Fintech Entry, Lending Market Competition and Welfare*

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Abstract

In a spatial model of lending competition, we study what drives fintech entry and how it affects competition, stability, and welfare. Depending on the fintech's monitoring efficiency, fintech entry can be blockaded, prevented, or allowed. A fintech with no advantage in monitoring efficiency or funding cost may enter the market if it can price more flexibly than banks. The fintech's lending volume and loan quality will increase if bank concentration is higher. Fintech borrowers are more likely to default than bank borrowers with similar characteristics. An improvement in fintech technology will increase its competitive advantage, causing some banks to exit the market and making the remaining less stable. The welfare effect of fintech entry is ambiguous in general; however, if fintech monitoring efficiency is sufficiently good, then its entry increases social welfare.

JEL Classification: G21, G23, I31

Keywords: digital technology, monitoring, credit, bank restructuring, bank stability, Big Data, price discrimination

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1 Introduction

In recent years one important development in the lending market is that FinTech and BigTech companies are playing an increasingly significant role. In 2019, FinTech and BigTech firms lending volume reached nearly 800 billion USD globally (Cornelli et al., 2020). In emerging and developing markets, BigTech companies have made inroads in lending to small and medium enterprises. For example, in China, Ant Financial and WeBank provide lending to millions of small and medium firms (Frost et al., 2019). In developed economies, FinTech lenders have a relevant penetration. According to the US Federal Reserve's Small Business Credit Survey (2019), almost one third of small and medium firms that sought financing applied with a FinTech firm or online lender, up from 19% in 2016. The annual growth rate of FinTech business lending volume in US was over 40% from 2016 to 2020 (Berg et al., 2021). The COVID-19 pandemic has further stimulated the penetration of FinTech/BigTech firms ("fintech" hereafter for short) because of the surging demand for remote services.

What are the determinants of the entry of fintech lenders? How does fintech entry affect the competition in the lending market and, especially, the behavior of traditional banks? How does fintech entry affect bank stability and social welfare? To answer those questions and to help explain some facts about fintech lending, we build a model of spatial competition in which banks and a fintech compete to provide loans to entrepreneurs. In particular, our model will illuminate the following empirical results:

- Fintechs extend more loans in markets with a less competitive (or more concentrated) banking sector (Claessens et al., 2018; Jagtiani and Lemieux, 2018; Frost et al., 2019; Hau et al., 2021).

- Unanticipated/exogenous bank (branch) closures lead to an increase in fintech market share and quality of their borrowers (Avramidis et al., 2021; Gisbert, 2021).

- Fintech credit can be a complement (Tang, 2019) or a substitute (Gopal and Schnabl, 2022) of bank credit.

- Fintech borrowers are more likely to default than bank borrowers after controlling for observable characteristics (Di Maggio and Yao, 2021; Chava et al., 2021; Beaumont et al., 2021).

- Superior information technology by itself cannot explain the rise of fintech lending (Beaumont et al., 2021).

- Borrowers with better access to bank financing request loans at lower interest rates on a fintech platform (Butler et al. (2017)).

We model the lending market as a circular city à la Salop (1979) where several banks, located equidistantly, and a potential fintech located at the center of the circle compete for entrepreneurs who are distributed along the city. Entrepreneurs can undertake risky investment projects, which may either succeed or fail, but have no initial capital; hence they require funding from lenders. Lenders (banks and the fintech) have no direct access to investment projects, so their profits are derived from offering loans to entrepreneurs. In addition to financing entrepreneurs, another critical function of lenders is monitoring entrepreneurs in order to increase the probability of their projects' success (see e.g. Martinez-Miera and Repullo, 2019 and Vives and Ye, 2021). Monitoring is more costly for a bank if there is more distance between the bank and the monitored entrepreneur. This distance can be physical[1] or in characteristics space from the expertise of the bank on certain sectors or industries.[2] The fintech, however, is located at the center of the circular city and hence is equidistant from all entrepreneurs, which captures the idea that the use of digital technology by a fintech lender makes its monitoring efficiency independent of the physical lender-borrower distance or its expertise on certain sectors or industries.

Banks are incumbents of the lending market, while the fintech is a new entrant. After realizing fintech entry, a bank can choose to leave the market and to recover a salvage value. The remaining banks and the fintech will compete by posting loan rates. The incumbent banks post uniform loan rates first and the fintech moves second posting a discriminatory loan rate schedule based on entrepreneurs' locations. The fintech can price discriminate for two reasons: First, the customer-centric nature and more advanced digital technology of fintech lenders allow them to customize products and implement more effective price discrimination policies (Bofondi and Gobbi, 2017; Navaretti et al., 2018; Vives, 2019). For example, Fuster et al. (2022) find that machine learning model increases the loan rate disparity among different borrowers. Second, existing legal rules are not so effective in reducing the discrimination of algorithm-based credit pricing adopted by fintech lenders.[3] In contrast, technology adoption and transformation to a customer-centric

[1]There is evidence that firm–bank *physical* distance matters for bank lending. See Petersen and Rajan (2002) and Brevoort and Wolken (2009).

