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Reengineering Payment Settlement: An Economic Analysis of Blockchain-Based Systems for Liquidity Optimization and Systemic Risk Reduction

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Abstract

Digital payment systems are frequently perceived as real-time, yet underlying settlement processes often remain delayed and fragmented across institutional ledgers. This separation generates liquidity inefficiencies, operational frictions, and systemic risk through the accumulation of unsettled obligations. This study examines whether blockchain-based settlement systems can improve the economic performance of payment networks by enhancing liquidity efficiency and reducing systemic risk. The paper develops a formal model that conceptualizes payment settlement as a networked coordination problem characterized by settlement delays, information asymmetry, and process fragmentation. The analysis compares traditional delayed settlement systems with blockchain-enabled real-time settlement architectures within a simulation-based empirical framework calibrated to stylized interbank payment networks. The simulation environment incorporates alternative network structures, transaction volumes, settlement delays, and adoption levels to evaluate how settlement architecture influences liquidity demand, exposure dynamics, reconciliation frictions, and contagion propagation. The results indicate that blockchain-based settlement substantially reduces intraday liquidity requirements by minimizing the accumulation of unsettled payment obligations. Real-time settlement also compresses the duration of counterparty exposure, thereby limiting the propagation of financial distress across institutions. These effects become more pronounced in high-volume and densely connected networks and exhibit nonlinear gains as adoption increases. Robustness analysis further indicates that the core findings remain stable across alternative network configurations, stress conditions, and parameter specifications. The study contributes to payment economics by demonstrating that the relationship between liquidity efficiency and systemic risk depends critically on settlement architecture rather than representing a fixed structural trade-off. It further contributes to information systems research by linking distributed ledger infrastructure design to macro-financial outcomes, including coordination efficiency and systemic resilience. The findings suggest that blockchain-based settlement systems may provide a viable pathway toward more efficient and resilient financial networks when implemented within coordinated and institutionally governed environments.

Keywords

Blockchain, Payment Settlement Systems, Liquidity Efficiency, Systemic Risk, Distributed Ledger Technology (DLT), Financial Networks, Real-Time Settlement, Interbank Payments, Network Effects, Financial Infrastructure

1. Introduction

Digital payment systems are frequently characterized as fast, instant, or real-time, reflecting the ability of users to initiate and confirm transactions within seconds. However, this perception masks a fundamental disconnect between front-end transaction speed and back-end settlement finality. In most payment networks, transaction initiation, clearing, reconciliation, and settlement remain institutionally fragmented and temporally separated across multiple ledgers and processing layers (Bech & Garratt, 2017; Kahn & Roberds, 2009). As a result, payments that appear complete from a user perspective may still involve unsettled obligations among financial institutions. This distinction has important economic implications. Settlement delay is not merely a technical feature but a structural source of friction within financial systems. When settlement is deferred, participating institutions must maintain precautionary liquidity buffers to ensure that pending obligations can be met (Freixas & Parigi, 1998; Martin & McAndrews, 2008). At the same time, delayed settlement exposes institutions to counterparty risk during the interval between transaction initiation and finality, creating the potential for cascading failures under stress conditions (Allen & Gale, 2000; Eisenberg & Noe, 2001). These frictions are further compounded in fragmented ledger environments, where institutions maintain independent records and must reconcile transaction data ex post, increase operational costs and introduce uncertainty regarding the true state of obligations (Kahn, McAndrews, & Roberds, 2005). As transaction volumes increase and financial networks become more interconnected, these inefficiencies scale, raising concerns for both market efficiency and systemic stability. Recent advances in distributed ledger technology (DLT) have been proposed as a potential solution to these challenges. By enabling a shared, tamper-resistant ledger, blockchain-based systems allow participating institutions to maintain a synchronized record of transactions, reducing reliance on reconciliation and enabling near real-time settlement (Catalini & Gans, 2020; Cong & He, 2019). In principle, such architecture can compress settlement time, improve transparency, and enhance transaction finality.

To maintain institutional realism, the analysis focuses on a permissioned distributed ledger architecture designed for interbank settlement rather than an open, permissionless blockchain environment. Transactions are validated by authorized financial institutions or designated settlement nodes operating under predefined governance rules. Settlement occurs using tokenized central bank reserves or equivalent fiat-denominated settlement assets, ensuring that payment finality remains anchored to sovereign monetary liabilities rather than volatile crypto-assets. This architecture reflects emerging industry and central bank approaches to wholesale payment modernization, where distributed ledger systems are implemented within regulated financial infrastructures rather than fully decentralized public networks (Auer, Monnet, & Shin, 2021; Bech & Garratt, 2017). Accordingly, the analysis isolates the economic implications of synchronized ledger-based settlement while abstracting from speculative token dynamics and permissionless consensus mechanisms.

However, the economic value of blockchain in payment systems cannot be inferred from its technical properties alone. The central question is whether distributed ledger architectures fundamentally alter the economic structure of settlement in ways that improve liquidity efficiency and reduce systemic risk. Existing research provides only a partial answer to this question. The blockchain literature has primarily focused on technological feasibility, governance mechanisms, and adoption dynamics (Yermack, 2017; Catalini & Gans, 2020). In parallel, the payment economics literature has developed rich models of liquidity demand, settlement delay, and systemic risk in traditional clearing and settlement systems (Freixas & Parigi, 1998; Bech & Garratt, 2017). Yet these two streams remain largely disconnected. In particular, there is limited formal analysis of how distributed ledger–based settlement architectures affect core economic outcomes such as intraday liquidity requirements, counterparty exposure, reconciliation costs, and systemic risk propagation within interbank networks.

This study addresses this gap by developing a formal economic model of payment settlement under two alternative infrastructures: a traditional delayed-settlement system and a blockchain-enabled real-time settlement system. The model conceptualizes settlement as a networked coordination process in which financial institutions exchange obligations over time, manage liquidity buffers, and face exposure to unsettled claims. Under the traditional system, settlement occurs with delay and requires reconciliation across decentralized institutional records. Under the blockchain-based system, transactions are validated through a shared ledger and achieve finality more rapidly, reducing both temporal exposure and informational fragmentation. The core argument of this paper is that blockchain-based settlement improves economic efficiency through three interrelated mechanisms. First, temporal compression reduces the duration of unsettled obligations, lowering liquidity requirements and exposure. Second, ledger synchronization mitigates information asymmetry by providing a shared representation of transaction states. Third, process integration reduces operational frictions by combining verification, clearing, and settlement within a unified infrastructure. The effectiveness of these mechanisms, however, depends on contextual factors such as transaction volume, network density, adoption scale, and governance design.

