



Blockchain Technology Adoption in Trade Finance: Implications for Cross-Border Transaction Efficiency and Trust Among Emerging Market Enterprises

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Abstract

Cross-border trade finance remains one of the most friction-intensive domains of international commerce, characterized by documentary redundancies, prolonged settlement cycles, and persistent trust deficits among counterparties operating across heterogeneous legal and institutional environments. Blockchain technology, with its properties of immutability, distributed consensus, and programmable smart contracts, has been widely proposed as a structural solution to these inefficiencies. Yet rigorous empirical evidence on whether and how blockchain adoption translates into measurable efficiency and trust gains for enterprises in emerging markets remains limited. This study employs a longitudinal panel design spanning 36 months to examine blockchain adoption outcomes among 284 export-oriented enterprises in South Africa, India, and Taiwan. Difference-in-differences estimation with firm fixed effects is used to isolate the causal effect of blockchain platform adoption on three outcomes: trade document processing time, letter of credit discrepancy rates, and inter-firm trust scores. Results indicate that blockchain adoption reduces average document processing time by 61.4% ($p < 0.001$), letter of credit discrepancy rates by 44.2% ($p < 0.001$), and significantly improves inter-firm trust scores (Cohen's $d = 0.79$). Interoperability constraints, legacy system integration costs, and regulatory uncertainty are identified as primary barriers to scaling adoption. The study contributes to the nascent empirical literature on blockchain in trade finance and offers actionable recommendations for enterprises, financial intermediaries, and trade facilitation bodies.

Keywords: - Blockchain, Trade Finance, Smart Contracts, Cross-Border Commerce, Transaction Efficiency, Emerging Markets, Difference-In-Differences

I. INTRODUCTION

International trade is the engine of economic integration and growth, yet the documentary and institutional infrastructure underpinning cross-border transactions has changed remarkably little since the codification of the Uniform Customs and Practice for Documentary Credits by the International Chamber of Commerce in 1933. Letters of credit, bills of lading, certificates of origin, and commercial invoices continue to circulate largely on paper or in non-interoperable digital formats, generating significant friction, error, and delay at every node of the trade finance chain (ICC, 2020). The World Trade Organization estimated in 2019 that trade documentation costs account for between 5 and 15 percent of total transaction value for cross-border shipments involving emerging market participants, a burden that falls disproportionately on smaller exporters with limited capacity to absorb processing delays and discrepancy resolution costs (WTO, 2019).

Blockchain technology, originally conceptualized by Nakamoto (2008) as a mechanism for peer-to-peer electronic cash transfer, has attracted intense interest from the trade finance community as a potential structural remedy for documentary inefficiency and counterparty trust deficits (Ganne, 2018). The core properties of distributed ledger technology including immutable transaction records, shared visibility across permissioned network participants, and programmable smart contract execution offer a conceptually compelling architecture for trade document management, letter of credit automation, and supply chain provenance verification (Tapscott & Tapscott, 2016). Major financial institutions including HSBC, Standard Chartered,

and DBS Bank, as well as multilateral platforms such as we.trade and Contour, have deployed blockchain-based trade finance systems in operational environments since 2018.

Despite this commercial momentum, the academic literature on blockchain adoption outcomes in trade finance contexts remains sparse and methodologically limited. Most published studies are conceptual or case-based, documenting implementation experiences without rigorously isolating causal effects (Kamble et al., 2019). The few quantitative studies available draw primarily on single-country samples from advanced economies, leaving open fundamental questions about whether efficiency and trust benefits observed in high-institutional-capacity environments translate to emerging market contexts where the need for transaction cost reduction is most acute (Kouhizadeh et al., 2021).

Furthermore, the literature has paid insufficient attention to the heterogeneity of blockchain adoption outcomes across enterprise types, trade corridors, and commodity categories. The moderating roles of firm-level absorptive capacity, trade partner network characteristics, and national regulatory frameworks have not been systematically examined. This study addresses these gaps through a rigorous multi-country longitudinal analysis that exploits the staggered rollout of blockchain platforms across a panel of export-oriented enterprises.

This study is guided by three research questions:

- Does blockchain adoption significantly reduce trade document processing time and letter of credit discrepancy rates among emerging market exporters?
- Does blockchain adoption enhance inter-firm trust in cross-border trade relationships?
- What enterprise-level and contextual factors moderate the efficiency and trust effects of blockchain adoption?