[2]Blickle et al. (2021) find that a bank "specializes" by concentrating its lending disproportionately into one industry about which the bank has better knowledge. Paravisini et al. (2021) document that exporters to a given country are more likely to be financed by a bank that has better expertise in the country. Duquerroy et al. (2022) find that in local markets there exist specialized bank branches that concentrate their SME lending on certain industries.

[3]Gillis and Spiess (2019), using a simulation exercise based on real-world credit data, find that the

model are far from successful for banks because of their obsolete legacy systems, rigid internal processes, reliance on human-based decision making, and the need to comply with a myriad of regulations (Stulz, 2019 and Carletti et al., 2020). Therefore we assume that a bank can only offer a uniform loan rate to all entrepreneurs it lends to; we analyze also what would happen if banks could also discriminate in Section 5.

In our baseline model depositors in banks are protected by (fairly priced) deposit insurance and investors in the fintech are not but they can assess the risk position the fintech takes. These assumptions can be relaxed as in Vives and Ye (2021). Our model also admits a reinterpretation in terms of screening in place of monitoring loans.

Under the set-up just described, we study how the emergence of a fintech lender, affects the competition in the lending market and obtain results consistent with available empirical evidence. We find that three types of equilibria may arise depending on the monitoring efficiency of the fintech: blockaded entry, prevented entry, and allowed entry. In the blockaded entry equilibrium, the fintech cannot make any difference to the lending market and hence banks behave as if the fintech threat does not exist; this blockaded entry equilibrium arises when fintech monitoring efficiency is low. If the fintech monitoring efficiency is at an intermediate level, then the prevented entry equilibrium will arise, in which case banks decrease their loan rates to protect their market shares in response to the fintech technology shock; in this prevented entry case, the fintech cannot lend to any entrepreneur because of banks' actions. Finally, if the fintech monitoring efficiency is good enough, then banks will give up preventing fintech entry and hence the fintech can lend to a positive mass of entrepreneurs, giving rise to the allowed entry equilibrium.

Fintech entry will affect banks' decisions about whether or not to leave the market. When fintech entry is not blockaded, the fintech's emergence brings additional competitive pressure to banks and hence reduces their profits. Therefore some bank(s) may leave the market and recover the salvage value as a response to the fintech presence. More banks will leave the market as the fintech's competitive advantage increases, which happens if the fintech (resp. bank) monitoring efficiency is higher (resp. lower) or if banks' funding cost goes up relative to the fintech's.

In the prevented entry equilibrium, the fintech serves no entrepreneurs because of

existing legal rules are not so effective in reducing the discrimination of algorithm-based credit pricing because (a) these rules were developed to regulate human-based decision making and (b) the complexity of machine learning hinders the application of existing law. For example, ECOA forbids race, religion, or age from being considered in credit terms; FHA prohibits discrimination based on race, color, and national origin. Those rules provide little guidance if lenders set credit terms based on machine learning and big data.

banks' actions. Preventing fintech entry will become harder if banks' competitive advantage over the fintech decreases. Hence banks must offer a lower loan rate to protect their market shares if the fintech monitoring efficiency is higher relative to banks or if the banking system has a higher concentration.

When entry is allowed, the fintech enjoys a competitive advantage and hence can lend to entrepreneurs at locations that are far from all banks. At locations where borrowers are closer to banks, the fintech offers lower loan rates, which is in line with Butler et al. (2017) who document that borrowers with better access to bank financing request loans at lower interest rates on a fintech platform. The fintech will have a higher competitive advantage if its monitoring efficiency becomes higher relative to banks, in which case the fintech's market share will increase.

A higher bank concentration will increase the fintech's market share because it will induce less bank presence in the market, and more locations distant from any bank. This finding is consistent with the stylized fact that fintechs extend more loans in markets with a less competitive banking sector (Claessens et al., 2018; Jagtiani and Lemieux, 2018; Frost et al., 2019; Hau et al., 2021).[4] Another consequence of a higher bank concentration is that the fintech will face less competitive pressure from banks and so will raise its overall loan rate, which will increase the fintech's monitoring effort and hence its borrowers' success probability. This result is in line with Avramidis et al. (2021) who find that exogenous bank (branch) closures lead to an increase in the quality of fintech borrowers.