Building on this framework, the study makes three contributions. First, it extends the payment economics literature by introducing distributed ledger-based settlement as an alternative coordination mechanism and formally modeling its impact on liquidity demand and systemic risk. Second, it contributes to the information systems literature by demonstrating how digital infrastructure design can influence macro-financial outcomes, thereby linking system architecture to economic performance. Third, it provides a theory-driven foundation for empirical and simulation-based evaluation of blockchain-enabled settlement systems, offering a structured approach for assessing their potential role in financial infrastructure modernization.

2. Theoretical Foundations and Related Literature

The theoretical foundation for the study by integrating four streams of literature: payment settlement and liquidity economics, systemic risk in financial networks, information and coordination frictions in inter-organizational systems, and distributed ledger-based financial infrastructure. Rather than reviewing these streams in isolation, the section synthesizes them into a unified framework that conceptualizes payment settlement as an economic coordination problem shaped by temporal, informational, and process-level mechanisms. This integrated perspective directly supports the study's objective of examining how alternative settlement architectures influence liquidity efficiency and systemic risk.

2.1. Payment Settlement and Liquidity Economics

Payment systems function as institutional mechanisms for coordinating the transfer of financial obligations among interconnected entities. In traditional systems, settlement is characterized by a temporal separation between transaction initiation and final settlement, with obligations accumulating over time before being cleared through netting arrangements or batch processing (Freixas & Parigi, 1998; Kahn & Roberds, 2009). In infrastructures operated by institutions such as the Federal Reserve, different payment rails exhibit varying settlement delays, reflecting trade-offs between liquidity usage and operational efficiency. The economic consequence of delayed settlement is the need for intraday liquidity provisioning. Financial institutions must maintain sufficient balances to meet uncertain and time-varying settlement obligations, often holding precautionary reserves to guard against payment delays and queue formation (Martin & McAndrews, 2008). Prior research demonstrates that liquidity demand increases with settlement delay, volatility in payment flows, and the degree of network interdependence (Bech & Garratt, 2017). This gives rise to a well-established trade-off in payment economics: faster settlement reduces counterparty risk but requires higher immediate liquidity, whereas delayed settlement economizes on liquidity at the cost of increased exposure. Real-time gross settlement (RTGS) systems partially mitigate settlement risk by enabling immediate finality at the transaction level. However, RTGS architecture often shifts the burden toward higher liquidity requirements, as each transaction must be funded individually at the time of execution. Consequently, literature has largely treated liquidity efficiency and risk reduction as competing objectives embedded in the design of settlement systems.

2.2. Systemic Risk and Network Interdependence

Settlement systems operate within networks of interdependent financial institutions, where each participant's ability to fulfill obligations depends on the actions and solvency of others. This interconnectedness creates the potential for systemic risk, defined as the propagation of localized shocks through the financial network (Allen & Gale, 2000; Eisenberg & Noe, 2001). In delayed settlement environments, unsettled obligations accumulate over time, increasing exposure across participants and creating channels through which financial distress can spread. If one institution fails to meet its obligations, this can trigger liquidity shortages or defaults among its counterparties, potentially leading to cascading failures. Network-based models show that the structure of interconnections, such as density, centrality, and clustering, plays a critical role in determining the magnitude and speed of contagion (Wei et al., 2022; Doostmohammadian et al., 2020). A key insight from this literature is that the duration of exposure is a fundamental driver of systemic risk. The longer obligations remain unsettled, the greater the window during which shocks can propagate across the network. Thus, settlement timing is not only an efficiency parameter but also a central determinant of financial stability.

2.3. Information Frictions and Reconciliation Costs

In addition to temporal delays, traditional settlement systems are characterized by informational fragmentation. Each institution maintains its own ledger, and transactions must be verified and reconciled across multiple, potentially inconsistent records. Communication infrastructures such as SWIFT facilitate the exchange of payment messages but do not eliminate the need for independent record-keeping and post-transaction reconciliation (Clack, 2023). These conditions introduce two interrelated frictions. First, information asymmetry arises because institutions may have incomplete or delayed knowledge about the true state of obligations. Second, reconciliation processes impose significant operational costs, requiring resources to identify discrepancies, verify transactions, and resolve errors (Kahn, McAndrews, & Roberds, 2005). From an economic perspective, these frictions increase both direct costs and uncertainty in settlement processes. More importantly, they weaken coordination across institutions, particularly during periods of financial stress when timely and accurate information is critical. Information systems research emphasizes that effective coordination depends not only on communication but also on the existence of shared representations of data (Malone & Crowston, 1994). In the absence of such shared representations, coordination requires additional verification and monitoring, increasing both delay and cost.

2.4. Distributed Ledger Technology as a Coordination Mechanism

Distributed ledger technology introduces a fundamentally different approach to organizing settlement processes by replacing fragmented institutional ledgers with a shared, synchronized record of transactions. In DLT-based systems, transactions are validated through consensus mechanisms and recorded in an append-only ledger that is visible to all authorized participants, ensuring consistency and immutability (Catalini & Gans, 2020; Cong & He, 2019). This architecture transforms settlement along three key dimensions. First, it compresses the time structure of settlement by enabling near real-time validation and finality, reducing the gap between transaction initiation and settlement completion. Second, it alters the information structure by providing a single source of truth, thereby reducing discrepancies and information asymmetry across participants. Third, it integrates process stages, such as verification, clearing, and settlement, into a unified workflow, eliminating the need for sequential processing and reconciliation. Unlike traditional systems, where messaging and settlement operate as distinct layers, DLT-based architecture combines these functions into a single infrastructure. This integration has the potential to reduce operational complexity and enhance coordination efficiency. Importantly, the analysis does not assume that all efficiency gains arise uniquely from blockchain technology itself. Conventional real-time gross settlement (RTGS) systems already reduce settlement delay and counterparty exposure by enabling immediate transaction finality. However, RTGS infrastructures typically continue to rely on institution-specific ledgers, sequential reconciliation processes, and centralized coordination mechanisms. The focus of this study is therefore not solely on real-time settlement, but on the additional economic implications of synchronized shared-ledger architectures. In particular, the analysis examines whether blockchain-based settlement systems generate incremental benefits through information synchronization, integrated processing, and reduced reconciliation frictions beyond those achievable under conventional RTGS frameworks. By comparing blockchain-based settlement primarily against delayed settlement systems, the study isolates the broader structural effects of transitioning from fragmented batch processing toward synchronized distributed settlement infrastructures. However, these benefits are contingent on several factors, including system scalability, governance design, and regulatory compatibility.

Moreover, the advantages of synchronization depend critically on network adoption; without sufficient participation, the benefits of a shared ledger may not fully materialize.

