Impact of Fintech Innovation on Cross-border Payments: SWIFT vs. Blockchain

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This paper examines the impact of fintech innovation with blockchain on the competitive dynamics and pricing strategies for the cross-border payments market, particularly in relation to the traditional SWIFT system. Our findings indicate that blockchain integration can significantly reduce costs of cross-border payments for customers, challenging the dominant position of SWIFT. The results highlight a strategic pathway for banks considering blockchain, revealing that early adopters can leverage technological benefits to capture greater market share, despite facing new risks associated with system integration and regulatory compliance.

The ratio of costs stemming from systemic risks for blockchain-enabled transfers to the costs occurring at a SWIFT transfer due to the involvement of intermediaries determines the functionality of the blockchain adoption for the pioneering banks and the market. We find that this fintech innovation would increase the total user surplus in the market and translate into market leadership in terms of market share for the pioneering bank. However, this would not always translate into a higher profit for the pioneering bank if the risks involved with blockchain technology are too high. The study contributes to the theoretical understanding of fintech innovations in financial markets and offers managerial insights into the adoption of new technologies for cross-border transfers.

Keywords: blockchain, SWIFT, cross-border payments, fintech, international banking, market dynamics

1. Introduction

The Society for Worldwide Interbank Financial Telecommunications (SWIFT) is a communication network established to facilitate the transmission and reception of encrypted data on instructions for cross-border monetary transfers. Established in 1973 by 239 banks representing 15 nations,
SWIFT emerged as a cooperative entity headquartered in Brussels, Belgium (Scott and Zachariadis 2012). It currently serves as the prime establishment for secure financial messaging among its membership base of approximately 11,000 banks and financial institutions spanning more than 200 countries and territories. Notably, SWIFT processes nearly 38 million encrypted transactions daily.

When it comes to transferring money, the process comprises agreements where the paying bank adjusts its records to show reduced debt after the transfer, while the receiving bank increases its obligation to the recipient. This ledger adjustment occurs domestically through clearing systems managed by central banks or government monetary bodies. However, for international transfers, banks rely on correspondent banking relationships to handle different currencies. Before SWIFT, these transfers were manual, primarily through Telex networks.

SWIFT does not transfer money directly but transmits detailed instructions between banks. Members access SWIFT Net using unique codes known as Business Identifier Codes (BICs) to send encrypted messages. The messaging format, such as MT103, contains sender, receiver, and transaction information. SWIFT transfers typically take 24-48 hours but can extend to five days for complex cross-border transactions (SWIFT 2024).

Using SWIFT incurs costs for each transfer due to fees charged by the bank(s) of the sender and/or the recipient. Moreover, if the sender’s and the recipient’s banks do not hold accounts with each other, intermediary banks would be involved in the transfer and they will also receive commission fees for the transfer. One such instance including intermediary bank fees is shown below [1].

One alternative that emerged due to the invention of cryptocurrencies is using blockchain technology to facilitate cross-border transfers without intermediaries. The current level of distributed ledger network structures allows financial institutions to become members of such a network, e.g. Ripple, to provide blockchain transfers to their customers that are to be sent to the customers of another member institution in the same distributed ledger network. For example, Banco Santander partnered with Ripple to send blockchain-enabled transfers to financial institutions located at currently two dozen countries (Belsky and Dubovik 2024).
Hence, there exists a feasible technology for a pioneering bank to integrate, and in this paper, we analyze the impact of such an integration on 1) the pricing strategy for the traditional SWIFT transfers offered by the pioneering bank (alongside blockchain transfers) and the other banks, 2) the market shares and profits for all banks, and 3) the total user surplus in the market.

Blockchain technology is being experimented with by the global banking and finance system. The SWIFT network is currently experimenting with providing a single-point entry for asset tokenization and other transfers that would connect different distributed ledger networks. Experimentation with this new structure required SWIFT to collaborate with Chainlink, the provider of the cross-chain interoperability protocol that allowed the different blockchains to connect for the transfer (due to the sender’s and receiver’s digital wallets being in different blockchains) (Liljeqvist 2022). This update is still being experimented with and needs a significant governance shift (Margaroli 2023). It reflects on the existing structure of SWIFT that connects the otherwise “disconnected” financial entities and is different from the currently operating blockchain and cryptocurrency-based transfer networks which directly connect all their members without charging the customers for any interoperability and/or intermediary structure for the payment.

Therefore, the trade-off we capture via our stylized model is between these two system structures for international fund transfers where:

- One system determines a pathway to securely connect otherwise disconnected banks of the sender and the receiver via designating intermediary connection points, and
• The other system (such as Ripple) creates a network structure of connected banks where a limited number of banks have the resources and capability to be a part of this structure and the regulatory establishment is still being developed.

As in the example of Banco Santander, the pioneering banks in each market are currently joining systems belonging to the second category above to immediately allow their customers benefit from blockchain-enabled international transfers.

Our stylized model sheds light on this critical decision for a pioneering bank in a national financial system and characterizes the conditions for the existence of equilibrium with this fintech innovation. To describe the system dynamics, we focus on the ratio of two percentage costs, namely, the ratio of the percentage cost of systemic risk factors involved with blockchain-enabled transfers, to the percentage cost of intermediary commissions involved with the SWIFT transfers. We show that if this ratio is high (and hence the cost of risk factors for blockchain transfers dominates the cost of intermediaries for SWIFT transfers), integrating blockchain transfers would decrease the market share and the profit of the pioneering bank, else if the ratio is medium, it would allow the pioneering bank to become the market leader in cross-border payments but decrease its profit, and only if this ratio is low, then the pioneering bank will both become the market leader and increase its profit at the same time.

The rest of this paper is organized as follows. In the next section, we review the literature. Then, in Section 3 we present closed-form analytical models of the benchmark case where only SWIFT transfers are offered to the customers by all banks in the market (Section 3.1) and the case where the pioneering bank starts offering blockchain transfers along with SWIFT transfers and the other banks keep offering SWIFT transfers only (Section 3.2). In Section 3.3 we compare the equilibrium prices, market shares, and profits for each bank as well as the total user surplus existing in the market at each case. In Section 4 we discuss our findings and conclude the paper.

2. Literature Review

Since the invention of cryptocurrencies and blockchain network structures, the impact of blockchain on financial services has been one of the most intensely discussed topics in multiple disciplines.
There are many white papers and reviews on how different types of financial services could be developed via blockchain integration ((Fanning and Centers 2016)), and blockchain-enabled cross-border payments have been the focus of extant literature on the banking industry ((Guo and Liang 2016)). The regulatory development to realize these fintech innovations has also been explored in the literature on jurisprudence ((Cheng and Geva 2016)); however, the pace of regulatory developments has been slow compared to technical developments.

After blockchain applications improved beyond the proof of concept to production and scaling, their impact began to be acknowledged and explored more in the information systems and service operations literature ((Hendershott et al. 2021); (Babich and Kouvelis 2018)).

The approaches in the extant information systems literature toward blockchain technology adoption involved conceptual framework development to address the institutional, market, and technical perspectives of this adoption ((Janssen et al. 2020)).