The fintech's exclusive ability to price discriminate contributes to its competitive advantage over banks. When a bank competes with the fintech at a given location, the bank will worry that lowering its loan rate at this location will decrease its lending profit from all other locations. In contrast, the fintech does not have such concerns because of its ability to offer discriminatory loan rates. Consequently, fintech entry can occur even if the fintech has no advantage in monitoring efficiency or funding cost when the fintech can price discriminate while banks cannot. When banks and the fintech have the same funding cost and serve borrowers of similar characteristics, the fintech will offer a lower loan rate and hence exert less monitoring effort than banks. As a result, fintech borrowers

[4] Jagtiani and Lemieux (2018) find that Lending Club's consumer lending tends to penetrate highly concentrated banking markets; Claessens et al. (2018) and Frost et al. (2019) find that the FinTech/BigTech platforms lend more in economies with a more concentrated banking system; Hau et al. (2021) document that Ant Financial extends more credit lines in rural areas of China with less banks; Avramidis et al. (2021) and Gisbert (2021) find that the merger-related bank closing led to an increase in the amount of fintech lending.

have lower success probabilities than bank borrowers who have similar characteristics. This is consistent with empirical evidence documenting that fintech borrowers are more likely to default than bank borrowers after controlling for other observable characteristics (Di Maggio and Yao, 2021; Chava et al., 2021; Beaumont et al., 2021).

If banks can also discriminate, then some results will change. First, fintech entry will not occur if the fintech has no advantage in monitoring efficiency or funding cost. Second, more banks will remain at the market in the allowed entry equilibrium, because banks can make higher lending profits if they can price in a more flexible way in the bank-fintech competition. For the same reason, the fintech's market share will be smaller when banks can also price discriminate.

Fintech entry, when it is prevented or allowed, will also affect bank stability. In the prevented entry case, fintech entry will decrease bank stability for two reasons. First, there is a competition effect: fintech entry increases the competitive pressure faced by banks, which decreases banks' loan rate, monitoring intensity and hence stability. Second, there is a market area effect: fintech entry may decrease the number of banks staying at the market; this will force each bank to serve more distant entrepreneurs who are harder to monitor, hence reducing bank stability. In the allowed entry case, the stability effect of fintech entry is more complex. The competition effect still reduces bank stability as in the prevented entry case. However, the market area effect may improve bank stability because the fintech, when its entry is allowed, will erode the market share of banks, which induces banks to specialize in closer entrepreneurs that are easier to monitor. Our numerical study finds that the competition effect dominates. Therefore, fintech entry decreases bank stability when it is either prevented or allowed.

Finally, we analyze the welfare effect of fintech entry. Fintech entry will bring several competing effects on social welfare. First, there is an option value effect: banks have the option to leave the market and recover their salvage value, which mitigates the negative welfare effect of decreasing banks' lending profit. If fintech entry transfers banks' lending profit to other parties (fintech or entrepreneurs), then social welfare should improve based on this effect. Second, there is a project value effect: the progress of fintech monitoring efficiency will decrease banks' loan rate, which reduces banks' incentive to monitor entrepreneurs and hence hurts social welfare at locations served by banks. However, if fintech entry is allowed, then the progress in fintech monitoring efficiency has an ambiguous effect on the fintech's loan rates, which causes an ambiguous welfare effect at locations served by the fintech. Therefore, the direction of the project value effect is ambiguous in general; it is welfare-reducing if the fintech has a small market share but not otherwise.

Third, there is a cost-saving effect: fintech entry can bring better monitoring technology into the market, which increases the overall monitoring efficiency of the market and hence improves social welfare. Finally, there is a business stealing effect: the fintech can obtain market share by posting low loan rates, even if its monitoring efficiency is not as good as that of banks; hence the fintech always marginally replaces banks' higher profits with its lower fintech profit, which reduces social welfare. The net welfare effect of fintech entry depends on which effect dominates. When fintech entry is prevented, only the option value and the welfare-reducing project value effects exist because the fintech serves no entrepreneurs; the welfare-reducing project value effect will dominate if no or few banks leave market. When fintech entry is allowed, we find that entry improves social welfare when the fintech's monitoring efficiency is sufficiently good relative to that of banks, because then the cost-saving effect is large enough to dominate other effects.

