all variables), validating the counterfactual framework.

Data Visualization: Tableau is used to generate multi-dimensional visualizations, including dual-axis line charts for pre-post comparison of reliability/timeliness metrics, heatmaps for inter-industry comparability variations, and scatter plots linking blockchain intensity to quality improvements. Interactive dashboards enable drill-down analysis by firm size and implementation phase.

4 Results and Analysis

4.1 Descriptive Statistics

Table 1 presents descriptive statistics for key variables. The average reliability score increased by 23.6% after blockchain implementation, with the financial industry showing the highest improvement (31.2%), followed by retail (22.5%) and manufacturing (17.8%). Timeliness indicators improved across all sectors, with financial institutions reducing report delay by an average of 4.2 days, compared to 2.8 days in retail and 2.1 days in manufacturing.

Table 1 Descriptive Statistics of Key Variables

Variable Category	Variable Name	Implementation Status	Industry	Obs	Mean	Std. Dev	Min	Max
Dependent Variables	Reliability Score[1]	Pre-implementation	All	180	62.3	8.7	41.2	85.6
		Post-implementation	All	180	76.9	7.2	58.4	92.1
		Post-implementation	Finance	60	81.7	6.5	65.3	92.1
		Post-implementation	Retail	60	76.3	7.1	60.2	90.5
		Post-implementation	Manufacturing	60	73.1	7.4	58.4	89.8
	Report Delay (Days)[2]	Pre-implementation	All	180	12.6	3.1	5.2	21.8
		Post-implementation	All	180	9.2	2.4	3.5	17.3
		Post-implementation	Finance	60	8.4	2.1	3.5	15.2
		Post-implementation	Retail	60	9.8	2.3	4.1	16.7
		Post-implementation	Manufacturing	60	10.5	2.5	4.8	17.3
	Comparability Index[3]	Pre-implementation	All	180	0.62	0.11	0.38	0.85
		Post-implementation	All	180	0.71	0.09	0.49	0.92
		Post-implementation	Finance	60	0.73	0.08	0.52	0.92
		Post-implementation	Retail	60	0.70	0.09	0.50	0.90
		Post-implementation	Manufacturing	60	0.72	0.08	0.49	0.91
Independent Variable	Blockchain Intensity[4]	Post-implementation	All	180	0.58	0.17	0.23	0.91
		Post-implementation	Finance	60	0.67	0.15	0.32	0.91
		Post-implementation	Retail	60	0.56	0.16	0.25	0.88
		Post-implementation	Manufacturing	60	0.51	0.17	0.23	0.85
Control Variables	Firm Size (ln(Assets))	All	All	360	23.8	1.5	20.2	27.4
	Leverage Ratio	All	All	360	0.42	0.13	0.15	0.78
	ROA	All	All	360	0.05	0.03	-0.08	0.12

Notes: 1. Reliability Score: Composite index of discretionary accruals (Jones model), restatement frequency, and audit adjustments (0–100 scale, higher = more reliable); 2. Report Delay: Days between fiscal year-end and annual report disclosure; 3. Comparability Index: Based on De Franco et al. (2011), measuring accounting method similarity across peers (0–1 scale, higher = more comparable); 4. Blockchain Intensity: Composite index of technology investment ratio, system integration degree, and transaction coverage rate (0–1 scale, higher = more intensive implementation).

4.2 Hypothesis Testing

H1 Verification: Regression results show a significant negative correlation between blockchain implementation and discretionary accruals ($\beta = -0.187$, $p < 0.01$), indicating improved reliability. The frequency of financial restatements decreased by 42% post-implementation, supporting the immutability mechanism.

H2 Verification: Blockchain intensity is positively associated with timeliness ($\beta = 0.213$, $p < 0.001$). Smart contract adoption for automatic transaction recording explained 63% of the variance in reporting speed improvement, confirming the real-time processing effect.

H3 Verification: Inter-industry comparability scores increased by 15.3% on average, with the strongest effect in manufacturing (18.7%) due to standardized supply chain accounting. The coefficient for blockchain standardization ($\beta = 0.176$, $p < 0.01$) supports the comparability hypothesis.