A recent example ((Franke et al. 2024)) investigates the trade-offs between blockchain’s capacity for improving information environments and reducing dependency on intermediaries for satisfying the information needs of corporations through blockchain-enabled resources rather than third-party intermediaries such as auditors and rating agencies.

We also analyze trade-offs related to the reduction of intermediaries, but we focus on the financial markets. Since any systemic errors and regulatory gaps might cause significant and direct monetary losses for cross-border payments, we investigate the trade-off related to this type of risk and the cost advantages to be gained by reducing intermediaries.

Our focus is not on the technical and computer science perspective but rather on the market dynamics such as pricing strategies for the traditional and new technology for cross-border payments. We characterize the impact of this change on the market shares and profits of each bank as well as the total user surplus in a national banking and finance system. In this sense, the dynamics we capture resemble the shifts mail ordering and e-tailing caused in the retail markets and the traditional bricks-and-mortar outlets ((Balasubramanian 1998)). Our benchmark case reflects on
cross-border payment services provided to individual and corporate customers via SWIFT network, and our fintech innovation with blockchain case reflects on the impact of an alternative service for cross-border payments that is offered to the market online and in a standardized way.

Reflecting on the example cited above for banks joining distributed ledger networks for cross-border payments, we consider blockchain adoption as an alternative service to be initiated by a pioneering bank for competitive advantage. We characterize the case of a pioneering bank breaking the similarity between the competing banks in the market by adopting blockchain-enabled cross-border transfers to offer as an alternative. Our analysis pertains to the current dynamics where a limited set of banks at each market have become capable of this fintech innovation due to the regulatory framework not being scaled yet and a certain level of transaction volume would be required to make this innovation profitable. We present the conditions for this innovation to be economically viable, explaining the dynamics currently observed in practice. To our knowledge, our analysis serves to be a first step in addressing market analysis on blockchain adoption for cross-border payments, with the potential to lead to more detailed and comprehensive analyses as noted in the future research recommendations.

3. Model Set-up, Notation, and Analysis

Our analysis begins with a benchmark case that only offers cross-border monetary transfers facilitated through SWIFT. We first define the equilibrium conditions and pricing strategies for this case. Afterward, we consider the case where the pioneering bank introduces the fintech innovation with blockchain-enabled cross-border transfers. In this second case, this bank will be offering both types of cross-border payments (via blockchain and SWIFT), whereas other banks will keep offering cross-border payments via SWIFT only.

We establish closed-form equilibria for both the benchmark model and the fintech innovation with blockchain, the specifics of which are detailed in Appendices. Then, we compare the equilibrium prices, market shares, profits, and user surpluses of these two models. To ensure that our findings are comparable, we apply a uniform set of assumptions across all analyzed models. We explicitly express these assumptions below.
We employ the Salop circular model (Salop 1979) to integrate customers’ diverse preferences effectively. In this model, customers are uniformly positioned around a circle with a circumference of 1, representing the total market population.

In our analytical framework, we postulate that the market is fully covered by the existing participants in all of our models. This assumption allows us to concentrate solely on examining the impacts of fintech innovation with blockchain, providing a clearer view of its effects.

Assumption 1. The market is fully covered by the existing players in all our models.

Within our models, this assumption is operationalized by ensuring that the utility of indifferent users remains positive. The specifics of these calculations and the constraints they introduce for each model are detailed in the Appendix.

Our analysis focuses on the competition among banks for transactions within unit time, with the assumption that each customer will engage in no more than one transaction. The customers exhibit single-homing behavior, preferring to transact with only one bank that maximizes their utility for cross-border monetary transfers. For tractability of profit calculations for the banks, we assume the transaction amounts are identical and denote them with $M$. It corresponds to the average monetary amount to be sent as a cross-border payment per unit time, and since we express the prices charged by the banks for this service as commission percentages, this assumption does not affect the demand segmentation in the market. While the variable $M$, representing the transaction amount, is currently treated as a constant in our model, we plan to revise this simplification in future iterations. Our next steps involve relaxing this assumption to allow for $M$ to have a more complex distribution. This adjustment aims to explore how variations in transaction amounts impact the adoption and effectiveness of fintech innovation with blockchain for cross-border payments.

Within this framework, we define $d$ as the transportation cost in the Salop model. Along with other lacking aspects of the service provided by the bank under consideration, the transportation cost ($d$) increases if the trade volume between the sender’s bank and the destination of the recipient’s bank is low. This necessitates the involvement of intermediary banks to facilitate the transfer,
passing funds from the sender’s bank to one intermediary and then to another until the funds reach the receiver’s bank.

In terms of bank placement, for the benchmark model (SWIFT only), we assume that banks are symmetric and equidistant. The first bank is positioned at 0, at the apex of the circle. This spatial arrangement reflects customers’ preferences between different banks. Figure 2 illustrates this configuration on the Salop circular model. While banks may not be perfectly symmetric in reality, this assumption allows us to isolate and evaluate the impact of fintech innovation with blockchain by a pioneering bank. Focusing on the competition between existing banks, we do not explicitly consider fixed entry costs. This assumption is planned to be relaxed in future versions of this paper. We present the notation table below for ease of perusal.

Figure 2  Salop Circular Model of Banks

3.1. Benchmark Model (SWIFT Only)

We consider $N$ banks located over a Salop circle representing a national market, and each customer’s location to be uniformly distributed over the circle. In this case, we consider that banks are symmetric and offer cross-border transfers via SWIFT only. Each bank is located at one of the endpoints of an arc of length $1/N$, and a customer located on an arc will choose to work with a
neighbouring bank located at one of these endpoints and providing the highest utility for his/her cross-border transfer. We denote with $x$ the distance of this customer to the neighbouring bank that is closer to the apex of the circle, and the distance with the other closest neighbour would be $1/N - x$. To express the utility functions determining the customer’s preference, without loss of generality and stemming from the symmetry of banks, we consider the utilities associated with Bank 1 and its two closest neighbours. Since we consider a bank and its two neighbours from either side, we assume that there has to be more than 2 banks in the market, $N > 2$.

The banks charge a SWIFT commission price expressed as a percentage of the transaction, namely, we denote the percentage price charged by Bank 1 with $p_{S1}^{BM}$, and the percentage price charged by one of its neighbours with $p_{SNeighbour}^{BM}$. Since we assume no undercutting, the customer will compare the two utilities for a transfer corresponding to Bank 1 and a neighbour, denoted with $U_{S1}^{BM}$ and $U_{SNeighbour}^{BM}$:

$$U_{S1}^{BM} = M(1 - p_{S1}^{BM} - dx),$$  \hspace{1cm} (1)
We assume that banks do not undercut the pricing strategies of their neighbouring banks. By adopting this assumption, we aim to stabilize the market at an equilibrium where no entity is forcibly ousted. This is formalized as follows:

**Assumption 2. Banks do not undercut their neighbouring banks in the benchmark model.**

In our stylized model, Assumption 2 is operationalized by evaluating the utility of Bank 1 at the location of its neighbouring banks and ensuring that the utility of the neighbouring bank at its own location surpasses that of Bank 1 at the same location. This assumption is essential for maintaining the theoretical framework where banks do not engage in undercutting each other, yet it does not impose a specific operational constraint.