2.5. Research Gap and Theoretical Positioning

Although the existing literature provides important insights into payment systems, systemic risk, and information coordination, it remains fragmented across disciplinary boundaries. Payment economics has focused on liquidity-risk trade-offs, network theory has examined contagion dynamics, and information systems research has explored coordination and data integration. Meanwhile, blockchain research has primarily emphasized technological capabilities and institutional adoption. What is missing is an integrated theoretical framework that links settlement system architecture to economic outcomes through clearly defined mechanisms. In particular, three gaps are especially salient. First, there is limited formal modeling of how real-time, shared-ledger settlement affects intraday liquidity demand. Second, the role of information synchronization in mitigating systemic risk remains under-theorized. Third, the interaction between network structure and distributed settlement efficiency has not been rigorously examined. This study addresses these gaps by developing a formal mathematical model that conceptualizes settlement systems as coordination mechanisms shaped by temporal, informational, and process design. By explicitly modeling both traditional and blockchain-based settlement architectures within a unified framework, the study derives testable implications for liquidity efficiency and systemic risk. In doing so, it directly advances the research objective of evaluating whether distributed ledger-based settlement systems can fundamentally improve the economic performance of modern payment networks.

3. Formal Model

This section develops a stylized yet tractable model of payment settlement under two alternative infrastructures: 1) a traditional delayed (batch/net) settlement system and 2) a blockchain-enabled real-time settlement system. The model conceptualizes settlement as a networked coordination problem in which financial institutions exchange obligations over time under liquidity constraints, settlement delays, and information frictions. This approach builds on established models of financial networks and payment systems (Eisenberg & Noe, 2001; Glasserman & Young, 2016).

3.1. Environment

Time is discrete, indexed by $t = 0,1,2,\cdots,T$. The economy consists of N financial institutions indexed by $i \in \{1,\cdots,N\}$.

Let $A = \left[a_{ij}\right]$ denote the adjacency matrix of payment relationships, where $a_{ij} \geq 0$ captures the intensity of payment flows from institution i to institution j. This representation follows standard formulations in financial network models (Elliott, Golub, & Jackson, 2014).

At each period t, institution i initiates payment obligations to institution j:

$$x_{ij}(t) \geq 0, i \neq j.$$

Total outflows and inflows are defined as:

$$X_i^{out}(t) = \sum_{j \neq i} x_{ij}(t), X_i^{in}(t) = \sum_{j \neq i} x_{ji}(t).$$

Each institution holds intraday liquidity $L_i(t) \geq 0$, evolving according to:

$$L_i(t+1) = L_i(t) + S_i(t) - F_i(t),$$

where $S_i(t)$ and $F_i(t)$ denote settled inflows and outflows. This liquidity dynamics framework is consistent with payment system models emphasizing funding constraints (Freixas & Parigi, 1998; Martin & McAndrews, 2008).

3.2. Settlement Technologies

We model two settlement regimes that differ along three dimensions: time (delay), information (synchronization), and process (integration).

1) Traditional Delayed Settlement System

In the traditional system, payments are settled with delay $\tau \geq 1$, reflecting batch processing or deferred net settlement mechanisms (Kahn & Roberds, 2009).

Settlement rule:

$$S_i^T(t) = \sum_j x_{ji}(t-\tau), F_i^T(t) = \sum_j x_{ij}(t-\tau).$$

Unsettled exposure:

$$E_i^T(t) = \sum_{k=0}^{\tau-1} \left(X_i^{out}(t-k) - X_i^{in}(t-k) \right).$$

Delayed settlement generates a stock of outstanding obligations, increasing liquidity demand and exposure (Freixas & Parigi, 1998).

Liquidity constraint:

$$L_i(t) \geq \theta_i + \phi \cdot \mathbb{E}\left[E_i^T(t) \right],$$

where θ_i is a minimum liquidity buffer and ϕ captures precautionary behavior.

Reconciliation cost:

$$C_i^{rec}(t) = \kappa \cdot \mathrm{Var}\left(\tilde{x}_{ij}(t) - x_{ij}(t) \right),$$

capturing discrepancies across decentralized ledgers and the cost of post-settlement verification (Kahn, McAndrews, & Roberds, 2005).

2) Blockchain-Based Real-Time Settlement System

In the blockchain-based system, transactions are validated and settled with near real-time finality. Let $\delta \in [0,1)$ denote a small confirmation lag (Catalini & Gans, 2020; Cong & He, 2019).

Settlement rule:

$$S_i^B(t)=\sum_j x_{ji}(t-\delta), F_i^B(t)=\sum_j x_{ij}(t-\delta).$$

Unsettled exposure:

$$E_i^B(t)\approx 0 \text{ as } \delta\to 0.$$

Liquidity constraint:

$$L_i(t)\geq \theta_i+\phi\cdot\mathbb{E}\left[E_i^B(t)\right]\approx\theta_i.$$

Information synchronization:

$$\tilde{x}_{ij}(t)=x_{ij}(t), \forall i,j,t.$$

Reconciliation cost:

$$C_i^{rec}(t)=0.$$

3.3. Objective Function

Each institution minimizes expected total costs:

$$\min_{\{x_{ij}(t)\}}\mathbb{E}\left[\sum_{t=0}^{T}\left(r\cdot L_i(t)+\lambda\cdot E_i(t)+C_i^{rec}(t)\right)\right],$$

where r is the opportunity cost of liquidity and λ captures counterparty risk exposure. This formulation aligns with models linking liquidity costs and financial stability (Brunnermeier & Oehmke, 2013).

3.4. Systemic Risk Propagation

Let $p_i(t)\in\{0,1\}$ denote solvency status. Default occurs when:

$$p_i(t+1)=1\left\{L_i(t)+S_i(t)-F_i(t)-\omega_i(t)\geq 0\right\}.$$

Contagion arises through inter-institution exposures:

$$\text{Loss}_i(t)=\sum_j \alpha_{ij}\cdot E_{ij}^T(t)\cdot\left(1-p_j(t)\right).$$

This structure follows established contagion models in financial networks (Eisenberg & Noe, 2001; Glasserman & Young, 2016).

Under blockchain-based settlement:

$$E_{ij}^B(t)\approx 0\Rightarrow \text{Loss}_i(t)\approx 0,$$

implying reduced propagation channels.

3.5. Comparative Statics

Expected exposure:

$$\mathbb{E}\left[E_i^T\right]=\tau\cdot\mathbb{E}\left[X_i^{out}-X_i^{in}\right], \mathbb{E}\left[E_i^B\right]\approx 0.$$

Liquidity difference:

$$\Delta L_i\approx\phi\cdot\tau\cdot\mathbb{E}\left[X_i^{out}-X_i^{in}\right].$$

Risk difference:

$$\Delta R_i > 0.$$

3.6. Network Effects and Adoption

Let $\gamma \in [0,1]$ denote adoption of blockchain settlement:

$$E_i(\gamma) = (1-\gamma)E_i^T + \gamma E_i^B.$$

$$\frac{\partial E_i}{\partial \gamma} < 0.$$

This reflects network effects common in financial infrastructure adoption (Bech & Garratt, 2017).

