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# Structural Inefficiencies in Cross-border Digital Payments: The Relationship Between Cost, Speed, Foreign Exchange Fluctuations, and Consumer Behavior

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**Abstract:** Cross-border digital payments have become an essential component of global commerce and personal remittances. Despite rapid technological adoption, these payment systems continue to exhibit persistent inefficiencies, including elevated transaction costs, delayed settlement, and exposure to foreign exchange fluctuations. Existing discussions often address these issues in isolation, providing limited insight into their structural interdependence. This paper develops a structural and mechanism-based analytical framework to examine the interaction among payment costs, settlement speed, and foreign exchange volatility within cross-border digital payment systems. By positioning settlement time as a central transmission channel, the analysis explains how foreign exchange risk is converted into effective payment costs under different institutional arrangements. The study further incorporates a consumer behavior perspective, demonstrating how cognitive perception, trust, and risk tolerance mediate payment method selection under structural constraints. The findings suggest that settlement speed plays a pivotal role in reinforcing the trade-off between cost efficiency and payment predictability, with implications for both system-level performance and user behavior. Based on this framework, the paper proposes system-level improvement directions aimed at enhancing transparency, reducing structural costs, and mitigating foreign exchange risk exposure. The analytical approach developed in this study provides practical insights for fintech product design, regulatory policy, and the broader evolution of cross-border payment infrastructure.

**Keywords:** cross-border digital payments; payment system efficiency; exchange rate volatility; consumer decision-making; financial infrastructure

Received: 17 December 2025

Revised: 06 February 2026

Accepted: 18 February 2026

Published: 25 February 2026



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## 1. Introduction

Cross-border payments are increasingly conducted through digital channels and are embedded in a wide range of economic activities, including international e-commerce, cross-border service trade, and personal remittances. While digitalization has improved accessibility and operational scalability, the underlying payment processes continue to exhibit structural inefficiencies. High transaction costs, prolonged settlement cycles, and exposure to foreign exchange fluctuations remain common features of cross-border digital payments, limiting their efficiency and predictability.

These inefficiencies are not merely the result of technological limitations or isolated operational frictions. Rather, they are rooted in the institutional structure of cross-border payment systems, where multiple intermediaries, heterogeneous regulatory environments, and staged settlement mechanisms jointly shape cost formation and risk transmission. As funds remain in transit across jurisdictions and platforms, settlement delays amplify foreign exchange exposure and introduce uncertainty into final payment

outcomes. Consequently, payment costs, settlement speed, and exchange rate volatility are intrinsically linked through the time dimension of the settlement process.

At the user level, structural inefficiencies are further reflected in consumer decision-making. Complex fee structures, opaque exchange rate spreads, and delayed settlement outcomes increase the cognitive burden on users and affect their perception of “true” payment costs. As a result, payment choices often reflect perceived predictability and familiarity rather than nominal efficiency, reinforcing path dependence in cross-border payment behavior.

Existing studies on cross-border payments have made important contributions by examining technological innovation, regulatory coordination, and payment system design. However, much of the literature addresses cost efficiency, settlement speed, and foreign exchange risk as separate issues, offering limited insight into their joint interaction and behavioral consequences. This gap makes it difficult to explain why improvements in individual segments of the payment process do not necessarily translate into higher overall efficiency or improved user outcomes.

This paper addresses this gap by developing a structural and conceptual analytical framework that integrates payment system mechanics with consumer behavior considerations. Methodologically, the study adopts a mechanism-based analysis rather than an empirical estimation approach. The framework is informed by institutional and system-level analysis of cross-border payment architecture and user-facing design constraints. By decomposing payment costs into explicit fees, time-related costs, and foreign exchange-related components, the framework highlights settlement time as a key transmission channel through which foreign exchange risk is transformed into effective payment costs.