Denoting the marginal percentage cost of a transaction with \( c \), which is expressed as a percentage cost of the amount to be transferred, the profits for Bank 1 and its neighbouring bank will be denoted as below:

\[
\pi_{S_{1}}^{BM} = M[(p_{S_{1}}^{BM} - c) \ast D_{S_{1}}^{BM}] 
\]

\[
\pi_{S_{\text{Neighbour}}}^{BM} = M[(p_{S_{\text{Neighbour}}}^{BM} - c) \ast D_{S_{\text{Neighbour}}}^{BM}], \quad \text{Neighbour} = \{2, N\}. 
\]

We now calculate the distance to Bank 1 of the indifferent customer(s) on either side of Bank 1. These customers gain equal utilities from Bank 1 and its neighbouring banks along the arc(s) of length \( 1/N \) on either side.

\[
U_{S_{1}}^{BM} = U_{S_{\text{Neighbour}}}^{BM} \implies x_{\text{Indifferent}}^{BM} = \frac{d + N(p_{S_{\text{Neighbour}}}^{BM} - p_{S_{1}}^{BM})}{2dN} 
\]
Assuming simultaneous decisions by competing banks, we derive the pure strategy Nash equilibrium prices as below by maximizing the above profit functions using the first and second-order conditions.

\[
D_{BM_{1}}^{S} = 2x_{Indifferent}^{BM} = \frac{d + N(p_{BM_{Neighbour}}^{S} - p_{BM_{1}}^{S})}{dN} \tag{6}
\]

\[
D_{BM_{Neighbour}}^{S} = 2\left(\frac{1}{N} - x_{Indifferent}^{BM}\right) = \frac{d - N(p_{BM_{Neighbour}}^{S} - p_{BM_{1}}^{S})}{dN}, \text{ Neighbour} = \{2, N\}. \tag{7}
\]

\[
\pi_{BM_{1}}^{S} = \frac{M(p_{BM_{1}}^{S} - c)(d + N(p_{BM_{Neighbour}}^{S} - p_{BM_{1}}^{S}))}{dN}, \tag{8}
\]

\[
\pi_{BM_{Neighbour}}^{S} = \frac{M(p_{BM_{Neighbour}}^{S} - c)(d - N(p_{BM_{Neighbour}}^{S} - p_{BM_{1}}^{S}))}{dN}, \text{ Neighbour} = \{2, N\}. \tag{9}
\]

The optimal prices result in these equilibrium demand and profit functions for the two neighbouring banks.

\[
p_{BM_{1}}^{S*} = p_{BM_{Neighbour}}^{S*} = c + \frac{d}{N}, \text{ Neighbour} = \{2, N\}. \tag{10}
\]

The optimal prices result in these equilibrium demand and profit functions for the two neighbouring banks.

\[
D_{BM_{1}}^{S*} = D_{BM_{Neighbour}}^{S*} = \frac{1}{N}, \text{ Neighbour} = \{2, N\}. \tag{11}
\]

\[
\pi_{BM_{1}}^{S*} = \pi_{BM_{Neighbour}}^{S*} = \frac{dM}{N^2}, \text{ Neighbour} = \{2, N\}. \tag{12}
\]

The assumed symmetry of the banks in the market provides the grounds for these results where the optimal prices, demands, and profits of the neighbouring banks and Bank 1 are the same. While the solution is explicitly described for two competing neighbours, any other bank in the market would have the same optimal values as above due to symmetry. We will refer to the optimal values for bank \( i, i \in \{1, 2, ..., N\} \), with \( p_{BM_{i}}^{S*} \), \( D_{BM_{i}}^{S*} \), and \( \pi_{BM_{i}}^{S*} \).
p_{S_i}^{BM*} = c + \frac{d}{N}, D_{S_i}^{BM*} = \frac{1}{N}, \pi_{S_i}^{BM*} = \frac{dM}{N^2} \quad \forall \quad i \in \{1, 2, ..., N\}. \tag{13}

The equilibrium prices are higher than the marginal percentage cost, \( p_{S_i}^{BM*} > c \), which shows that this pricing strategy is profitable. Given the necessary conditions for the existence of equilibrium, \( c + \frac{3d}{2N} < 1 \), which is explained in the Appendix, we present the lemma below.

**Lemma 1 (Benchmark Model (SWIFT only)).** In equilibrium under the benchmark model:

(a) The banks set a symmetric SWIFT commission price that increases in transportation cost \( d \) and marginal percentage cost \( c \), but decreases in the total number of banks in the market \( N \).

(b) The market share of each bank decreases with the total number of banks in the market \( N \).

(c) The profit of each bank increases with the transportation cost \( d \) and the transaction amount \( M \) but decreases with the total number of banks in the market \( N \).

Prices are positively correlated with marginal percentage costs, reflecting the economic necessity that, for profitability, banks must set prices above costs. Consistently, an escalation in market competition due to an increase in the number of banks catalyzes a decrease in SWIFT commission prices. Furthermore, as the transportation cost rises, the price elasticity of demand among customers diminishes, permitting banks to escalate their charges and thereby enhance their profitability.

User surplus from each bank is derived as follows:

\[
US_{S_1}^{BM} = 2 \int_{0}^{x_{Indifferent}^{BM}} M(1 - p_{S_1}^{BM} - d \cdot x) \, dx \tag{14}
\]

\[
US_{S_{Neighbour}}^{BM} = 2 \int_{\frac{1}{N} - x_{Indifferent}^{BM}}^{\frac{1}{N}} M(1 - p_{S_{Neighbour}}^{BM} - d \cdot x) \, dx \tag{15}
\]

Total user surplus in equilibrium is the sum of user surplus from all banks, derived as follows:

\[
US^{BM} = US_{S_1}^{BM} + (N - 1)US_{S_{Neighbour}}^{BM} = M \left( 1 - c - \frac{5d}{4N} \right). \tag{16}
\]

The same procedure for the description of the solution that is followed here will be followed for the case of fintech innovation with blockchain model in the next subsection.
3.2. Model for Fintech Innovation with Blockchain

In this case, we will explore the impact of fintech innovation with blockchain by one of the banks (the pioneering bank). We will analyze the equilibrium where the pioneering bank integrates blockchain technology into its cross-border transfers and becomes capable of offering both SWIFT and blockchain-enabled transfers to its customers.

Without loss of generality, we will take the pioneering bank to be Bank 1. Then, we will explicitly analyze Bank 1’s nearest competitors, Bank 2 and Bank \( N \); and we will denote the other banks in the market as Bank \( G \) (\( G \) referring to Generic) due to the symmetry between this particular group of banks. In this case, the pioneering bank creates asymmetry in the market by becoming the only bank capable of offering blockchain-enabled transfers.

Blockchain technology for cross-border transfers establishes a distributed ledger network holding accounts of all financial institutions that joined this network. If the sender’s and the receiver’s banks are both members of this network, then the transfer between them could be made by recording it on the joint ledger without involving any intermediary institutions. Due to this advantage, the price of the cross-border transfer could decrease (advantageous for the customer) compared to a SWIFT transfer, while the bank can charge more due to not sharing any margins with any intermediaries. One such network where banks and financial institutions can subscribe by paying membership fees is Ripple, and this fintech provider also offers its cryptocurrency (XRP) to facilitate transfers (see Figure 3).