4. Theoretical Implications and Propositions

This section derives theory-driven propositions from the formal model by focusing on the underlying economic mechanisms through which settlement architecture influences liquidity efficiency and systemic risk. Rather than restating the model, the analysis interprets how differences in settlement timing, information structure, and process integration reshape the fundamental coordination problem in payment systems. In doing so, the section directly advances the study's central objective: to evaluate whether blockchain-based settlement systems can improve liquidity allocation while reducing systemic risk.

4.1. Liquidity Efficiency and Temporal Compression

A central implication of the model is that settlement delay (τ) is the primary determinant of intraday liquidity demand. In traditional settlement systems, institutions must provision liquidity against the accumulation of unsettled obligations within the settlement pipeline. As exposure increases with delay, institutions respond by holding precautionary liquidity buffers, consistent with prior findings in payment system design (Bech & Garratt, 2017; Martin & McAndrews, 2008). Blockchain-based settlement systems fundamentally alter this dynamic through temporal compression. By reducing settlement delay toward real-time finality ($\delta \to 0$), the accumulation of unsettled obligations is effectively eliminated. This reduces the need for liquidity provisioning beyond minimum operational requirements. Importantly, this mechanism differs from traditional real-time gross settlement systems, where faster settlement often requires higher liquidity usage. In contrast, the model suggests that when real-time settlement is combined with synchronized information, liquidity demand can decline rather than increase. This insight challenges the conventional view that liquidity efficiency and settlement speed are inherently in tension.

Proposition 1 (*Liquidity Efficiency*)

Blockchain-based settlement systems reduce intraday liquidity requirements relative to traditional delayed settlement systems by minimizing the duration and accumulation of unsettled obligations.

4.2. Scaling Effects: Transaction Volume and Network Density

The model further indicates that the benefits of blockchain-based settlement are not uniform but scale with transaction activity and network structure. In traditional systems, higher transaction volumes and greater network density increase both the size and volatility of unsettled exposures. This amplifies liquidity demand and increases coordination complexity, particularly in densely connected financial networks (Acemoglu, Ozdaglar, & Tahbaz-Salehi, 2015). In contrast, blockchain-based systems maintain near-zero exposure regardless of transaction volume, as obligations are settled continuously. As a result, the relative efficiency gains of blockchain settlement increase with system scale. This reflects a key departure from traditional infrastructures, where higher volume often exacerbates inefficiencies.

Proposition 2 (*Scaling Effect*)

The liquidity efficiency gains from blockchain-based settlement increase with transaction volume and network density, as real-time settlement prevents the accumulation of exposures in high-activity environments.

4.3. Systemic Risk and Exposure Duration

Systemic risk in the model arises from the propagation of shocks through networks of unsettled obligations. In delayed settlement systems, exposures persist over time, creating channels through which financial distress can spread across institutions. The longer these exposures remain outstanding, the greater the likelihood and magnitude of contagion (Glasserman & Young, 2016). Blockchain-based settlement reduces systemic risk by compressing the duration of these exposures. When obligations are settled in real time, the window during which shocks can propagate is significantly reduced. As a result, the network becomes less vulnerable to cascading failures. This mechanism aligns with network-based theories of financial stability, which emphasize exposure duration as a key determinant of systemic risk. By shortening this duration, blockchain-based systems weaken the transmission channels of contagion.

Proposition 3 (*Systemic Risk Reduction*)

Blockchain-based settlement systems reduce systemic risk by shortening the duration of counterparty exposure and limiting the propagation of shocks through unsettled obligations.

4.4. Information Synchronization and Coordination Stability

A defining feature of blockchain-based systems is information synchronization. In traditional settlement environments, institutions maintain independent ledgers, leading to discrepancies, delays in verification, and uncertainty regarding the state of obligations. These informational frictions increase coordination costs and can exacerbate instability during periods of stress (Kahn, McAndrews, & Roberds, 2005). In contrast, blockchain-based systems provide a shared ledger that serves as a single source of truth. This eliminates discrepancies across records and ensures that all participants observe a consistent transaction state. From a coordination perspective, this reduces both information asymmetry and verification costs, improving system-wide stability. Beyond operational efficiency, synchronized information enhances collective decision-making. When institutions have access to accurate and timely information, they can respond more effectively to shocks, reducing the likelihood of coordination failures.

Proposition 4 (*Information Efficiency*)

Shared-ledger synchronization reduces information asymmetry and reconciliation costs, thereby improving coordination and stability in payment networks.

4.5. Process Integration and Operational Efficiency

Traditional settlement systems separate messaging, verification, clearing, and settlement into distinct processes. This fragmentation introduces delays, increases operational complexity, and necessitates reconciliation across institutional boundaries. These inefficiencies are well documented in the payment systems literature (Mills et al., 2016). Blockchain-based systems integrate these processes into a unified infrastructure. By combining validation, clearing, and settlement within a single system, they eliminate the need for sequential processing and post-transaction reconciliation. This integration reduces operational costs and simplifies coordination across institutions. The model captures this effect through the elimination of reconciliation costs under full synchronization, highlighting the importance of process design in determining economic efficiency.

Proposition 5 (*Operational Integration*)

Blockchain-based settlement systems improve operational efficiency by integrating verification, clearing, and settlement processes, thereby reducing reconciliation costs and coordination complexity.

4.6. Network Adoption and Institutional Conditions

The benefits of blockchain-based settlement depend critically on the extent of network adoption. Because the efficiency gains arise from synchronization across participants, partial adoption limits their effectiveness. In mixed systems, where both traditional and blockchain-based infrastructures coexist, exposures persist in the non-adopting segment, reducing overall efficiency.

The model captures this dynamic through the adoption parameter (γ), showing that exposure declines as adoption increases, with nonlinear gains due to network effects. This is consistent with research on financial infrastructure and platform adoption, which emphasizes the importance of participation thresholds (Auer, Monnet, & Shin, 2021). At the same time, adoption is shaped by institutional factors, including regulatory alignment, governance mechanisms, and interoperability with existing systems. Without these conditions, the theoretical benefits of blockchain-based settlement may not be fully realized.

Proposition 6 (*Adoption Effect*)

The efficiency and risk-reduction benefits of blockchain-based settlement systems increase with the level of network adoption.

Proposition 7 (*Institutional Moderation*)

The effectiveness of blockchain-based settlement systems is positively moderated by regulatory alignment, governance quality, and interoperability with existing financial infrastructure.

4.7. Reframing the Liquidity-Risk Trade-Off

Taken together, these propositions lead to a broader theoretical implication. Traditional payment systems operate under a fundamental trade-off between liquidity efficiency and systemic risk: faster settlement reduces exposure but requires higher liquidity, while delayed settlement conserves liquidity at the cost of increased risk. The model suggests that this trade-off is not structural but architectural. When settlement systems are redesigned to combine real-time processing with synchronized information and integrated processes, both liquidity efficiency and risk reduction can be achieved simultaneously. This reframing shifts the focus of research and policy from optimizing trade-offs to redesigning infrastructure.