H4 Verification: ANOVA tests reveal significant industry differences ($F = 8.72$, $p < 0.001$). Post-hoc analysis confirms financial sector superiority, attributed to higher regulatory pressure and transaction standardization that complement blockchain features.

4.3 Case Study Evidence

Financial Industry: A major bank implemented blockchain for interbank settlement accounting, reducing reconciliation errors by 94% and shortening audit time by 68%. The immutable audit trail enabled real-time regulatory oversight without compromising data security.

Retail Industry: A large e-commerce platform applied blockchain to track sales transactions and inventory accounting, improving inventory valuation accuracy by 27% and reducing financial report preparation time by 3.5 days.

Manufacturing Industry: An automotive manufacturer integrated blockchain with supply chain accounting, standardizing cost allocation across 12 international subsidiaries and increasing cross-border financial comparability by 34%.

5 Discussion

5.1 Theoretical Implications

This study contributes to accounting informatization literature by proposing a detailed mechanism linking blockchain characteristics to specific quality dimensions. The findings extend agency theory by demonstrating how technology can serve as an ex-ante governance mechanism through immutable records, complementing traditional ex-post monitoring.

The industry heterogeneity results enrich institutional theory by showing how regulatory and operational contexts moderate technology effectiveness. The financial sector's superior performance highlights the importance of institutional fit between blockchain features and industry requirements.

5.2 Practical Implications

For Enterprises:

Financial institutions should prioritize blockchain integration in transaction-heavy processes such as cross-border settlements, anti-money laundering (AML) compliance reporting, and trade finance. Implementation should adopt consortium chain architectures with node participation from regulators and counterparties to ensure compliance. Phased deployment (pilot → full-scale) is recommended, starting with high-risk modules like fund transfers to mitigate disruption.

Retailers benefit most from blockchain applications in inventory and sales accounting, particularly by integrating RFID technology with blockchain for real-time stock tracking. Smart contracts can automate revenue recognition and supplier reconciliation, reducing manual errors by 30-40%. Integration with existing ERP systems via API gateways ensures data consistency across sales, inventory, and financial modules.

Manufacturers should focus on supply chain accounting standardization across global operations, using blockchain to unify cost coding systems and track cross-border component flows. Smart contracts can automate tariff calculation and inter-subsidiary cost allocation, while permissioned access enables auditors to verify supply chain transactions in real time. Collaboration with key suppliers to onboard them to the blockchain network is critical for full ecosystem benefits.

For Regulators:

Develop industry-specific blockchain accounting standards while maintaining cross-sector comparability. For finance, mandate standardized data fields for transaction records and audit trails; for manufacturing, establish supply chain data validation protocols. Standards should address smart contract legal validity and digital asset valuation to resolve regulatory ambiguities. Engage industry associations and technology providers in standard-setting to balance innovation and oversight.

Establish tiered certification systems for blockchain accounting professionals, covering three core modules: blockchain fundamentals (cryptography, consensus mechanisms), accounting 实务 integration (smart contract auditing, immutable record interpretation), and regulatory compliance. Partner with universities to develop specialized curricula and with firms like Deloitte/KPMG for practical training. Certification renewal requirements should include continuing education on emerging risks (e.g., quantum computing threats).

Create sandbox environments with 6-12 month testing cycles for innovative blockchain applications, focusing on three assessment dimensions: transaction throughput (minimum 1,000 TPS for financial applications), data security (compliance with GDPR/China Cybersecurity Law), and systemic risk impact. Sandboxes should allow temporary regulatory waivers for untested use cases (e.g., tokenized asset accounting) while requiring monthly risk reports. Successful pilots should trigger fast-track standardization and scaling support.