Despite these advantages, blockchain is an emerging technology prone to unprecedented errors and lacking governance. Due to the technical setup of blockchain-enabled cross-border payments, any errors that could cause extra cost to the customer would be associated with the blockchain network itself rather than the sender’s and the recipient’s banks specifically. The customers are assumed to be considering these costs, which are denoted with \( r \) in the utility function for blockchain, representing the average percentage cost of systemic errors and lack of governance common to all transfers in the distributed ledger network.

\[ \text{https://ripple.com/solutions/cross-border-payments/} \] [Accessed April 15, 2024]
Blockchain-enabled cross-border transfers offered by Bank 1 will compete with the two SWIFT providers at each segment of $1/N$ (Figure 2) and create a buffer that blocks the competition between the two SWIFT offerings. Specifically, the customers located on the arc of length $1/N$ between Bank 1 and Bank 2 will consider choosing between Bank 1’s SWIFT, Bank 1’s blockchain, and Bank 2’s SWIFT-based services. Similarly, the customers located on the arc of length $1/N$ between Bank 1 and Bank N will consider choosing between Bank 1’s SWIFT, Bank 1’s blockchain, and Bank N’s SWIFT-based services. The utility functions for Bank 1’s SWIFT and Bank 1’s blockchain are denoted with $U_{S1}^{FT}$ and $U_{B1}^{FT}$, respectively. The superscript $FT$ refers to the fintech innovation with blockchain, and the subscripts $S_1$ and $B_1$ refer to whether the utility is for the SWIFT or blockchain-enabled transfers offered by Bank 1, respectively. Similarly, we denote the pricing decisions by Bank 1 for these services with $p_{S1}^{FT}$ and $p_{B1}^{FT}$.

\[ U_{S1}^{FT} = M(1 - p_{S1}^{FT} - dx), \]  
\[ U_{B1}^{FT} = M(1 - p_{B1}^{FT} - r). \]  

(17)  
(18)

Note that Bank 2 and Bank N will continue to offer SWIFT transfers only, and hence their utilities will be the same for the customer. We name this subset consisting of Bank 2 and Bank N as the ‘Neighbour’ subset with a common utility function shown below.

\[ U_{S_{Neighbour}}^{FT} = M(1 - p_{S_{Neighbour}}^{FT} - dx), \quad \text{Neighbour} \in \{2, N\} \]  

(19)
The rest of the banks in the market will be symmetric and continue to offer SWIFT transfers only, with the blockchain-based transfers creating buffers in between as described above. We name this subset consisting of Banks 3, 4, ⋯, Bank \((N - 1)\) as the ‘Generic’ subset with the common utility function shown below.

\[
U^{FT}_{S_{Generic}} = M(1 - p^{FT}_{S_{Generic}} - dx), \quad Generic \in \{3,...,(N - 1)\}
\] (20)

For the fintech innovation model with blockchain, we extend an assumption comparable to Assumption 2 above. Specifically, we posit that there is no undercutting in this model. Thus, blockchain transfers at Bank 1 do not undercut its SWIFT transfers, nor SWIFT transfers by its neighbouring banks; similarly, Bank 1’s SWIFT transfers do not undercut the SWIFT transfers of other banks.

**Assumption 3.** There is no undercutting in the model for fintech innovation with blockchain.

In our stylized model, Assumption 3 is operationalized by evaluating the utility of both SWIFT and blockchain transfers offered by Bank 1 at the locations of its neighbouring banks, ensuring that the utility of the neighbouring bank at its own location surpasses that of Bank 1 at the same location. The methodology for this calculation and its implications are detailed in the Appendix.

The total profit of Bank 1 will be composed of the profits obtained from the SWIFT and blockchain-enabled transfers as presented below. \(\pi^{FT}_1\) denotes the total profit of Bank 1 from both services for the model of fintech innovation with blockchain \((FT)\), \(\pi^{FT}_{S_1}\) denotes the profit obtained from SWIFT transfers, and \(\pi^{FT}_{B_1}\) denotes the profit obtained from blockchain-oriented transfers.

\[
\pi^{FT}_1 = \pi^{FT}_{S_1} + \pi^{FT}_{B_1} \text{ where }
\]

\[
\pi^{FT}_{S_1} = M[(p^{FT}_{S_1} - c) * D^{FT}_{S_1}], \quad \pi^{FT}_{B_1} = M[(p^{FT}_{B_1} - c) * D^{FT}_{B_1}].
\] (22)

Using similar notation, profits for the ‘Neighbour’ and ‘Generic’ banks are shown below.
\[ \pi^{FT}_{S_{Neighbour}} = M[(p^{FT}_{S_{Neighbour}} - c) * D^{FT}_{S_{Neighbour}}], \quad Neighbour \in \{2, N\}. \quad (23) \]

\[ \pi^{FT}_{S_{Generic}} = M[(p^{FT}_{S_{Generic}} - c) * D^{FT}_{S_{Generic}}], \quad Generic \in \{3, \ldots, (N-1)\}. \quad (24) \]

The indifference points that will determine the demand allocation between Bank 1’s SWIFT transfers, Bank 1’s blockchain transfers, and the SWIFT transfers offered by the other banks will be as follows:

\[ U^{FT}_{S_{1}} = U^{FT}_{B_{1}} \implies x^{FT}_{Indifferent_{1}} = \frac{r + p^{FT}_{B_{1}} - p^{FT}_{S_{1}}}{d}, \quad (25) \]

\[ U^{FT}_{S_{Neighbour}} = U^{FT}_{B_{1}} \implies x^{FT}_{Indifferent_{2}} = \frac{r + p^{FT}_{B_{1}} - p^{FT}_{S_{Neighbour}}}{d}, \quad Neighbour \in \{2, N\}, \quad (26) \]

\[ U^{FT}_{S_{Generic}} = U^{FT}_{B_{1}} \implies x^{FT}_{Indifferent_{3}} = \frac{r + p^{FT}_{B_{1}} - p^{FT}_{S_{Generic}}}{d}, \quad Generic \in \{3, \ldots, (N-1)\}. \quad (27) \]

Building on Assumption 3, our model introduces a specific spatial consideration involving indifferent users within each market segment, which corresponds to an arch of \(1/N\). It is crucial that the locations of these indifferent users—those who are equally likely to choose between two competing services—do not overlap or cross within their designated segments. Specifically, the location of the indifferent user between Bank 1’s SWIFT transfers and Bank 1’s blockchain transfers must be positioned lower than the location of the indifferent user between Bank 1’s blockchain transfers and a neighbouring bank’s SWIFT transfers. We formalize this spatial hierarchy with the following assumption:

**Assumption 4.** The locations of indifferent users within an arch of \(1/N\) do not cross each other.

The mathematical formulation of this assumptions and constraint it brings are explained in the Appendix.