This paper makes three contributions. First, it provides a structural decomposition of cross-border digital payment costs that explicitly links settlement speed with foreign exchange risk transmission. Second, it introduces a consumer behavior-oriented analytical framework that explains how cognition, trust, and risk perception interact with structural inefficiencies in shaping payment method selection. Third, it derives system-level improvement directions that are applicable to fintech product architecture and regulatory policy in cross-border payment markets.

The remainder of the paper is organized as follows. Section 1 examines the manifestations and institutional origins of structural inefficiencies in cross-border digital payments. Section 2 analyzes the interaction mechanisms among payment costs, settlement speed, and foreign exchange fluctuations. Section 3 explores consumer payment adoption behavior under structural constraints. Section 4 discusses system-level improvement directions aimed at enhancing efficiency, transparency, and predictability in cross-border digital payment systems [1].

## **2. Manifestations and Formation Mechanisms of Structural Inefficiencies in Cross-border Digital Payments**

### *2.1. Main Manifestations of Structural Inefficiencies in Cross-border Digital Payments*

Rather than treating high costs, delayed settlement, and foreign exchange exposure as isolated frictions, this section conceptualizes them as interdependent manifestations of structural inefficiency embedded in cross-border digital payment systems. These manifestations should be understood as outcomes of system design and institutional arrangements, rather than temporary operational anomalies. At the cost level, the involvement of multiple intermediaries and multi-point pricing mechanisms combines explicit transaction fees with implicit time- and exchange-related costs, resulting in elevated and opaque overall payment expenses. Importantly, these cost components are not independently formed, but accumulate sequentially along the payment and settlement chain. At the settlement level, the cross-border clearing process is complex, and fund settlement is often delayed, creating uncertainty in payment outcomes. In terms of

foreign currency settlement, exchange rate differences and settlement cycles introduce volatility in the actual amount received [2]. When combined with limited information transparency, these factors further complicate the payment process. As a result, the cost structure and exchange rate formation mechanisms are not fully transparent to users, increasing the difficulty of understanding and evaluating payment outcomes and weakening consumers' ability to form accurate expectations regarding final settlement results.

### 2.2. Formation Logic and Institutional Roots of Structural Inefficiencies in Cross-border Payment Systems

The structural inefficiency of cross-border payment systems can be traced to the institutional design of international settlement mechanisms. Under prevailing international settlement arrangements, capital flows typically pass through multiple intermediate platforms for clearing and settlement. Moreover, regulatory policies, compliance requirements, and operational standards vary from country to country, which increases the complexity of cross-border transactions. The settlement procedure has a phased feature, which causes funds to stay in multiple steps, resulting in additional time and operational costs. In foreign exchange risks, these costs are transferred to the participants and reflected in the settlement delay process. This hidden cost becomes the actual payment cost. Payment information is passed down step by step, making it difficult to clearly identify the composition of costs and the sources of risks. This is also one of the manifestations of inefficient operation [3]. From a structural perspective, cross-border payment costs can be analytically decomposed into explicit fees, time-related costs, and foreign exchange-related components. This decomposition serves to clarify how different institutional and operational stages of the payment process contribute to total user-facing costs. This decomposition is intended as a conceptual framework rather than a precise accounting identity, highlighting the main channels through which structural inefficiencies are transmitted to users:

$$C_{\text{total}} = C_f + C_t + C_{fx} \quad (1)$$

Among them,  $C_f$  represents the explicit handling fee,  $C_t$  represents the time cost caused by settlement delay, and  $C_{fx}$  represents the implicit cost brought about by foreign exchange fluctuations. This decomposition method reveals the main sources of inefficient costs in cross-border payments from a structural perspective, providing a basis for subsequent analysis of the interrelationships among different factors.