5. Empirical Strategy

This study employs a hybrid empirical strategy that integrates simulation-based analysis with econometric modeling to evaluate the economic implications of alternative settlement architectures. The primary objective is to identify how blockchain-based settlement systems affect liquidity demand, exposure dynamics, operational efficiency, and systemic risk within interbank payment networks. Because large-scale transaction-level data for distributed ledger-based settlement systems remain limited, the empirical design relies on simulation to construct controlled counterfactual environments. This approach allows for systematic comparison of traditional delayed settlement and blockchain-based real-time settlement while preserving the structural features of financial networks (Glasserman & Young, 2016; Bech & Garratt, 2017). The empirical framework directly operationalizes the model's mechanisms by mapping settlement design to observable economic outcomes.

5.1. Identification Strategy

The empirical analysis is designed to estimate the causal effect of settlement architecture on key system-level outcomes. Identification is achieved through a counterfactual framework in which identical payment networks are evaluated under two alternative regimes:

1) a traditional delayed settlement system characterized by settlement lag $\tau > 0$, and

2) a blockchain-based settlement system with near real-time confirmation $\delta \approx 0$.

By holding network topology, transaction flows, and institutional characteristics constant across regimes, the analysis isolates the effect of settlement design from confounding structural factors. This approach follows established methodologies in financial network simulations, where counterfactual system configurations are used to evaluate systemic risk and liquidity outcomes (Acemoglu et al., 2015; Elliott et al., 2014). The identification strategy is therefore grounded in structural comparability: any observed differences in outcomes can be attributed to changes in settlement architecture rather than differences in network composition or behavior. Future extensions may incorporate direct benchmarking against RTGS architectures to isolate the incremental contribution of shared-ledger synchronization beyond settlement speed alone.

5.2. Simulation-Based Comparative Analysis

The empirical analysis adopts a simulation-based comparative framework rather than a regression-based identification strategy. This approach is appropriate because the study's primary objective is to evaluate how alternative settlement architectures influence liquidity efficiency and systemic risk under controlled network conditions. Given the limited availability of transaction-level data from large-scale blockchain-based settlement systems, simulation provides a tractable method for isolating the structural effects of settlement design while preserving the interdependent dynamics of financial networks. The analysis compares two settlement regimes: 1) a traditional delayed settlement system characterized by settlement lag and fragmented reconciliation processes, and 2) a blockchain-based settlement system with near real-time finality and synchronized ledger coordination. All network structures, transaction-generation processes, and institutional characteristics are held constant across regimes to isolate the effect of settlement architecture on system outcomes.

Simulation outputs are evaluated using four primary performance metrics: intraday liquidity requirements, settlement exposure, reconciliation costs, and systemic risk contribution. Comparative results are generated across alternative network topologies, transaction volumes, adoption levels, and stress conditions to assess the robustness of the underlying mechanisms identified in the formal model. Rather than estimating causal effects through econometric coefficients, the analysis evaluates how structural changes in settlement architecture alter the dynamics of liquidity allocation and contagion propagation within payment networks. This simulation-based approach is consistent with prior research in financial network modeling and systemic risk analysis (Glasserman & Young, 2016; Acemoglu et al., 2015).

5.3. Network Effects and Heterogeneity

To examine how the effectiveness of blockchain-based settlement varies with adoption and system scale, the analysis incorporates interaction terms.

First, adoption effects are captured as:

$$\begin{aligned} Y_{it} = {} & \beta_0 + \beta_1 Blockchain_{it} + \beta_2 Adoption_t + \beta_3 \left(Blockchain_{it} \times Adoption_t \right) \\ & + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned}$$

where $Adoption_t$ represents the proportion of institutions participating in the blockchain network. A negative β_3 indicates increasing efficiency gains as adoption expands, consistent with network externalities in financial infrastructures (Auer et al., 2021).

Second, scaling effects with transaction volume are modeled as:

$$Y_{it} = \beta_0 + \beta_1 Blockchain_{it} + \beta_2 Volume_{it} + \beta_3 \left(Blockchain_{it} \times Volume_{it}\right) + \mu_i + \lambda_t + \varepsilon_{it}$$

A negative interaction coefficient implies that blockchain-based systems deliver larger efficiency gains in high-volume environments, reflecting the elimination of exposure accumulation under real-time settlement.

5.4. Simulation Framework

Given the absence of comprehensive real-world data for blockchain-based settlement systems, the study constructs a simulation framework calibrated to stylized features of interbank payment networks, including those observed in systems operated by the Federal Reserve. The payment system is modeled as a directed network $G = \left(N, E\right)$, where nodes represent financial institutions and edges represent payment relationships. Multiple network structures, including random, scale-free, and dense configurations, are considered to capture variation in interbank connectivity.

Bilateral payment flows are generated as:

$$x_{ij}\left(t\right) \sim \text{Lognormal}\left(\mu, \sigma^2\right),$$

reflecting the empirically observed skewness of payment distributions.

Settlement regimes differ only in timing:

$$t_{\text{settle}} = t + \tau\left(\text{traditional}\right), t_{\text{settle}} = t + \delta\left(\text{blockchain}\right), \delta < \tau.$$

Liquidity requirements are computed as the maximum net funding gap:

$$L_i^{min} = \max_t \left[F_i\left(t\right) - S_i\left(t\right)\right],$$

and aggregate system liquidity is:

$$L^{system} = \sum_{i=1}^{N} L_i^{min}.$$

Settlement exposure is measured as:

$$E = \sum_t \sum_i \sum_j x_{ij}\left(t\right) \cdot d,$$

where $d \in \left\{\tau, \delta\right\}$ captures settlement delay.

5.5. Simulation Calibration

The simulation environment is calibrated to stylized characteristics of interbank payment systems and large-value settlement networks. The baseline configuration consists of $N = 50$ financial institutions connected through directed payment relationships. To capture heterogeneity in network structure, the analysis considers three alternative topologies: random networks, scale-free networks, and dense interconnected networks. Network density parameters range from 0.10 to 0.60 to reflect varying degrees of institutional connectivity.

Payment flows are generated from a lognormal distribution:

$$x_{ij}(t) \sim \text{Lognormal}\left(\mu, \sigma^2\right),$$

where $\mu = 2.0$ and $\sigma = 1.0$, producing positively skewed transaction distributions consistent with empirical payment activity observed in interbank systems. Simulation horizons are set to $T = 250$ periods to capture repeated settlement cycles and liquidity dynamics over time.

Under the traditional settlement regime, settlement delay parameters are calibrated within the range $\tau \in [1, 5]$, reflecting varying degrees of deferred settlement and reconciliation lag. Under the blockchain-based regime, confirmation lag is assumed to approach near real-time settlement ($\delta \approx 0$). Exogenous liquidity shocks are introduced through:

$$\omega_i(t) \sim \mathcal{N}\left(0, \sigma_\omega^2\right),$$

where shock variance is varied across stress scenarios to evaluate systemic resilience under alternative market conditions.