Based on these indifference points, the market share of SWIFT transfers for Bank 1, the ‘Neighbour’ banks, and the ‘Generic’ banks are confined to:
\[
D_{S1}^{FT} = 2 * x_{Indifferent1}^{FT} = \frac{2(r + p_{B1}^{FT} - p_{S1}^{FT})}{d}, \tag{28}
\]
\[
D_{SNeighbour}^{FT} = 2 * x_{Indifferent2}^{FT} = \frac{2(r + p_{B1}^{FT} - p_{SNeighbour}^{FT})}{d}, \text{ Neighbour} \in \{2, N\}, \tag{29}
\]
\[
D_{SGeneric}^{FT} = 2 * x_{Indifferent3}^{FT} = \frac{2(r + p_{B1}^{FT} - p_{SGeneric}^{FT})}{d}, \text{ Generic} \in \{3, ..., (N - 1)\}. \tag{30}
\]

The market share for Bank 1’s blockchain transfers will be what is left in the market from the total market share of SWIFT transfers by Bank 1 itself, Bank 2 and Bank N as the ‘Neighbour’ banks, and Banks 3, 4, · · ·, Bank N − 1 as the ‘Generic’ banks. Via Assumption 1, (28), and (29), we express the market share for Bank 1’s blockchain transfers as below.

\[
D_{B1}^{FT} = 1 - D_{S1}^{FT} - 2 * D_{SNeighbour}^{FT} - (N - 3)D_{SGeneric}^{FT} = \frac{d + 2(p_{S1}^{FT} + 2p_{SNeighbour}^{FT} + (N - 3)p_{SGeneric}^{FT} - N(r + p_{B1}^{FT}))}{d} \tag{31}
\]

Substituting the market shares of each bank in their profit functions gives the below formulation for the profit of Bank 1, Bank 2 and Bank N as the ‘Neighbour’ banks, and Banks 3, 4, · · ·, Bank N − 1 as the ‘Generic’ banks as presented below.

\[
\pi_{S1}^{FT} = \frac{2M(p_{S1}^{FT} - c)(r + p_{B1}^{FT} - p_{S1}^{FT})}{d}, \tag{32}
\]
\[
\pi_{B1}^{FT} = \frac{M(p_{B1}^{FT} - c)(d + 2(p_{S1}^{FT} + 2p_{SNeighbour}^{FT} + (N - 3)p_{SGeneric}^{FT} - N(r + p_{B1}^{FT})))}{d}, \tag{33}
\]
\[
\pi_{1}^{FT} = \pi_{S1}^{FT} + \pi_{B1}^{FT} = \frac{M}{d} \left[2(p_{S1}^{FT} - c)(r + p_{B1}^{FT} - p_{S1}^{FT}) \right. \\
+ (p_{B1}^{FT} - c)(d + 2(p_{S1}^{FT} + 2p_{SNeighbour}^{FT} + (N - 3)p_{SGeneric}^{FT} - N(r + p_{B1}^{FT}))), \tag{34}
\]
\[
\pi_{SNeighbour}^{FT} = \frac{2M(p_{SNeighbour}^{FT} - c)(r + p_{B1}^{FT} - p_{SNeighbour}^{FT})}{d}, \text{ Neighbour} \in \{2, N\}, \tag{35}
\]
\[
\pi_{SGeneric}^{FT} = \frac{2M(p_{SGeneric}^{FT} - c)(r + p_{B1}^{FT} - p_{SGeneric}^{FT})}{d}, \text{ Generic} \in \{3, ..., (N - 1)\}. \tag{36}
\]
We now present the optimal commission prices for the SWIFT transfers provided by all banks along with the optimal commission price of blockchain transfers offered by Bank 1. We assume banks make the commission pricing decisions simultaneously. This assumption is motivated by the fact that the decision-makers are institutional players in a highly regulated type of industry. It is not possible to start a fintech innovation as a banking institution without applying for approval from the regulatory bodies. This process would provide the information to the market to allow for simultaneous decision-making in the market with fintech innovation with blockchain.

Similar to the benchmark model (SWIFT only), we derive the pure strategy Nash equilibrium prices as below by maximizing the above profit functions (34), (35), and (36) using the first and second-order conditions:

\[
\begin{align*}
    p^{FT*}_{S1} &= c + \frac{1}{6}(r + \frac{2d}{N-1}), \\
    p^{FT*}_{B1} &= c + \frac{1}{3}\left(\frac{d}{N-1} - r\right), \\
    p^{FT*}_{SNeighbour} &= c + \frac{1}{6}(2r + \frac{d}{N-1}), \\
    p^{FT*}_{SGeneric} &= c + \frac{1}{6}(2r + \frac{d}{N-1}).
\end{align*}
\]

For banks to remain viable within our model, it is vital that the optimal commission prices exceed their marginal costs. This requirement is essential for ensuring that the banks can cover their operational expenses and generate a profit. We formalize this critical economic principle with the following assumption:

**Assumption 5.** The optimal commission prices exceed the marginal cost.

The calculations used to verify this assumption, along with the constraints it imposes, are detailed in the Appendix.

Given the necessary conditions for the existence of equilibrium, \( c < \frac{d}{3-3N} - \frac{2r}{3} + 1 \) and \( \frac{r}{d} < \frac{1}{2+N} \), which is explained in the Appendix, we present the lemma below.
Lemma 2 (Model for Fintech Innovation with Blockchain). In the equilibrium under the model for fintech innovation with blockchain:

(a) SWIFT commission prices charged by the pioneering bank, the subset of ‘Neighbour’ banks, and the subset of ‘Generic’ banks increase in the risk factor of blockchain transfers \(r\), the transportation cost \(d\) for SWIFT transfers, and the marginal percentage cost \(c\), whereas they decrease in total number of banks in the market \(N\).

(b) Blockchain commission price charged by the pioneering bank increase in the transportation cost for SWIFT transfers \(d\) and marginal percentage cost \(c\), whereas it decreases in the risk factor of blockchain transfers \(r\) and total number of banks in the market \(N\).

Similar to the benchmark model, both the SWIFT and the blockchain transfers are economically viable at the equilibrium, and prices are higher than the marginal percentage cost. Hence, the prices increase with the marginal percentage cost. Moreover, the price elasticity for SWIFT commission price decreases as the transportation cost and the risk factor of blockchain transfers increase. However, the price elasticity for blockchain commission price decreases for consumers as the transportation cost increases or the risk factor of blockchain transfers decreases. This shows that the influence of the transportation cost for SWIFT transfers is dominating the pricing strategies of all transfers such that it allows the SWIFT transfers to charge higher prices which in return allows for blockchain transfers to charge more. This is due to SWIFT transfers having a total market share that is higher than the market share of blockchain transfers. However, when the risk factor increases, this enables SWIFT to leverage the disadvantage of its competitor and charge a higher price, while blockchain suffers from this and decreases its price to protect its market share. As anticipated, an increase in market competition—attributable to a higher number of banks—leads to a reduction in commission prices for both SWIFT and blockchain transfers.