## 3. Interaction Mechanisms Among Cost, Speed, and Foreign Exchange Fluctuations

### 3.1. Trade-off Between Cross-border Payment Costs and Settlement Speed

Within cross-border payment systems, a structurally embedded trade-off exists between payment costs and settlement speed. This trade-off arises not from the pricing strategy of any single institution, but from the institutional design of clearing, settlement, and liquidity allocation mechanisms that operate across jurisdictions. Accelerating settlement typically relies on faster clearing channels, pre-arranged liquidity, or priority processing. These arrangements require additional resources or risk-bearing capacity, which are reflected in higher service fees or implicit costs [4]. In contrast, cost-saving payment routes usually adopt multi-intermediary settlement structures, resulting in longer settlement cycles as funds remain at intermediate stages for extended periods. This relationship is embedded in the operational rules of the cross-border payment system and manifests differently across payment methods and channels. This institutional trade-off provides the structural condition under which settlement speed influences both cost formation and exposure to foreign exchange risk:

$$C = g(T), \quad \frac{\partial C}{\partial T} < 0 \quad (2)$$

Here,  $C$  represents the overall cost of cross-border payment,  $T$  represents the settlement cycle of cross-border payment, and the function  $g(.) \frac{\partial C}{\partial T} < 0$  indicates the structural relationship between cost and settlement cycle. Under the given payment system, when the settlement cycle is extended, the payment cost shows a downward trend. This expression is intended to capture a structural tendency rather than an empirically estimated functional relationship.

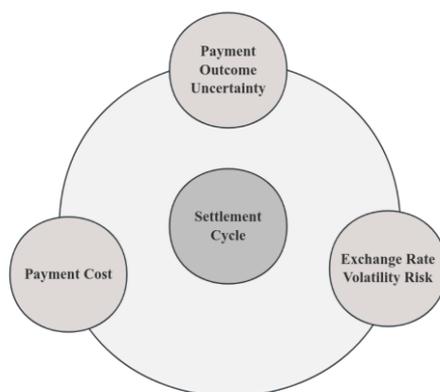
### 3.2. Amplification of Foreign Exchange Risk Through Extended Settlement Cycles

Within cross-border digital payment systems, payment costs, settlement speed, and foreign exchange fluctuations are linked through institutional arrangements and operational structures, rather than operating as independent dimensions. An extended settlement cycle tends to reduce unit payment costs by relying on lower-priority settlement channels, while simultaneously increasing exposure to foreign exchange risk as funds remain in transit for longer periods [5]. As foreign exchange risk intensifies, its impact is reflected in payment costs through risk premiums and exchange rate spreads, further reinforcing the trade-off between cost and settlement speed. In this process, time functions as a key transmission channel through which foreign exchange risk accumulates and is converted into payment costs. The interactions among these factors along the payment chain create a compound constraint on cross-border payment efficiency. This interaction helps explain why improvements in individual segments of the payment process do not necessarily translate into higher overall system efficiency:

$$L = \alpha C + \beta T + \gamma \sigma_{fx} \quad (3)$$

Among them,  $L$  represents the degree of structural inefficiency in cross-border payments,  $C$  represents payment costs,  $T$  represents settlement cycles,  $\sigma_{fx}$  represents foreign exchange fluctuation risks, and  $\alpha$ ,  $\beta$ , and  $\gamma$  are weight coefficients reflecting the degree of influence of each factor. The above relationship formula provides a general description of the interaction among payment costs, settlement cycles and foreign exchange fluctuations. However, it is still necessary to present the interaction paths among the three at the structural level in the operation process of cross-border payments intuitively. For this purpose, the relevant linkage mechanism is illustrated in the form of a schematic diagram.

Figure 1 illustrates the core analytical contribution of this paper by positioning the settlement cycle as the central transmission hub that links payment costs and foreign exchange volatility within the cross-border payment process. It visually summarizes how extended settlement time simultaneously lowers nominal fees and amplifies exchange rate exposure, thereby increasing uncertainty in final payment outcomes [6].



**Figure 1.** Schematic diagram of the linkage mechanism among cost, settlement speed and foreign exchange fluctuations in cross-border digital payments.