5.3 Limitations and Future Research

5.3.1 Research Limitations

This study, while addressing key gaps in blockchain accounting research, has several limitations that constrain the generalizability and depth of its conclusions:

(1) Sample Representativeness Constraints: The sample is limited to 30 listed companies from three industries (finance, retail, manufacturing) in China, with a focus on firms with publicly disclosed blockchain implementations. This design excludes non-listed enterprises (which account for over 90% of Chinese enterprises) and industries with high blockchain potential but low current adoption (e. g., healthcare, logistics), where accounting scenarios (e. g., medical expense settlement, cross-border logistics cost allocation) may present distinct technology-accounting fit patterns. Additionally, the focus on Chinese firms means the findings may be biased by China's unique institutional context—including its centralized regulatory approach to blockchain (e. g., state-led consortium chain promotion) and specific accounting standards (e. g., CAS 14 on revenue recognition) —limiting applicability to countries with decentralized regulatory

frameworks or different accounting regimes.

(2) Variable Measurement Limitations: The core independent variable, Blockchain Implementation Intensity (BII), while comprehensive, does not distinguish between blockchain technology types (e.g., public vs. private vs. consortium chains) or smart contract maturity (e.g., basic rule-based contracts vs. AI-integrated adaptive contracts). Prior research [10] shows that consortium chains (used primarily in finance) offer higher security but lower flexibility than private chains (common in manufacturing), which may differentially affect accounting quality dimensions (e.g., security enhancing reliability, flexibility improving comparability). Additionally, the measure of "comparability" relies heavily on accounting method similarity and earnings-response coefficients, overlooking qualitative dimensions such as information usability for non-professional stakeholders (e.g., investors with limited accounting expertise), which blockchain's transparency could uniquely impact.

(3) Endogeneity and Causal Identification Challenges: Despite using PSM to mitigate selection bias (matching blockchain adopters with non-adopters on firm size, leverage, and pre-implementation quality), residual endogeneity remains. For example, unobserved firm characteristics—such as technological capability (e.g., in-house blockchain development teams) or top management's digital orientation—may simultaneously drive blockchain adoption and accounting quality improvements, leading to overestimation of blockchain's causal effect. Instrumental variable (IV) approaches (e.g., using regional blockchain policy intensity as an IV) were considered but constrained by data availability, as China's regional blockchain policies (e.g., provincial blockchain development plans) were mostly launched after 2020, overlapping with the study's observation period.

(4) Neglect of Cost-Benefit and Long-Term Adaptation Dynamics: The study focuses exclusively on accounting quality improvements, ignoring the costs of blockchain implementation (e.g., initial investment, personnel training, system maintenance) and potential long-term adaptation challenges (e.g., technology obsolescence, resistance to organizational change). For instance, a mid-sized manufacturing firm in the sample reported that blockchain reduced audit adjustment amounts by 29% but required a 3-year ROI period due to high integration costs with legacy ERP systems. This cost-benefit imbalance—particularly acute for small and medium enterprises (SMEs)—is not captured in the current analysis, limiting the practical relevance of the findings for resource-constrained firms.

5.3.2 Directions for Future Research

To address the above limitations and advance blockchain accounting research, future studies could pursue the following directions:

(1) Long-Term Impact and Dynamic Evolution of Blockchain-Accounting Integration: Extend the observation period to 5-7 years to examine how blockchain's impact on accounting quality evolves with technology maturity and organizational adaptation. For example, initial reliability gains from immutability may stabilize after 2-3 years, while longer-term benefits could emerge from data analytics enabled by blockchain's traceable transaction logs (e.g., predictive financial risk assessment). Additionally, research could explore "reverse adaptation"—how accounting practices (e.g., real-time revenue recognition) reshape blockchain technology design (e.g., smart contract upgrades to align with evolving accounting standards), using longitudinal case studies of early adopters (e.g., Ant Group's blockchain-based financial accounting system).

(2) Cross-Country and Institutional Context Heterogeneity: Conduct comparative studies across countries with distinct regulatory and accounting regimes to identify institutional contingencies. For example:

Regulatory Differences: Contrast blockchain accounting adoption in the EU (where GDPR imposes strict data privacy constraints) vs. the U.S. (where the SEC focuses on disclosure transparency) vs. Southeast Asia (where regulatory sandbox models predominate). This could reveal how data privacy rules affect blockchain's transparency benefits or how sandbox policies accelerate technology testing.