Substituting the optimal commission prices in the market share and profit functions above would give the equilibrium market shares and profits for the banks for the fintech innovation with the blockchain model. We present these values below:
User surplus from each bank is derived as follows:

\[
\text{US}_{FT}^{S_1} = 2 \int_0^{x_{Indifferent_1}^{FT}} M (1 - p_{S_1}^{FT} - d \ast x) dx
\]

\[
\text{US}_{FT}^{B_1} = 2 \int_{x_{Indifferent_1}^{FT}}^{x_{Indifferent_2}^{FT}} M (1 - p_{B_1}^{FT} - r) dx + 2(N - 2) \int_{x_{Indifferent_2}^{FT}}^{x_{Indifferent_3}^{FT}} M (1 - p_{B_1}^{FT} - r) dx
\]

\[
\text{US}_{FT}^{S_{Neighbour}} = 2 \int_{x_{Indifferent_2}^{FT}}^{x_{Indifferent_3}^{FT}} M (1 - p_{S_{Neighbour}}^{FT} - d \ast x) dx
\]

\[
\text{US}_{FT}^{S_{Generic}} = 2 \int_{x_{Indifferent_3}^{FT}}^{x_{Indifferent_3}^{FT}} M (1 - p_{S_{Generic}}^{FT} - d \ast x) dx
\]

Total user surplus in the equilibrium is the sum of user surplus from all banks, derived as follows:

\[
\text{US}^{BM} = \text{US}_{FT}^{S_1} + \text{US}_{FT}^{B_1} + 2 \text{US}_{FT}^{S_{Neighbour}} + (N - 3) \text{US}_{FT}^{S_{Generic}}
\]

\[
= - \frac{M (4d(N - 1)((25 - 11N)N - 18)r - 3(c - 1)(5(N - 2)N + 6)) + (N - 1)^2 r (24(c - 1)(N - 2)N)}{36d(N - 1)^2 N} - \frac{M (7(4N - 5)Nr) + d^2((61 - 29N)N - 36))}{36d(N - 1)^2 N}
\]
3.2.1. Comparative Statics

**Lemma 3 (Commission Price Comparison in Fintech Innovation with Blockchain).**

In the equilibrium under fintech innovation with blockchain model:

(a) The optimal SWIFT commission price charged by the pioneering bank is always higher than both the SWIFT commission prices charged by the other banks and the blockchain commission price charged by the pioneering bank itself.

(b) Furthermore, if \( \frac{1}{4(N-1)} < \frac{r}{d} \), the optimal SWIFT commission price charged by each ‘Neighbour’ and ‘Generic’ bank (which are equal to each other, \(39, 40\)) is higher than the optimal blockchain commission price charged by the pioneering bank.

(c) If \( \frac{r}{d} < \frac{1}{4(N-1)} \), the optimal blockchain commission price charged by the pioneering bank is higher than the optimal SWIFT commission price charged by each ‘Neighbour’ and ‘Generic’ bank.

Due to the cannibalization between the SWIFT and blockchain transfers offered by the pioneering bank, this bank always charges the highest price in the market for its SWIFT transfers. Moreover, when the percentage cost of systemic errors for blockchain transfers is relatively high compared to the transportation cost for SWIFT transfers, the pioneering bank charges the lowest price in the market for its blockchain transfers (compared to the prices charged by other banks for SWIFT transfers) to survive in the market. On the other hand, when the percentage cost of systemic errors for blockchain transfers is relatively low compared to the transportation cost for SWIFT transfers, hence the blockchain technology is more reliable, other banks end up charging the lowest price in the market for SWIFT transfers to survive.

**Lemma 4 (Market Share Comparison in Fintech Innovation with Blockchain).** In the equilibrium under fintech innovation with blockchain model:

(a) Market share for blockchain transfers offered by the pioneering bank is always higher than the market share for SWIFT transfers offered by the pioneering bank.

(b) If \( \frac{2N-3}{2N^2+2N-3} < \frac{r}{d} \), Market share for SWIFT transfers offered by each ‘Neighbour’ and ‘Generic’ bank is higher than the market share for blockchain transfers offered by the pioneering bank which
is higher than the market share for SWIFT transfers offered by the pioneering bank.

(c) If \( \frac{r}{d} < \frac{2N-3}{2N^2-N-3} \), Market share for blockchain transfers offered by the pioneering bank is higher than the market share for SWIFT transfers offered by each ‘Neighbour’ and ‘Generic’ bank which is higher than the market share for SWIFT transfers offered by the pioneering bank.

(d) The total market share of the pioneering bank (i.e., market share of SWIFT and blockchain transfers combined) is higher than the market share for SWIFT transfers offered by each ‘Neighbour’ and ‘Generic’ bank.

The introduction of fintech innovation with blockchain disrupts market symmetry, conferring a competitive advantage to the pioneering bank, which subsequently achieves the highest cumulative market share. While blockchain transfers from the pioneering bank cannibalize its own SWIFT transfers, they also capture market share from other banks’ SWIFT transfers. The dynamics between the market shares of other banks’ SWIFT transfers and the pioneering bank’s blockchain transfers hinge critically on the ratio of the percentage cost of systemic errors for blockchain to the transportation cost for SWIFT. A high ratio, indicating greater risk associated with blockchain compared to SWIFT’s transportation costs, results in other banks maintaining a superior market share over the pioneering bank’s blockchain transfers, with the pioneering bank’s SWIFT services attracting the least market share. Conversely, when this ratio is low, suggesting a lower relative risk for blockchain, the pioneering bank’s blockchain transfers tend to dominate, relegating its SWIFT transfers to the lowest market share.

**Lemma 5 (Profit Comparison in Fintech Innovation with Blockchain).** In the equilibrium under fintech innovation with blockchain model:

(a) If \( \frac{2(2N+1)-6\sqrt{N}}{4N^2-5N+1} < \frac{r}{d} \), each ‘Neighbour’ and ‘Generic’ bank has a higher profit than the profit of the pioneering bank from SWIFT transfers which is higher than the profit of the pioneering bank from blockchain transfers.

(b) If \( \frac{4N-3\sqrt{N}-1}{4N^2-6N+2} < \frac{r}{d} < \frac{2(2N+1)-6\sqrt{N}}{4N^2-5N+1} \), each ‘Neighbour’ and ‘Generic’ bank has a higher profit than the profit of the pioneering bank from blockchain transfers which is higher than the profit of
the pioneering bank from SWIFT transfers.

(c) If \( \frac{r}{d} < \frac{4N-3\sqrt{2N-1}+1}{4N^2-8N+2} \), the profit of the pioneering bank from blockchain transfers is higher than the profit of each ‘Neighbour’ and ‘Generic’ bank from SWIFT transfers which is higher than the profit of the pioneering bank from SWIFT transfers.

(d) The total profit of the pioneering bank (i.e., profit from SWIFT and blockchain transfers combined) is always higher than the profit of each ‘Neighbour’ and ‘Generic’ bank from SWIFT transfers.

The introduction of fintech innovation with blockchain guarantees the pioneering bank a higher total profit (profits from SWIFT and blockchain transfers) compared to all other banks in the market. When the competition between the SWIFT and blockchain transfers offered by the pioneering bank is explicitly considered, the competition dynamics are similar to the competition for market shares with different thresholds determining the high, medium, and low levels of the ratio under consideration. The profits of other banks are higher than the profit of the pioneering bank from SWIFT transfers for all levels of this ratio; and the profit of the pioneering bank from blockchain transfers is lowest when this ratio is high (and hence blockchain technology has low reliability), is medium when the ratio is at the medium level, and is highest when the ratio is low (and hence blockchain technology is reliable).