### 3.3. Linkage Effects of Cost, Settlement Speed, and Foreign Exchange Fluctuations

During the operation of cross-border digital payments, payment costs, settlement speed, and foreign exchange fluctuations are jointly mediated through the time dimension of the settlement process. Settlement time determines the duration for which funds are exposed to exchange rate movements and therefore functions as a central structural node linking cost formation and risk transmission.

A longer settlement cycle increases exposure to exchange rate volatility, amplifying uncertainty in final payment outcomes and raising the foreign exchange-related component of total payment costs. At the same time, changes in the magnitude of exchange rate fluctuations feed back into payment pricing arrangements through wider spreads and risk premiums, partially offsetting the nominal cost advantages associated with slower settlement channels. As a result, settlement speed influences not only payment timeliness but also plays a pivotal role in shaping the composition and predictability of payment costs.

This interdependence among time, cost, and foreign exchange risk imposes a compound constraint on cross-border payment efficiency, such that inefficiency is manifested through their simultaneous interaction rather than being driven by any single factor. This relationship can be summarized conceptually as follows:

$$C_{fx} = h(T, \sigma_{fx}) \quad (4)$$

Here,  $C_{fx}$  represents the payment cost attributable to foreign exchange fluctuations,  $T$  denotes the settlement cycle, and  $\sigma_{fx}$  captures exchange rate volatility. This relationship characterizes the pivotal role of the settlement cycle in the transmission of foreign exchange fluctuation risks to payment costs, thereby highlighting the inefficient linkage feature of cross-border payments. More broadly, it underscores settlement time as a key transmission channel through which exchange rate volatility is converted into foreign exchange-related payment costs.

## 4. Cross-border Payment Adoption from a Consumer Behavior Perspective

Building on the structural mechanisms identified in Section 2, this section examines how cost-speed trade-offs and foreign exchange risk transmission are perceived and internalized by consumers, and how these perceptions shape cross-border payment adoption behavior.

### 4.1. Consumer Cognitive Characteristics Regarding Cost, Speed, and Foreign Exchange Risk

Consumers' judgments of cross-border payment options are shaped not only by objective indicators such as fees and settlement speed, but also by subjective perceptions formed under structural constraints. In the presence of opaque pricing, delayed settlement, and exchange rate uncertainty, individuals rely more heavily on cognitive heuristics, trust, and familiarity when evaluating payment alternatives. As a result, the perceived "true cost" of a payment often diverges from its nominal price structure.

The way costs are presented, the predictability of fund settlement, and the visibility of exchange rate spreads play a critical role in shaping users' cost assessments. Some consumers systematically underestimate hidden fees and exchange losses, while others overestimate the uncertainty associated with delayed settlement, leading to distorted comparisons across payment methods. These perceptual differences are further influenced by past usage experience, information-processing ability, and individual risk aversion, which jointly determine tolerance for foreign exchange fluctuation risks.

To capture the integrated perception of cost, time, and foreign exchange uncertainty, perceived payment cost can be represented conceptually as follows:

$$\tilde{C} = C_f + \lambda C_{fx} + \eta \frac{T}{1+T} + \rho |\Delta s| + \kappa (\Delta s)^2 \quad (5)$$

Here,  $\tilde{C}$  denotes consumers' perceived cost,  $C_f$  represents explicit handling fees,  $C_{fx}$  captures foreign exchange-related costs,  $T$  denotes the settlement cycle, and  $\Delta s$  reflects exchange rate fluctuations. The parameters  $\lambda$ ,  $\eta$ ,  $\rho$ , and  $\kappa$  represent cognitive weights

assigned to different cost and risk components. This formulation is intended as a conceptual representation of how consumers integrate multiple sources of uncertainty into a unified cost perception, rather than as an empirically estimated behavioral model.