The paper proceeds as follows. Section 2 reviews the theoretical foundations and empirical literature. Section 3 describes the research methodology. Section 4 presents the empirical results. Section 5 discusses findings and their implications. Section 6 concludes with recommendations and limitations.

II. Literature Review

2.1. The Architecture of Trade Finance Inefficiency

Trade finance facilitates approximately 80% of global merchandise trade through instruments that mitigate payment risk and provide working capital to exporters and importers (ICC, 2020). Letters of credit, the most widely used instrument in emerging market trade corridors, involve a multi-party documentary chain that typically requires 5 to 10 business days for processing and generates discrepancy rates exceeding 70% on first presentation, according to the ICC's annual Trade Register (ICC, 2020). These discrepancies primarily arise from manual data entry errors, inconsistencies across independently prepared documents, and mismatches between physical goods and documentary descriptions.

Transaction cost theory, as elaborated by Williamson (1985), provides a foundational framework for understanding these inefficiencies. Williamson identified asset specificity, uncertainty, and transaction frequency as the primary determinants of governance choice. Trade finance transactions, characterized by high uncertainty arising from geographic and institutional distance, high asset specificity in the form of customized documentary requirements, and high repetition, are prime candidates for governance mechanisms that reduce opportunism and information asymmetry. Conventional trade finance addresses these challenges through relational contracting and bank intermediation, both of which are costly and dependent on pre-existing institutional trust (North, 1990).

2.2. Blockchain as a Trade Finance Infrastructure

Blockchain technology addresses trade finance inefficiencies through three primary mechanisms. First, shared distributed ledgers eliminate documentary duplication by enabling all permissioned parties including exporters, importers, freight forwarders, port authorities, banks, and insurers to access a single version of transactional truth in real time (Ganne, 2018). Second, smart contracts automate conditional payment release and document verification, reducing manual processing steps and associated error rates. Third, cryptographic hashing and consensus mechanisms create immutable audit trails that deter fraud and reduce the verification burden on intermediaries (Tapscott & Tapscott, 2016).

Early empirical evidence from blockchain pilots supports these theoretical mechanisms. HSBC reported that its blockchain-based letter of credit transaction for Cargill in 2018 was completed in 24 hours compared to the conventional 5 to 10 day processing cycle, representing a reduction of approximately 80% (HSBC, 2018). Contour, a blockchain trade finance network built on R3's Corda platform, reported a 90% reduction in letter of credit processing time across its pilot transactions (Contour, 2020). These figures, while striking, derive from controlled pilot environments and may not generalize to diverse operational contexts with heterogeneous counterparty technological capabilities.

2.3. Blockchain Adoption in Emerging Market Trade Contexts

The application of blockchain to trade finance in emerging markets presents both heightened opportunity and distinctive challenges. On the opportunity side, emerging market trade corridors typically exhibit higher documentation costs, greater counterparty opacity, and weaker institutional enforcement mechanisms, suggesting that trust-enhancing distributed ledger infrastructure could generate proportionally larger efficiency gains (Kouhizadeh et al., 2021). On the challenge side, the absorptive capacity constraints common among emerging market firms, including limited IT infrastructure, lower digital literacy, and constrained investment budgets, may impede adoption depth and limit the realization of potential benefits (Cohen & Levinthal, 1990).

Kamble et al. (2019) examined blockchain adoption intentions among Indian supply chain managers and found that perceived usefulness, trust in technology, and top management support were the strongest predictors of adoption, consistent with the Technology Acceptance Model (Davis, 1989). Queiroz and Fosso Wamba (2019) conducted a comparative study of

blockchain adoption intentions in the United States and India, finding that social influence and facilitating conditions exerted stronger effects in the Indian context, suggesting that network externalities and institutional support play more critical roles in adoption decisions in emerging economies.

2.4. Trust in Cross-Border Trade Relationships

Trust is a foundational governance mechanism in international commerce, particularly in contexts where formal legal enforcement is costly, slow, or unavailable (Zucker, 1986). Sako (1992) distinguished three forms of commercial trust: contractual trust (adherence to agreements), competence trust (belief in counterparty capability), and goodwill trust (commitment beyond contractual obligation). Dyer and Chu (2003) demonstrated empirically that higher inter-firm trust reduces transaction costs in automotive supplier relationships across the United States, Japan, and Korea, providing cross-cultural validation of trust's economic value.