3.3. Comparison of Models

In this analysis, we examine the commission prices, market share, and profitability of banks within the benchmark and fintech models. In the benchmark model, banks are assumed to be symmetric, and are therefore aggregated into a single group referred to as “all banks in the benchmark.” Contrarily, the fintech model introduces differentiation among banks: a pioneering bank distinguishes itself by incorporating blockchain technology as an alternative to the SWIFT transfers used by itself and other banks. This distinction results in three initial categories of banks in the fintech model: the pioneering bank, neighbour banks, and generic banks.
However, within the equilibrium dynamics of the fintech model, the behaviors of generic banks and neighbour banks converge, effectively reducing the model to two distinct bank types. Consequently, our comparative analysis focuses on contrasting all banks in the benchmark model against the pioneering bank and the aggregated group of other banks in the fintech model.

**Proposition 1 (Commission Price Comparison).** *In the fintech innovation model with blockchain, the SWIFT commission prices of both the pioneering bank and other banks are always lower than the SWIFT commission prices of all banks in the benchmark model.*

The model for fintech innovation with blockchain portrays the competition between two technologies (SWIFT vs. blockchain) in the background serving the same purpose with different advantages and disadvantages. In the benchmark model, SWIFT operates in the market as the only technology providing cross-border payments. When a new technology serving the same purpose (blockchain) is introduced to the market, the banks using the existing technology are forced to decrease their prices.

**Proposition 2 (Market Share Comparison).** *By introducing the fintech innovation with blockchain to the market, the pioneering bank is posited to ascend to market leadership, achieving the highest market share ever obtained. On the other hand, all the other banks in the market with fintech innovation have a lower market share compared to their market shares at the benchmark model with SWIFT transfers only.*

The introduction of blockchain technology and the subsequent attainment of equilibrium in a market utilizing this fintech innovation indicate that blockchain has established a sustainable presence within the market. This enables the pioneering bank, which first adopted blockchain, to capture a portion of the market share previously held by other banks. Consequently, this redistribution of market share accounts for why the pioneering bank achieves the highest market share. Moreover, this shift clarifies why each bank in the benchmark model maintains a higher market share than the banks in the fintech model, excluding the pioneering bank. This is partly because, in
the prior model, these banks competed only with SWIFT transfers; however, with the integration of blockchain, the competitive landscape has broadened, introducing additional competition from blockchain transfers as well.

**Proposition 3 (Profit Comparison).** (a) If
\[
\frac{4N-3\sqrt{4N+6}-\frac{4}{N}}{N(4N+5)} < \frac{r}{d},
\]
the profit of each bank in the benchmark model exceeds their counterparts in the fintech model.

(b) If
\[
\frac{r}{d} < \frac{4N-3\sqrt{4N+6}-\frac{4}{N}}{N(4N+5)},
\]
the profit of the pioneering bank in the fintech model, encompassing profits from both its SWIFT and blockchain-enabled transfers, exceeds the profits of each bank in the benchmark model. Furthermore, any bank in the benchmark model commands a higher profit than other banks in the fintech model that do not include the pioneering bank.

Similar to the dynamics observed in market share, the decision by the pioneering bank to introduce blockchain technology into the market adversely affects all other banks in the fintech model, resulting in decreased profitability compared to those in the benchmark model. However, the profitability of adopting blockchain technology is not straightforward. Although the pioneering bank secures the highest market share, for this advantage to translate into profitability surpassing that of the benchmark model, the ratio of the percentage cost of systemic errors for blockchain transfers to the transportation cost for SWIFT transfers must be below a specified threshold.

**Proposition 4 (User Surplus).** User surplus is higher in the model with fintech innovation with blockchain compared to the benchmark model.

The increase in competition and the availability of an alternative to the SWIFT transfer are primary factors contributing to the enhanced user surplus in the model featuring fintech innovation with blockchain. These elements collectively benefit users by providing more choices and potentially lower costs, which are the driving forces behind the superior user surplus observed in the fintech model.

4. Discussion and Conclusion

Our research explores the competitive dynamics between traditional SWIFT transfers and emerging blockchain-enabled transfers for cross-border payments. We identified that while SWIFT remains
a dependable choice, primarily due to its established infrastructure and global reach, blockchain presents a compelling alternative by reducing intermediary involvement and potentially decreasing transaction costs.

The adoption of blockchain could significantly alter the strategic landscape of cross-border payments. Banks adopting this technology may be positioned as pioneers, leveraging the reduced costs to offer more competitive rates to their customers. However, our analysis also highlights the nuanced trade-offs involved. While blockchain reduces certain costs, it introduces new risks and technical complexities, particularly regarding systemic errors and regulatory compliance, which could hinder its adoption and integration into existing financial ecosystems.

From a managerial perspective, the decision to integrate blockchain technology should be carefully considered. Managers need to weigh the potential cost savings and increased market share against the risks associated with new technology adoption. Our study suggests that pioneering banks that adopt blockchain solutions could potentially disrupt existing market structures and capture significant market share, but this comes with the caveat of increased systemic risk and the need for robust governance structures.

Financial institutions should consider developing a phased integration strategy, perhaps by initially implementing blockchain solutions in less risky, smaller-scale operations. Additionally, ongoing investment in technology to mitigate risks and enhance system integration will be crucial.

This study is not without its limitations, which should be addressed in future research. The assumption of homogeneous transaction costs for SWIFT and blockchain transfers may not hold true universally, necessitating more nuanced models that account for variations in technology and implementation strategies. Furthermore, we plan to explore the longitudinal effects of blockchain adoption on market dynamics and customer behavior, including network externalities. As the technology becomes more scalable, the impact of network externalities will increase, and this transitional stage could potentially lead to employing empirical data as blockchain usage matures.

In conclusion, the integration of blockchain into cross-border payment systems represents a significant innovation that could reshape the financial landscape. While promising in reducing costs
and enhancing efficiency, careful consideration of the associated risks and regulatory challenges is imperative. As the technology matures and more data becomes available, ongoing research will be essential to fully understand the implications of blockchain technology in financial markets.

References


Margaroli IC (2023) Swift experiments with blockchain but may need a governance shift URL [https://www.fintechnexus.com/swift-experiments-with-blockchain-but-may-need-a-governance-shift/](https://www.fintechnexus.com/swift-experiments-with-blockchain-but-may-need-a-governance-shift/)
Appendix A: Proof of Benchmark Model (SWIFT Only)

In the Benchmark model, at equilibrium, the first-order conditions are given as:

\[
\frac{\partial \pi^{BM}_{S_i}}{\partial p^{BM}_{S_i}} = 0 \quad \forall i \in \{1, 2, ..., N\}
\]

We then confirm that the second order conditions are satisfied as follows:

\[
\frac{\partial^2 \pi^{BM}_{S_i}}{\partial p^{BM}_{S_i}^2} = -\frac{2M}{d} < 0 \quad \forall i \in \{1, 2, ..., N\}
\]

Appendix B: Proof of Model for Fintech Innovation with Blockchain

In the Fintech model, at equilibrium, the first-order conditions are given as:

\[
\frac{\partial \pi^{FT}_{S_i}}{\partial p^{FT}_{S_i}} = \frac{\partial \pi^{FT}_{1}}{\partial p^{FT}_{S_i}} = \frac{\partial \pi^{FT}_{1}}{\partial p^{FT}_{B_1}} = 0 \quad \forall i \in \{2, ..., N\}
\]