To ensure statistical stability, each simulation scenario is repeated 1000 times using independently generated transaction and shock realizations. Reported results represent average outcomes across simulation runs. Sensitivity analysis further evaluates robustness under alternative parameter configurations, including higher transaction intensity, varying network density, partial adoption, and extreme stress conditions. The baseline simulation environment used in the results section consists of $N = 100$ institutions observed over $T = 1000$ periods with 1000 independent simulation replications per scenario.

5.6. Outcome Variable Definitions

To ensure consistency between the theoretical framework and empirical analysis, the study operationalizes four primary outcome variables corresponding to the core mechanisms of settlement efficiency and systemic stability.

Intraday Liquidity Requirement

Intraday liquidity requirement measures the minimum liquidity buffer required for an institution to settle payment obligations without disruption during the simulation horizon. Formally, it is defined as:

$$L_i^{min} = \max_t \left[F_i(t) - S_i(t) \right],$$

where $F_i(t)$ and $S_i(t)$ denote settled outflows and inflows, respectively. System-wide liquidity demand is measured as:

$$L^{system} = \sum_{i=1}^{N} L_i^{min}.$$

Lower values indicate greater liquidity efficiency.

Settlement Exposure

Settlement exposure captures the cumulative value of unsettled obligations within the payment system. Exposure is measured as:

$$E = \sum_t \sum_i \sum_j x_{ij}(t) \cdot d,$$

where $x_{ij}(t)$ represents payment obligations and d denotes settlement delay under the relevant settlement regime. Higher exposure reflects longer durations of counterparty risk and greater systemic vulnerability.

Reconciliation Cost

Reconciliation cost measures the operational burden associated with verifying and aligning transaction records across institutions. In traditional settlement systems, reconciliation cost is modeled as the variance between institution-specific transaction records and realized transactions:

$$C_i^{rec}(t) = \kappa \cdot \mathrm{Var}\left(\tilde{x}_{ij}(t) - x_{ij}(t)\right),$$

where $\tilde{x}_{ij}(t)$ represents local institutional records and κ captures reconciliation intensity. Under fully synchronized distributed ledger systems, reconciliation discrepancies approach zero.

Systemic Risk Contribution

Systemic risk contribution measures the extent to which liquidity shocks propagate across the financial network. Following contagion-based financial network models, systemic risk is defined as:

$$SR = \frac{1}{N} \sum_{i=1}^{N} (1 - p_i),$$

where p_i is an indicator variable equal to one if institution i remains solvent and zero otherwise. Higher values of SR indicate a greater proportion of institutions affected by contagion and systemic distress.

Together, these measures provide an integrated evaluation of how settlement architecture influences liquidity efficiency, operational coordination, and systemic resilience.

5.7. Systemic Risk Measurement

Systemic risk is evaluated through stress testing. Exogenous liquidity shocks $\omega_i(t)$ are introduced such that:

$$\omega_i(t) > L_i(t),$$

triggering default when institutions cannot meet obligations.

Contagion is measured as:

$$SR = \frac{1}{N} \sum_{i=1}^{N} (1 - p_i),$$

where p_i indicates solvency. This approach follows standard measures of systemic vulnerability in financial networks (Glasserman & Young, 2016). Comparing SR across settlement regimes allows for direct estimation of how settlement architecture influences contagion dynamics.

5.8. Robustness and Sensitivity Analysis

To ensure robustness, the analysis evaluates multiple dimensions of model sensitivity. Settlement delays are varied to assess how blockchain advantages change with increasing lag in traditional systems. Alternative network structures are considered to capture differences in interbank connectivity. Transaction distributions are varied to test robustness across payment patterns. Partial adoption scenarios are analyzed to evaluate network effects, and stress scenarios with varying shock magnitudes are used to assess resilience under extreme conditions. Because the analysis is simulation-based rather than econometric, the results are interpreted comparatively across scenarios rather than through formal statistical hypothesis testing.

5.9. Empirical Contribution

The empirical strategy contributes to literature in three ways. First, it provides a rigorous framework for evaluating blockchain-based settlement systems using economically meaningful metrics rather than purely technical benchmarks. Second, it establishes a direct link between settlement architecture and key economic outcomes, including liquidity efficiency and systemic risk. Third, it offers a replicable methodology that can be extended to real-world data as distributed ledger–based settlement systems mature.

5.10. Assumptions and Interpretation

The interpretation of the simulation results depends on several important modeling assumptions. First, the blockchain-based settlement regime assumes near real-time confirmation and settlement finality, such that confirmation lag remains substantially lower than under traditional delayed settlement systems. Second, the analysis assumes synchronized ledger visibility across participating institutions, allowing authorized participants to observe a consistent transaction state with minimal informational discrepancies. Third, reconciliation frictions are assumed to be substantially reduced under the distributed ledger environment due to integrated validation and record synchronization mechanisms. In addition, the model abstracts from severe operational constraints associated with large-scale distributed ledger implementation, including extreme network congestion, validator coordination failures, and major scalability bottlenecks. The analysis therefore focuses on the economic implications of synchronized settlement architecture rather than the engineering performance of specific blockchain protocols. Accordingly, the reported gains in liquidity efficiency and systemic stability should be interpreted as arising under institutionally coordinated and operationally stable implementation conditions.

6. Results

This section presents the empirical results derived from simulation-based analysis. We begin with baseline comparisons between traditional delayed settlement and blockchain-based real-time settlement systems, followed by an examination of scaling effects, network dynamics, and system resilience under stress scenarios. **Table 1** summarizes the key findings, while **Figure 1** illustrates the evolution of liquidity demand and systemic risk across different levels of blockchain adoption. The baseline simulation environment consists of $N = 100$ financial institutions connected through directed payment networks calibrated under alternative topological structures, including random, scale-free, and densely interconnected configurations. Each simulation is conducted over $T = 1000$ discrete time periods to capture repeated settlement cycles and dynamic liquidity adjustment behavior. For each parameter configuration, the analysis performs 1000 independent simulation replications using randomly generated payment flows and liquidity shocks. Reported results represent average outcomes across replications. Network density parameters vary between 0.10 and 0.60, while settlement delay under the traditional regime ranges from $\tau = 1$ to $\tau = 5$ periods. The blockchain-based regime assumes near real-time confirmation with $\delta \to 0$.