The relationship between blockchain and commercial trust has received growing theoretical attention. Lumineau et al. (2021) argued that blockchain does not simply replicate institutional trust mechanisms but creates a distinct form of technology-mediated trust grounded in algorithmic consensus rather than relational reputation or third-party verification. This distinction has important implications for emerging market trade finance, where relational trust built through repeated interactions has historically been the primary governance mechanism and where the displacement or supplementation of relational trust by technological mechanisms may have complex and unpredictable effects.

2.5. Research Gaps

Four specific gaps motivate this study. First, longitudinal panel designs that track pre- and post-adoption outcomes for the same firms are absent from the empirical blockchain trade finance literature. Second, the causal identification problem, arising from the fact that technologically advanced firms are both more likely to adopt blockchain and to perform better on efficiency metrics, has not been adequately addressed. Third, cross-country comparative evidence from emerging markets spanning Asia and Africa is entirely lacking. Fourth, trust as an outcome variable rather than merely an adoption antecedent has received insufficient empirical attention in the trade finance context.

III. RESEARCH METHODOLOGY

3.1. Research Design

This study employed a longitudinal panel design with a 36-month observation window from January 2022 to December 2024. The design exploits the staggered adoption of blockchain trade finance platforms by firms within the panel to implement difference-in-differences (DiD) estimation, a quasi-experimental approach that controls for time-invariant firm-level confounders and common temporal trends. This design was selected because it offers stronger causal identification than cross-sectional designs while remaining feasible in operational commercial research contexts where randomized controlled trials are not practicable (Angrist & Pischke, 2009). A nested qualitative component comprising semi-structured interviews was incorporated to probe mechanisms and contextual factors beyond the reach of quantitative estimation.

3.2. Research Objectives

The study was structured around the following specific research objectives:

- Objective 1: To measure changes in trade document processing time following blockchain platform adoption using pre-post firm-level panel data.
- Objective 2: To assess the effect of blockchain adoption on letter of credit discrepancy rates among panel firms.
- Objective 3: To evaluate whether blockchain adoption generates measurable improvements in inter-firm trust scores among cross-border trade partners.
- Objective 4: To identify firm-level and contextual moderators of blockchain adoption outcomes.
- Objective 5: To document qualitative evidence on perceived barriers and enablers of blockchain integration in trade finance operations.

3.3. Hypotheses

The following hypotheses were specified for empirical testing:

- H1: Blockchain platform adoption significantly reduces trade document processing time among export-oriented enterprises.
- H2: Blockchain platform adoption significantly reduces letter of credit discrepancy rates.
- H3: Blockchain platform adoption significantly improves inter-firm trust scores between trading partners.
- H4: Firm-level absorptive capacity positively moderates the relationship between blockchain adoption and efficiency outcomes.
- H5: Regulatory clarity positively moderates the relationship between blockchain adoption and inter-firm trust outcomes.

3.4. Sample and Data Collection

The target population comprised export-oriented enterprises with annual export revenues exceeding USD 500,000 and a minimum of three years of cross-border trading experience. Three countries were selected to represent distinct institutional environments, blockchain regulatory stances, and trade finance ecosystem maturity levels: South Africa (Africa's most sophisticated financial services market with a cautiously enabling blockchain regulatory posture), India (a major emerging

economy with rapidly expanding fintech infrastructure and a growing blockchain regulatory dialogue), and Taiwan (a high-income East Asian economy with advanced semiconductor and electronics export sectors and proactive blockchain governance frameworks).

A total of 284 firms were recruited through national exporters' associations, trade finance banking partners, and blockchain network operator referrals. The panel comprised 97 South African firms, 101 Indian firms, and 86 Taiwanese firms. Within the observation period, 149 firms adopted a blockchain trade finance platform (treatment group) and 135 firms did not adopt (control group). Adoption timing varied across firms, with 48 firms adopting in 2022, 63 in 2023, and 38 in 2024, providing the staggered adoption structure required for DiD identification. Quarterly outcome data were extracted from firms' trade finance records with written consent, supplemented by bank-provided letter of credit transaction data under data sharing agreements. Semi-structured interviews were conducted with chief financial officers or heads of trade finance at 36 purposively selected firms post-adoption.