We then confirm that the second order conditions are satisfied as follows:

\[
\frac{\partial^2 \pi^{FT}_{S_i}}{\partial p^{FT}_{S_i}^2} = -\frac{4M}{d} < 0 \quad \frac{\partial^2 \pi^{FT}_{1}}{\partial p^{FT}_{S_i}^2} = -\frac{4MN}{d} < 0 \quad \forall i \in \{2, ..., N\}
\]

\[
det(\text{Hessian}) = \frac{\partial^2 \pi^{FT}_{1} \partial^2 \pi^{FT}_{1}}{\partial p^{FT}_{S_i} \partial p^{FT}_{B_1}} - \left(\frac{\partial^2 \pi^{FT}_{1}}{\partial p^{FT}_{S_i} \partial p^{FT}_{B_1}}\right)^2 = \frac{16M^2(N-1)}{d^2} > 0
\]
Appendix C: Assumptions

C.1. Assumption 1: Market Coverage for both Benchmark and Fintech Innovation with Blockchain Model

To ensure that the utility of the indifferent user at equilibrium remains positive in the Benchmark model, we have identified the following constraint:

\[ U_{S_1}^{BM^*} = M(1 - p_{S_1}^{BM^*} - dx) = M \left( -c - \frac{3d}{2N} + 1 \right) > 0 \implies c + \frac{3d}{2N} < 1 \]

Ensuring that the utility of indifferent users at equilibrium remains positive in the Fintech model, we derive the following constraints:

\[ U_{S_1}^{FT^*} = M(1 - p_{S_1}^{FT^*} - dx) = \frac{1}{3} M \left( -3c - \frac{d}{N-1} - 2r + 3 \right) > 0 \implies c < \frac{d}{3 - 3N} - \frac{2r}{3} + 1 \]

C.2. Assumption 2: No Undercutting in Benchmark Model

In order for Bank 1 to adhere to the non-undercutting principle in relation to its neighbour, it is necessary that at the neighbour’s location, \( x = \frac{1}{N} \), the utility derived from Bank 1’s services must be lower than the utility derived from the neighbour’s services at the same location. We formalize this condition as follows:

\[ U_{S_1}^{BM'} = M(1 - p_{S_1}^{BM'} - dx) = M \left( -c - \frac{2d}{N} + 1 \right), \]
\[ U_{S_{Neighbour}}^{BM'} = M(1 - p_{S_{Neighbour}}^{BM'} - d(\frac{1}{N} - x)) = M \left( -c - \frac{d}{N} + 1 \right) \implies U_{S_1}^{BM'} < U_{S_{Neighbour}}^{BM'} \]

C.3. Assumption 3: No Undercutting in Fintech Model

In order for pioneering bank, Bank 1, to adhere to the non-undercutting principle in relation to its neighbour, it is necessary that at the neighbour’s location, \( x = \frac{1}{N} \), the utility derived from pioneering bank’s both Blockchain and SWIFT services must be lower than the utility derived from the neighbour’s services at the same location. We formalize this condition as follows:

\[ U_{S_1}^{FT'} = M(1 - p_{S_1}^{FT'} - dx) = M \left( -c + \frac{d}{6 - 6N} - \frac{r}{3} + 1 \right), \]
\[ U_{B_1}^{FT'} = M(1 - p_{B_1}^{FT'} - r) = \frac{1}{3} M \left( -3c - \frac{d}{N-1} - 2r + 3 \right), \]
\[ U_{S_{\text{Neighour}}}^{FT'} = M(1 - p_{S_1}^{FT*} - d\left(\frac{1}{N} - x\right)) = M \left( -c + \frac{d}{6 - 6N} - \frac{r}{3} + 1 \right), \]

\[ U_{S_1}^{FT'} < U_{S_{\text{Neighour}}}^{FT'} \implies \frac{r}{d} < \frac{2}{N}. \]

**C.4. Assumption 4: Order of Indifferent Users in Fintech Model**

Within the competitive landscape defined by the pioneering bank and its neighbour, two indifferent user locations delineate the boundaries of the market share attributable to blockchain. For the blockchain service offered by the pioneering bank to maintain a viable market share, the location of the indifferent user between the pioneering bank’s SWIFT and its blockchain service must be situated closer to the pioneering bank than the location of the indifferent user between the neighbour bank’s SWIFT and the pioneering bank’s blockchain service. Similarly, the indifferent user locations between the neighbour bank and a generic bank also need to maintain a specific order: the location of the indifferent user between the neighbour bank and the pioneering bank’s blockchain should precede the location of the indifferent user between the generic bank and the pioneering bank’s blockchain in proximity to the pioneering bank. These spatial relationships are formalized as follows:

\[ x_{\text{Indifferent}_1}^{FT'} = \frac{r + p_{B_1}^{FT*} - p_{S_1}^{FT*}}{d}, \quad x_{\text{Indifferent}_2}^{FT'} = \frac{r + p_{B_1}^{FT*} - p_{S_{\text{Neighour}}}^{FT*}}{d}, \]

\[ x_{\text{Indifferent}_1}^{FT'} < \frac{1}{N} - x_{\text{Indifferent}_2}^{FT'} \implies \frac{r}{d} < \frac{5N - 6}{5N(N - 1)}. \]

\[ x_{\text{Indifferent}_2}^{FT'} = \frac{r + p_{B_1}^{FT*} - p_{S_{\text{Neighour}}}^{FT*}}{d}, \quad x_{\text{Indifferent}_3}^{FT'} = \frac{r + p_{B_1}^{FT*} - p_{S_{\text{Generic}}}^{FT*}}{d}, \]

\[ \frac{1}{N} + x_{\text{Indifferent}_2}^{FT'} < \frac{2}{N} - x_{\text{Indifferent}_3}^{FT'} \implies \frac{r}{d} < \frac{1}{2 + N}. \]

**C.5. Assumption 5: Profitability of Optimal Prices**

For optimal pricing strategies to be both profitable and logical within the Fintech model, they must exceed the marginal percentage cost. We formalize this essential condition as follows:

\[ p_{S_1}^{FT*} = c + \frac{1}{6}(r + \frac{2d}{N - 1}) \implies p_{S_1}^{FT*} > c, \]

\[ p_{B_1}^{FT*} = c + \frac{1}{3}\left(\frac{d}{N - 1} - r\right) > c \implies \frac{r}{d} < \frac{1}{N - 1}, \]

\[ p_{S_{\text{Neighour}}}^{FT*} = c + \frac{1}{6}(2r + \frac{d}{N - 1}) > c \implies p_{S_{\text{Neighour}}}^{FT*} > c, \]

\[ p_{S_{\text{Generic}}}^{FT*} = c + \frac{1}{6}(2r + \frac{d}{N - 1})p_{S_{\text{Generic}}}^{FT*} > c. \]
In summary, the necessary market conditions for ensuring the economic viability of both the Benchmark and Fintech models are delineated as follows:

- For the Benchmark model, the condition stipulated is: \( c + \frac{3d}{2N} < 1 \).

- For the Fintech model, two key conditions must be satisfied: \( c < \frac{d}{3N} - \frac{2r}{3} + 1 \) and \( \frac{r}{d} < \frac{1}{2N} \).