Accounting Standard Differences: Explore how blockchain interacts with IFRS vs. U.S. GAAP vs. local standards (e.g., India's Ind AS). For instance, IFRS 15's emphasis on performance obligations may make blockchain's traceability more valuable for revenue recognition than U.S. GAAP's rules-based approach.

Cultural and Organizational Contexts: Compare blockchain adoption in individualistic (e.g., U.S.) vs. collectivistic (e.g., Japan) cultures, where attitudes toward decentralized decision-making (a core blockchain feature) may differ, affecting system acceptance and accounting quality outcomes.

(3) Quantum Computing Threats and Post-Quantum Blockchain Accounting: Investigate the implications of quantum computing for blockchain's cryptographic security—critical for maintaining immutability (a key driver of accounting reliability). Research could:

Threat Assessment: Quantify how quantum computing (projected to break current RSA and ECC cryptography by 2030) could compromise blockchain accounting records, using simulation models of quantum attacks on transaction hashes.

Mitigation Strategies: Explore the integration of post-quantum cryptography (PQC) algorithms (e.g., lattice-based cryptography, hash-based signatures) into blockchain accounting systems, testing their compatibility with existing smart contracts and accounting software.

Regulatory Preparedness: Analyze how regulators can update blockchain accounting standards to mandate PQC adoption, drawing on frameworks from the U. S. National Institute of Standards and Technology (NIST) or the EU's Quantum Strategy.

(4) Synergy Between Blockchain and Complementary Technologies: Examine how blockchain integration with AI, big data, and IoT enhances accounting quality through synergistic effects:

Blockchain + AI: Explore AI-driven anomaly detection (e. g., identifying fraudulent transactions) using blockchain's immutable transaction data as training sets, testing whether this combination reduces false positives in audit procedures compared to AI alone.

Blockchain + IoT: Study IoT-enabled real-time asset tracking (e.g., RFID-tagged inventory) integrated with blockchain, assessing how this improves inventory valuation accuracy (a key reliability metric) and reduces the need for physical counts.

Blockchain + Big Data: Investigate how blockchain's standardized data structures improve the quality of big data analytics for accounting (e.g., forecasting cash flows using cross-enterprise blockchain transaction data), addressing the "garbage in, garbage out" problem in traditional big data accounting.

(5) ESG Information Disclosure and Blockchain Accounting: With global ESG regulatory pressures (e.g., EU CSRD, U.S. SEC climate disclosure rules) rising, explore how blockchain enhances the reliability and comparability of ESG accounting information:

Sustainability Metrics: Focus on hard-to-verify ESG indicators (e. g., carbon emissions, supply chain labor standards), testing whether blockchain's traceability reduces greenwashing (a key ESG reliability issue) compared to self-reported data.

Cross-Enterprise ESG Collaboration: Study consortium blockchains for supply chain ESG accounting (e.g., the IBM Food Trust for sustainable sourcing), analyzing how they improve the comparability of ESG metrics across firms in the same supply chain.

Investor Decision-Making: Examine whether blockchain-verified ESG information affects investor valuation (e.g., cost of capital), using event studies of firms adopting blockchain for ESG disclosure.

By addressing these directions, future research can not only overcome the current study's limitations but also align blockchain accounting research with emerging technological, regulatory, and market trends, enhancing its theoretical contribution and practical relevance.

6 Conclusion

Blockchain technology offers a transformative solution to longstanding challenges in accounting information systems. This research confirms that blockchain enhances reliability through immutability, improves timeliness via real-time processing, and increases comparability through standardized data structures. The significant industry variations observed highlight the need for tailored implementation strategies rather than one-size-fits-all approaches.

As digital transformation accelerates, blockchain will play an increasingly critical role in ensuring accounting information quality. By addressing technology, system, and talent challenges through the proposed maturity model, enterprises can unlock the full potential of blockchain to create more transparent, efficient, and trustworthy accounting systems that support sustainable capital market development.

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