3.5. Outcome Variables and Measures

Three primary outcome variables were specified. Trade document processing time was measured in business days from document presentation to acceptance or payment release, extracted from bank transaction records. Letter of credit discrepancy rate was measured as the proportion of first-presentation letter of credit submissions containing at least one discrepancy requiring amendment or resubmission, calculated quarterly at the firm level. Inter-firm trust was measured using a validated 12-item scale adapted from Dyer and Chu (2003), administered annually to a nominated senior trade relationship manager at each firm. The scale captures contractual, competence, and goodwill trust dimensions and demonstrated a Cronbach's alpha of 0.88 in the pilot administration.

Moderating variables included absorptive capacity, measured using a six-item scale adapted from Cohen and Levinthal (1990) and capturing IT capability, staff training investment, and prior digital system adoption; and regulatory clarity, measured using a four-item scale capturing the perceived clarity and consistency of national blockchain regulatory guidance. Control variables included firm size (log of annual revenue), export intensity (exports as a proportion of total revenue), trade corridor (intra-regional vs. intercontinental), commodity category, and years of blockchain experience.

3.6. Analytical Strategy

The primary quantitative method was two-way fixed effects DiD estimation, implemented in Stata 17 with firm and time fixed effects and standard errors clustered at the firm level. The parallel trends assumption was tested by examining pre-adoption trends in outcome variables between eventual adopters and non-adopters, and event study plots were generated to visualize dynamic treatment effects across quarters relative to adoption. For the trust outcome, which was measured annually rather than quarterly, a first-difference specification was employed. Heterogeneous treatment effects by absorptive capacity and regulatory clarity were estimated through interaction terms in the main DiD specification.

Effect sizes for continuous outcomes were reported as percentage changes (for processing time and discrepancy rates) and Cohen's *d* (for trust scores) to facilitate cross-study comparability. Robustness checks included alternative control group specifications, the exclusion of early adopters, and placebo tests using pre-adoption periods as falsification exercises. Semi-structured interview data were analyzed using directed content analysis (Hsieh & Shannon, 2005), with an a priori code scheme derived from the theoretical framework supplemented by inductively generated codes. Analysis was conducted using MAXQDA 2024.

IV. RESULTS

4.1. Sample Characteristics

The 284 panel firms spanned a range of export sectors: electronics and technology (28.5%), agricultural commodities and food processing (22.9%), chemicals and pharmaceuticals (18.7%), textiles and apparel (17.3%), and other manufactured goods (12.7%). Firm size ranged from medium enterprises with annual revenues of approximately USD 1 million to large corporations with revenues exceeding USD 500 million, with a median annual revenue of USD 12.4 million. Mean export intensity was 64.3% of total revenue (SD = 18.7%). Pre-adoption baseline comparisons between eventual adopters and non-adopters showed no statistically significant differences on firm size, export intensity, or sector composition, supporting the comparability of the two groups.

4.2. Parallel Trends Validation

Event study plots of pre-adoption trends in document processing time and discrepancy rates showed no statistically significant pre-treatment differences between adopters and non-adopters across the four quarters preceding adoption (all *p* values greater than 0.10). The parallel trends assumption was therefore deemed satisfied, supporting the validity of the DiD identification strategy. Placebo tests using a falsified adoption date two quarters prior to actual adoption yielded null results, providing additional confidence in the causal interpretation of post-adoption estimates.

4.3. Effect on Document Processing Time

The DiD estimate for the effect of blockchain adoption on trade document processing time was negative and highly significant (beta = -3.84 business days, SE = 0.47, *p* < 0.001), representing a reduction of 61.4% relative to the pre-adoption mean of 6.25 business days. This result supports H1. Dynamic event study estimates confirmed that the reduction emerged immediately following adoption and was sustained and slightly amplifying across the post-adoption observation period, with the largest effects observed 6 to 8 quarters post-adoption. Country-disaggregated estimates showed reductions of 64.1% in

Taiwan, 62.3% in India, and 57.8% in South Africa, with the smaller South African effect partially attributable to lower initial blockchain network density in that market.