4.2. Role of Trust and Understanding in Payment Method Selection

In cross-border payment contexts, consumer choice is influenced not only by perceived cost and settlement speed, but also by levels of trust and understanding. Complex payment rules, opaque fee structures, and uncertain settlement outcomes increase cognitive barriers and reduce consumers’ willingness to adopt unfamiliar payment methods. Under such conditions, trust functions as a compensatory mechanism that mitigates perceived uncertainty.

Regulatory endorsement, platform reputation, and accumulated usage experience help alleviate information asymmetry by enhancing perceptions of payment security and outcome predictability. When consumers possess a clearer understanding of payment processes and associated risks, trust is more likely to translate into actual adoption behavior. Trust and understanding therefore reinforce one another, jointly shaping payment method selection under structural inefficiency.

This interaction can be represented conceptually through the following utility formulation:

$$U_i = -\alpha\tilde{C}_i - \beta T_i + \delta Trust_i + \theta Info_i \tag{6}$$

Here,  $U_i$  represents the perceived utility of the  $i$ -th payment method,  $\tilde{C}_i$  denotes perceived cost,  $T_i$  reflects settlement time constraints,  $Trust_i$  captures perceived reliability and security, and  $Info_i$  represents the level of consumer understanding of payment rules and risks. The parameters  $\alpha, \beta, \delta,$  and  $\theta$  reflect the relative importance of these factors. This formulation serves as a conceptual device to illustrate how trust and information moderate the influence of structural inefficiencies on payment choice.

4.3. Behavioral Logic of Payment Choices under Structural Inefficiencies

Against the background of persistent structural inefficiency in cross-border payment systems, consumer payment preferences exhibit distinct behavioral patterns. When confronted with high perceived costs, uncertain settlement times, and exposure to foreign exchange fluctuations, many users favor traditional or familiar payment methods as a way to reduce perceived risk and decision-making ambiguity.

In contrast, consumers with stronger information-processing capabilities and higher risk tolerance are more willing to experiment with payment methods that offer faster settlement or greater pricing transparency. Payment choice is therefore not governed solely by the minimization of nominal costs, but by a trade-off among perceived cost, time pressure, and trust. Structural inefficiencies shape expectations regarding payment outcomes, reinforcing path dependence in adoption behavior and slowing the diffusion of more efficient payment technologies.

Table 1 summarizes the dominant behavioral patterns observed under different combinations of cognition, trust, and risk tolerance.

**Table 1.** Behavioral Logic of Consumers’ Cross-Border Payment Choices under Structural Inefficiency.

Behavioral Type	Level of Cognition and Trust	Preferred Payment Choice
Risk-averse	Lower level of understanding; trust based on past experience	Preference for traditional or familiar payment methods
Cost-sensitive	High sensitivity to fees	Preference for lower-cost options with slower settlement
Efficiency-oriented	Stronger understanding; higher level of trust	Preference for payment methods with faster settlement

Balanced decision-makers	High levels of understanding and trust	Trade-off between cost and settlement speed
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## 5. System-Level Improvement Directions for Structural Inefficiencies in Cross-border Digital Payments

Building on the structural mechanisms and behavioral responses identified in the preceding sections, this section derives system-level improvement directions aimed at mitigating structural inefficiencies in cross-border digital payments.

### 5.1. Optimization Directions for Reducing Structural Costs and Enhancing Payment Transparency

Improving the efficiency of cross-border digital payments requires system-level interventions that address both institutional design and user-facing transparency. Rather than focusing solely on technological upgrades, optimization efforts should target the structural sources of cost accumulation, settlement delay, and foreign exchange risk transmission identified earlier in this paper.

From an institutional perspective, unnecessary intermediate links in clearing and settlement chains can be streamlined to reduce repetitive processing and liquidity fragmentation. Optimizing interface configurations for settlement and reconciliation can further limit cost accumulation arising from staged fund holding. Standardized pricing frameworks may also help prevent hidden fees from being distributed across multiple stages of the payment process.