6.1. Baseline Results

The baseline analysis reveals systematic and economically meaningful differences between traditional delayed settlement and blockchain-based real-time settlement systems. Across all simulated network configurations, blockchain-based settlement leads to a substantial reduction in intraday liquidity requirements. This reduction is driven by the elimination of unsettled payment pipelines, which otherwise necessitate precautionary liquidity buffers under delayed settlement. Settlement exposure also declines sharply under blockchain-based systems. Because obligations are settled with near real-time finality, the accumulation of outstanding claims is minimized. As a result, the duration of counterparty exposure is significantly shortened, limiting the conditions under which financial distress can propagate across institutions. Operational efficiency improves as well. The removal of reconciliation processes reduces discrepancies across transaction records and lowers associated verification costs. Taken together, these findings provide strong empirical support for the theoretical mechanisms identified in the model.

6.2. Network and Scaling Effects

The magnitude of efficiency gains depends on network characteristics. In high-volume environments, the advantages of blockchain-based settlement are amplified. Under traditional systems, increased transaction volume leads to larger and more volatile exposure pipelines, raising both liquidity demand and coordination complexity. In contrast, real-time settlement prevents exposure accumulation, allowing efficiency gains to scale with transaction intensity. Network density further influences outcomes. In densely connected systems, delayed settlement generates extensive interdependencies that increase systemic vulnerability. Blockchain-based settlement mitigates these effects by compressing exposure duration, thereby weakening the channels through which shocks propagate.

6.3. Adoption and Network Effects

The results indicate strong network effects associated with blockchain adoption. As the adoption rate (γ) increases, both liquidity demand and settlement exposure decline in a nonlinear manner. This reflects the importance of synchronization across participants: the benefits of real-time settlement are realized more fully as a larger share of the network adopts the system. Figure 1 illustrates this relationship. Liquidity demand and systemic risk remain relatively high under traditional settlement but decline progressively under blockchain-based systems as adoption increases. The nonlinear shape of the curves highlights increasing returns to adoption, consistent with network-based dynamics. However, in partial adoption scenarios, inefficiencies persist. Institutions outside the blockchain network continue to generate delayed exposures, limiting overall system performance. This finding underscores the importance of coordinated adoption for achieving system-wide improvements.

6.4. Systemic Risk and Stress Scenarios

Stress testing results indicate that blockchain-based settlement systems substantially reduce systemic risk across simulated environments. Under traditional settlement, exogenous shocks propagate through networks of unsettled obligations, leading to cascading failures. In contrast, real-time settlement reduces the availability of such propagation channels by minimizing exposure duration. Consequently, the proportion of institutions affected by contagion is consistently lower under blockchain-based systems. This effect is particularly pronounced in highly connected networks and high-volume environments, where delayed settlement systems are most vulnerable to systemic disruption.

Table 1. Theoretical and empirical implications of settlement design on financial system performance.

Outcome	Traditional	Blockchain	Direction	Mechanism
Intraday Liquidity	High	Low	↓	Temporal compression
Settlement Exposure	High	Near-zero	↓	Real-time finality
Reconciliation Cost	Positive	Near-zero	↓	Shared ledger
Systemic Risk	Higher	Lower	↓	Reduced propagation
Volume Scaling	Worsens	Improves	↑ gains	No exposure accumulation
Network Density	Amplifies risk	Mitigates risk	↑ stability	Compressed exposures
Adoption (γ)	Limited gains	Increasing gains	Nonlinear ↓	Network effects

6.5. Robustness Results

The Robustness analysis indicates that the main findings are stable across alternative model specifications. Increasing settlement delays in traditional systems amplifies the relative advantages of blockchain-based settlement, as longer delays lead to greater exposure accumulation. Results are also consistent across different network structures and transaction distributions, indicating that the findings are not driven by specific modeling assumptions. Similarly, the effectiveness of blockchain-based settlement persists across varying levels of adoption and shock magnitudes. While the magnitude of efficiency gains varies with these parameters, the direction of the results remains unchanged, reinforcing the generalizability of the findings.

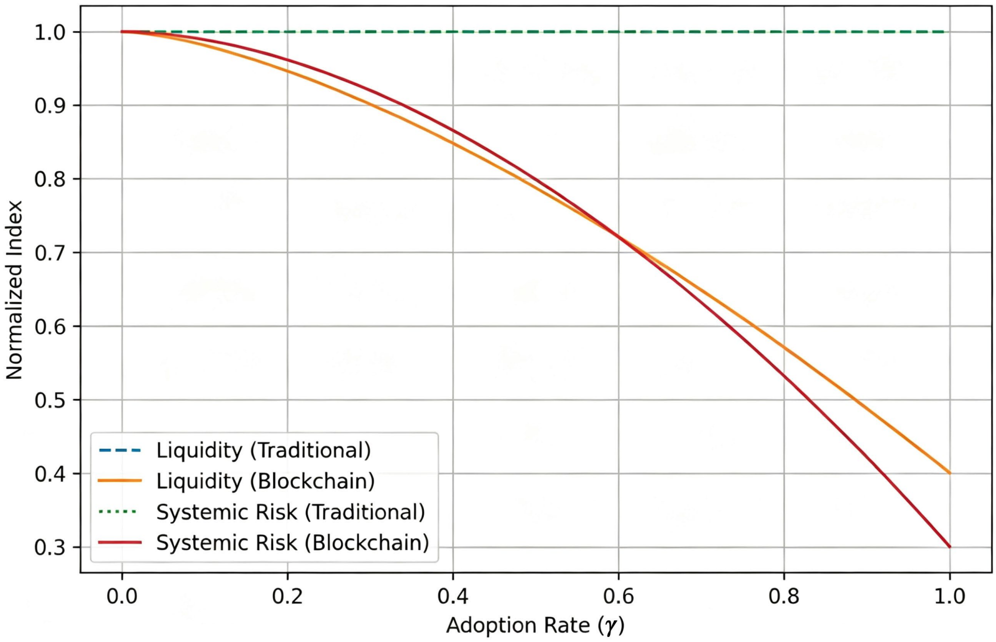

Figure 1. Simulation results: liquidity and systemic risk.

Figure 1 illustrates the evolution of liquidity demand and systemic risk as a function of blockchain adoption. Under traditional settlement, both liquidity requirements and systemic risk remain persistently high. In contrast, blockchain-based settlement produces a nonlinear decline in both measures as adoption increases, reflecting reduced exposure duration and improved coordination across institutions.

7. Discussion and Implications

This study reframes payment settlement as an economic coordination problem and demonstrates that settlement architecture plays a central role in shaping liquidity allocation and systemic risk. By integrating a formal model with simulation-based evidence, the analysis shows that differences between traditional and blockchain-based settlement systems are not merely technical, but structural, affecting how financial institutions synchronize obligations over time. A key insight emerging from the results is that inefficiencies in traditional settlement systems arise from the combined effects of temporal delay and informational fragmentation. Sequential processing, where transactions are initiated, recorded, reconciled, and settled across separate institutional ledgers, generates persistent liquidity demand and exposure. In contrast, blockchain-based settlement systems enable synchronized coordination by integrating validation, clearing, and settlement within a shared ledger. The resulting efficiency gains therefore reflect not only faster execution, but a fundamental reduction in coordination frictions embedded in system design.