4.4. Effect on Letter of Credit Discrepancy Rates

Blockchain adoption was associated with a 44.2 percentage point reduction in letter of credit discrepancy rates ($\beta = -0.442$, $SE = 0.063$, $p < 0.001$), supporting H2. Pre-adoption discrepancy rates averaged 68.3% in the treatment group, consistent with global industry benchmarks, and declined to a post-adoption mean of 24.1%. The discrepancy reduction was largest for firms operating on trade corridors with the highest counterparty blockchain adoption rates, consistent with the network externalities hypothesis: the efficiency gains from smart contract automation are maximized when all parties to a transaction are on the same distributed ledger. Robustness checks using alternative DiD specifications, including the stacked DiD approach of Cengiz et al. (2019) to address potential heterogeneity bias in the standard two-way fixed effects estimator, confirmed the stability of the primary estimate.

4.5. Effect on Inter-Firm Trust

Annual trust scores increased significantly following blockchain adoption, with a DiD estimate of 0.84 scale points on the 5-point composite trust measure ($SE = 0.19$, $p < 0.001$, Cohen's $d = 0.79$), providing strong support for H3. Disaggregation by trust dimension revealed that the largest gains were on the contractual trust sub-scale ($d = 0.91$), reflecting enhanced confidence in counterparty compliance enabled by smart contract enforcement, followed by competence trust ($d = 0.74$) and goodwill trust ($d = 0.63$). The goodwill trust finding is particularly notable, as it suggests that the transparency and accountability mechanisms of blockchain extend beyond procedural compliance to affect more dispositional and relational dimensions of trust.

4.6. Moderation Analysis

The interaction between blockchain adoption and absorptive capacity was positive and significant for both document processing time reduction ($\beta = 0.18$, $p < 0.05$) and discrepancy rate reduction ($\beta = 0.21$, $p < 0.05$), supporting H4. Firms with higher absorptive capacity, indicated by prior digital system adoption and staff IT training investment, achieved larger efficiency gains from blockchain adoption. The interaction between adoption and regulatory clarity was significant for the trust outcome ($\beta = 0.27$, $p < 0.01$), supporting H5: firms operating under clearer national blockchain regulatory frameworks reported larger trust improvements, potentially because regulatory certainty reduces the perceived legal risk of committing to blockchain-mediated contractual arrangements.

4.7. Interview Findings

Directed content analysis of the 36 post-adoption interviews generated three primary thematic clusters: realized operational benefits, persistent implementation barriers, and evolving perceptions of trust and transparency.

4.7.1. Theme 1: Realized Operational Benefits

Interview participants uniformly affirmed the quantitative findings, describing blockchain adoption as a transformative operational event. Heads of trade finance at Taiwanese electronics firms emphasized that smart contract automation had effectively eliminated the internal compliance review step for standard letter of credit verification, freeing specialist staff for higher-value relationship and risk management activities. Indian pharmaceutical exporters highlighted the provenance documentation capability of distributed ledgers as particularly valuable in regulated markets where chain-of-custody verification is mandatory, reducing customs clearance delays and regulatory audit burdens simultaneously.

4.7.2. Theme 2: Persistent Implementation Barriers

Three barriers recurred prominently across country and sector contexts. First, interoperability between competing blockchain trade finance platforms (we.trade, Contour, Marco Polo, and national variants) was universally cited as a structural limitation, with several firms describing parallel documentation processes maintained to accommodate counterparties on different networks. This finding is consistent with Kouhizadeh et al. (2021), who identified network fragmentation as the primary systemic risk to blockchain's scaling potential in trade finance. Second, legacy enterprise resource planning system integration costs were described as unexpectedly high, with several medium-sized South African firms noting that integration investments exceeded initial platform licensing costs by a factor of two to three. Third, regulatory uncertainty, particularly in India where the legal status of smart contract-executed payment obligations had not been definitively settled at the time of adoption, created organizational hesitancy and, in two cases, delayed full operational deployment.

4.7.3. Theme 3: Evolving Perceptions of Trust and Transparency

The trust theme yielded the most nuanced qualitative findings. Most participants described an initial period of heightened anxiety during which the novelty of algorithm-mediated transaction processing generated uncertainty rather than confidence, consistent with Lumineau et al. (2021). Over time, however, as the system's reliability became empirically demonstrable through successful transaction cycles, participants described a qualitative shift toward what several termed a new normal of operational confidence. Several interviewees noted that blockchain's transparency had created unexpected positive relational dynamics with long-standing trade partners, with shared access to real-time shipment and documentation data described as having strengthened communication frequency and mutual accountability beyond formal contractual requirements.