From a transparency perspective, enhanced pre-disclosure of service fees, exchange rate spreads, and potential foreign exchange losses is essential for improving predictability in payment outcomes. Presenting this information in a unified and simplified format can reduce cognitive burdens on users with heterogeneous levels of financial literacy, thereby narrowing the gap between nominal and perceived costs highlighted in Section 3.

### 5.2. Improvement Paths for Shortening Settlement Cycles and Mitigating Foreign Exchange Risk

As demonstrated in Section 2, prolonged settlement cycles serve as a key channel through which foreign exchange risk accumulates and is transmitted to users. Reducing settlement time is therefore central to lowering uncertainty in cross-border payment outcomes.

From a regulatory perspective, optimizing interbank payment timelines and improving system interoperability can reduce the duration for which funds remain in intermediate transit accounts, enhancing the continuity and controllability of settlement processes. Such measures directly weaken the time-based amplification mechanism of foreign exchange risk identified earlier.

From an operational perspective, pre-arranged liquidity solutions and advance matching mechanisms can be employed to lock in settlement conditions at the initiation stage of payment. These arrangements reduce effective settlement duration and limit exposure to exchange rate volatility. In addition, offering real-time or near real-time exchange rate commitments through instant settlement services can constrain the extent to which exchange rate fluctuations affect final payment amounts, thereby improving predictability for end users.

### 5.3. Consumer-Oriented Design Implications for Cross-border Payment Systems

Given the behavioral mechanisms discussed in Section 3, effective system improvements must account for consumers' cognitive constraints, trust formation, and decision-making processes. Payment system design should therefore incorporate behavioral considerations as a core component rather than as an afterthought.

At the interface and process design level, presenting payment costs in simplified and aggregated forms—such as comprehensive fees, exchange rate differentials, and expected settlement times—can reduce cognitive load and improve comparability across payment options. In the risk communication stage, tiered information disclosure strategies may be adopted to provide differentiated explanations based on users' experience levels, avoiding both information overload and critical omissions.

In terms of trust construction, emphasizing regulatory compliance, fund security safeguards, and transparent transaction histories can enhance confidence in payment outcomes. Post-transaction feedback mechanisms that allow users to review realized costs and settlement times can further support learning and promote more informed payment choices over time, reinforcing efficiency improvements without significantly increasing technical complexity.

**Conclusion:** This paper demonstrates that inefficiencies in cross-border digital payments are not primarily the result of technological limitations, but rather the outcome of long-standing interactions among payment system design, risk transmission mechanisms, and consumer behavior. The mutual constraints among cost, settlement time, and foreign exchange fluctuations create a structural environment in which efficiency improvements are difficult to achieve through isolated interventions. Moreover, consumers' perceptions, trust, and behavioral responses further reinforce existing operational patterns, contributing to path dependence in payment system adoption.

By positioning settlement time as a central transmission channel through which foreign exchange risk is transformed into effective consumer costs, this study provides a unified analytical framework for understanding the interaction between system-level inefficiencies and user-level decision-making. Without such an integrated framework, policy interventions and technological innovations risk remaining fragmented, addressing individual frictions while leaving the underlying mechanisms of cost accumulation and risk transmission unresolved.

From a policy and regulatory perspective, the analytical framework developed in this paper is particularly relevant to jurisdictions such as the United States, where cross-border remittances, digital financial inclusion, and consumer protection are key priorities. By clarifying how settlement delays amplify foreign exchange risk and reshape consumer cost perceptions, the framework offers a foundation for more coherent regulatory standards and payment system oversight that aligns infrastructure design with public interest objectives.

More broadly, the findings suggest that enhancing the efficiency of cross-border digital payments requires coordinated progress in institutional design, transparency, and user experience. Addressing structural inefficiencies and behavioral responses in tandem is therefore critical for advancing more stable, predictable, and inclusive cross-border payment systems.

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