7.1. Theoretical Implications

The findings contribute to the literature by challenging the conventional view of the liquidity–risk trade-off in payment systems. Prior research has largely treated this trade-off as structural, suggesting that faster settlement reduces counterparty exposure at the cost of higher liquidity requirements. The results presented here indicate that this relationship is contingent on settlement architecture. When real-time settlement is combined with synchronized information, the accumulation of unsettled obligations is eliminated without requiring proportional increases in liquidity buffers. As a result, liquidity efficiency and systemic risk reduction can be achieved simultaneously. This insight extends payment economics by identifying settlement design as a mechanism through which economic constraints can be relaxed rather than optimized. It also contributes to the information systems literature by demonstrating that digital infrastructure design has system-level economic consequences. Specifically, the analysis links architectural features of distributed ledgers, such as shared state, real-time validation, and process integration, to outcomes including liquidity usage, operational efficiency, and financial stability. More broadly, the study highlights the role of information synchronization as an economic mechanism. By reducing discrepancies across institutional records, shared-ledger systems lower reconciliation costs while improving coordination under uncertainty. This suggests that information design is not only an operational concern but a determinant of system-wide efficiency and resilience.

7.2. Implications for Financial Institutions

From a managerial perspective, the results indicate that blockchain-based settlement systems can significantly improve liquidity management and operational efficiency. The reduction in settlement delay lowers the need for large intraday liquidity buffers, allowing institutions to reallocate capital more productively. At the same time, the elimination of reconciliation processes reduces operational costs and simplifies transaction processing. Real-time settlement also enhances risk management by shortening the duration of counterparty exposure. This improves institutional resilience, particularly during periods of market stress when delayed settlement systems are more vulnerable to cascading failures. However, these benefits depend critically on the extent of network participation. Because the advantages of shared-ledger systems arise from synchronization across participants, partial adoption limits their effectiveness and preserves elements of fragmentation.

7.3. Policy and Regulatory Implications

The findings have important implications for policymakers and regulators seeking to modernize financial infrastructure. Efforts by institutions such as the U.S. Department of the Treasury and the Securities and Exchange Commission can benefit from recognizing settlement architecture as a key determinant of both efficiency and systemic stability. Blockchain-based systems offer the potential to reduce systemic risk by compressing exposure duration and improving transparency. At the same time, their effectiveness depends on regulatory alignment, governance design, and interoperability with existing infrastructures. Policymakers therefore face a dual challenge: enabling technological innovation while ensuring that new systems maintain robustness, accountability, and compliance. The presence of strong network effects further suggests that coordinated adoption may be necessary to realize system-wide benefits. Without sufficient participation, the advantages of shared-ledger systems remain partial, limiting their impact on liquidity efficiency and systemic risk.

7.4. Boundary Conditions and Limitations

Several boundary conditions should be acknowledged. First, the model assumes that blockchain-based systems can achieve near real-time settlement without significant performance constraints. In practice, scalability limitations may affect system performance. Second, the benefits of information synchronization depend on governance structures and access controls; poorly designed systems may introduce new vulnerabilities. Third, the empirical analysis relies on simulation calibrated to stylized payment networks. While appropriate for theory testing, empirical validation using real-world transaction data remains an important next step. Finally, institutional and regulatory frictions may slow adoption, delaying the realization of network-wide benefits.

7.5. Future Research Directions

The study opens several avenues for future research. As blockchain-based settlement systems are implemented, transaction-level data can be used to test the model's predictions empirically. Further research is also needed to examine governance mechanisms and incentive structures that facilitate coordinated adoption across institutions. In addition, many real-world implementations are likely to involve hybrid architectures combining traditional and distributed systems, raising new questions about interoperability and efficiency. Extending the analysis to cross-border payment networks, where fragmentation and settlement delays are more pronounced, represents another promising direction.

8. Conclusion

This study examined how settlement architecture influences liquidity allocation and systemic risk within modern payment networks. By developing a formal economic model and implementing a simulation-based comparative framework, the analysis evaluated the implications of transitioning from traditional delayed settlement systems to blockchain-based real-time settlement infrastructures. The central objective was to determine whether distributed ledger–based settlement systems can improve liquidity efficiency while simultaneously reducing systemic risk. The findings indicate that settlement design plays a critical role in shaping system-level financial outcomes. Across simulated environments, blockchain-based settlement systems substantially reduce intraday liquidity requirements by minimizing the accumulation of unsettled obligations and reducing the need for precautionary liquidity buffers. At the same time, real-time settlement compresses the duration of counterparty exposure, limiting the propagation of financial distress across interconnected institutions. These effects become more pronounced in high-volume and densely connected payment networks, where traditional settlement delays generate larger exposure pipelines and greater coordination frictions. Beyond the empirical findings, the study offers a broader theoretical contribution by reframing settlement systems as economic coordination mechanisms shaped by temporal structure, information synchronization, and process integration. The analysis suggests that the conventional trade-off between liquidity efficiency and systemic stability is not inherently structural but depends on the architecture through which settlement is organized. When real-time settlement is combined with synchronized shared-ledger coordination, liquidity efficiency and systemic resilience can improve simultaneously.

The study also contributes to the information systems literature by demonstrating that digital infrastructure design has macro-financial implications. Specifically, the findings link distributed ledger architecture to economic outcomes such as liquidity allocation, operational coordination, and systemic stability. In doing so, the paper bridges insights from payment economics, financial network theory, and information systems research within a unified analytical framework. From a practical perspective, the results suggest that blockchain-based settlement systems may provide a viable pathway toward more efficient and resilient financial infrastructures, particularly when implemented within institutionally coordinated and regulated environments. However, the realization of these gains depends on factors such as governance quality, interoperability, synchronized adoption, and operational scalability. The study demonstrates that blockchain-based settlement systems have the potential to reshape the economic organization of payment networks by reducing coordination frictions, improving liquidity efficiency, and limiting systemic risk propagation within interconnected financial systems.

Authors' Contributions

Muhammad Imam Hussain: Conceptualization, theoretical framework development, formal economic modeling, analysis of payment settlement mechanisms, manuscript writing, and revision.

Shahanaz Akter: Literature review, financial theory support, and manuscript review.

Md Khairul Islam Bhuiyan: Technical review, blockchain infrastructure interpretation, and support in analyzing distributed ledger applications.

Ayesha Arobee: Literature organization, manuscript formatting, and support in reviewing financial infrastructure discussions.

Farhad Akter: Data interpretation support, simulation framework review, and manuscript editing.

Mohammad Ikbal Hossain: Research design support, information systems framing, manuscript development, final review, and correspondence.

Conflicts of Interest

The authors have affirmed the absence of any conflict of interest in relation to this study.

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