V. Discussion

The findings of this study make four distinct contributions to the blockchain trade finance literature. First, the DiD estimates of a 61.4% reduction in document processing time and a 44.2 percentage point reduction in letter of credit discrepancy rates represent the most rigorous causal evidence to date on blockchain's operational efficiency effects in trade finance, extending and substantiating prior case-based estimates from the practitioner literature (HSBC, 2018; Contour, 2020) to a multi-country enterprise panel context. The consistency of these findings across South Africa, India, and Taiwan, three countries with markedly different institutional environments, strengthens confidence in the generalizability of blockchain's efficiency benefits.

Second, the trust findings (H3 supported, Cohen's $d = 0.79$) represent a theoretically significant contribution. Most prior blockchain adoption research treats trust as an antecedent of adoption rather than as an outcome. This study demonstrates that adoption generates trust improvements that are not merely procedural but extend to the goodwill and competence dimensions of inter-firm trust. This finding enriches Lumineau et al.'s (2021) framework by providing empirical evidence that technology-mediated trust, once operationally established, can reinforce and augment relational trust rather than displacing it. The practical implication is that blockchain adoption may generate positive relational externalities beyond the direct efficiency gains documented in quantitative metrics.

Third, the moderation findings extend the theoretical framework by demonstrating that blockchain's benefits are not uniformly distributed. Firms with higher absorptive capacity and those operating under clearer regulatory frameworks capture significantly larger efficiency and trust gains. This finding aligns with Cohen and Levinthal (1990) and supports the policy implication that investment in blockchain adoption programs should be accompanied by parallel investment in firm-level digital capabilities and regulatory framework development. Without these complementary investments, the efficiency and trust potential of blockchain will be unevenly captured and the technology's contribution to cross-border trade democratization will remain limited.

Fourth, the qualitative evidence on interoperability barriers provides important context for interpreting the quantitative findings. The efficiency gains documented in this study were achieved despite, not because of, a resolved interoperability landscape. As blockchain trade finance networks mature and standards bodies including the International Chamber of Commerce and the International Organization for Standardization (ISO) develop common data standards, the efficiency ceiling for blockchain-enabled trade finance is likely to be substantially higher than current evidence suggests.

VI. CONCLUSION

This study provides the most methodologically rigorous multi-country evidence to date that blockchain technology adoption in trade finance generates substantial and causally identified improvements in document processing efficiency, letter of credit accuracy, and inter-firm trust among emerging market exporters. The findings are robust to multiple specification checks and are consistent across South Africa, India, and Taiwan, three countries representing diverse institutional and regulatory environments.

For enterprise managers, the study establishes a compelling business case for blockchain trade finance adoption, particularly for firms operating on high-volume corridors with counterparties willing to co-adopt. The evidence on absorptive capacity as a moderator argues for strategic investment in IT infrastructure and staff training as preconditions for maximizing adoption returns. Firms considering adoption should conduct a thorough assessment of counterparty platform compatibility to avoid the productivity costs of parallel documentation processes.

For financial institutions and trade finance intermediaries, the findings suggest that blockchain adoption can significantly reduce the operational costs of letter of credit processing while enhancing client relationships through transparency and reliability improvements. However, institutions must invest in interoperability solutions and client onboarding support to ensure that efficiency gains are not confined to transactions between technologically sophisticated counterparties.

For policymakers and trade facilitation bodies, the regulatory clarity moderation finding argues strongly for the prioritization of clear, proportionate blockchain governance frameworks. Countries that provide definitive legal recognition of smart contract enforceability, distributed ledger document equivalence, and data sovereignty provisions will enable their exporting enterprises to capture the full efficiency dividend of blockchain trade finance adoption. Regional harmonization of blockchain trade finance standards, particularly within the AfCFTA, ASEAN, and South Asian Association for Regional Cooperation frameworks, deserves urgent attention.

This study carries several limitations that delineate directions for future research. The panel, while representing three geographically and institutionally diverse countries, does not include Latin America, the Middle East, or Southeast Asia, and future multi-regional studies should extend geographic coverage. The study examined adoption outcomes at the enterprise level, and future research should investigate how blockchain-generated efficiency gains propagate through supply chains to affect smaller tier-two and tier-three suppliers. Finally, the long-run implications of technology-mediated trust for relational governance in trade finance warrant sustained longitudinal investigation as blockchain ecosystems mature.

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