Related literature. Our paper is related to several strands of the literature. First of all, our work belongs to the theoretical research that studies how a new entrant affects lending market competition. Gehrig (1998) builds a model studying how the entry of a new bank affects banks' screening efforts and loan quality; the author finds that under certain conditions the entry of a new bank will decrease banks' screening efforts, and so reduce the quality of the overall loan portfolios. Different from our paper, the Gehrig model exogenously introduces a new bank into the lending market to study the effects brought by the new entrant; in our paper, however, whether or not an entrant can enter is endogenously determined. Another difference is that both the entrant and incumbents in the Gehrig model are banks that have no qualitative difference; in contrast, the new entrant in our model is a fintech which is different from a bank.

He et al. (2020) build a model studying the competition between a bank and a fintech. Their work focuses on how "open banking" – an information sharing mechanism that enables borrowers to share their customer data stored in a bank with a fintech lender – affects the lending competition between a bank who has consumer data, and a fintech who does not have such data. In contrast, our model focuses on what drives fintech entry and what are its consequences.

Avramidis et al. (2021) develop a model of competition between banks and a marketplace lender (which is the entrant); the authors find that the entry of a marketplace lender can absorb unmet credit demand. Our paper differs in that we consider lenders' ability to monitor borrowers, and that we focus on how technology progress affects fintech entry and how the entry affects lending market competition, bank stability and social welfare.

Parlour et al. (2020) study how banks compete with fintechs for payment flows that are useful for assessing borrowers' quality; in that paper (a) banks and fintechs do not directly compete in the loan market, and (b) fintechs cannot strategically set prices for their services because they do not have market power. In our model, banks and the fintech compete in the loan market; and all lenders can strategically choose their loan rates.

Our work builds on Vives and Ye (2021), where we analyze the impact of information technology on bank competition and show that the effects of an information technology improvement on competition, stability and welfare depend on whether or not it weakens the influence of bank–borrower distance on monitoring costs. The modeling of the return and monitoring technology are taken from that paper.

Our paper is also related to the thriving empirical literature on the rise of fintech in lending (see Vives, 2019 and Thakor, 2020 for surveys). To start with, there is considerable evidence showing that fintech lenders can use non-traditional data to participate in the lending market – such as soft information (Iyer et al., 2016), friendships and social networks (Lin et al., 2013), applicants' description text (Dorfleitner et al., 2016; Gao et al., 2018; Netzer et al., 2019), contract terms (Kawai et al., 2014; Hertzberg et al., 2016), and digital footprints (Agarwal et al., 2020; Berg et al., 2020) – to assess the quality of borrowers. Some papers try to explain the rise of fintech lending: Philippon (2016) claims that the existing financial system's inefficiency can explain the emergence of new entrants that bring novel technology to the sector. Buchak et al. (2018) find that regulation arbitrage can explain only a small proportion of the growth of fintech and "shadow" banks in the US mortgage market, whereas technology improvement is responsible for approximately 90% of the gains of fintechs and for 30% of shadow bank growth overall. Beaumont et al. (2021) find that superior information processing technology itself cannot explain the rise of fintech lending. Our model shows that fintech technology is indeed important in determining whether or not fintech entry is allowed; however, the fintech does not need superior monitoring technology to penetrate the market.

Some empirical studies look at the relation between bank lending and fintech credit. Tang (2019) finds that P2P lending is a substitute for bank lending in terms of serving infra-marginal bank borrowers, yet complements bank lending with respect to small loans. Gopal and Schnabl (2022) document that most of the increase in fintech credit substituted for a reduction in lending by banks. Our model finds that fintech entry will decrease banks' market shares, indicating a substitution relation between the fintech and banks; however, if banks have local monopolies, then the fintech will complement banks by lending to those previously underserved borrowers.

Whether or not fintech loans are more risky is an important question in the literature of fintech lending. Fuster et al. (2019) find that there is no evidence indicating that fintech lenders target risky or marginal borrowers. However, Di Maggio and Yao (2021) find that fintech borrowers are more likely to default than bank borrowers after controlling for observable characteristics. Chava et al. (2021) provide similar evidence that consumers who borrow from marketplace lending platforms (MPL) have higher default rates than those borrowing from traditional banks. Our findings are more consistent with the latter two papers.

The rest of our paper proceeds as follows: Section 2 presents the model set-up. In Section 3, we examine how fintech entry affects the type of the equilibrium that obtains in the lending market and causes banks to restructure. Section 4 characterizes the equilibria that may arise. Section 5 analyzes how the properties of equilibria change when banks can also price discriminate. In Section 6, we study how fintech entry affects bank stability, and Section 7 provides a welfare analysis. We conclude in Section 8 with a summary of our findings. Appendix: Proofs presents all the proofs.

2 The model

The economy and players. The economy is represented by a circular "city", of circumference 1, that is inhabited by entrepreneurs and lenders. A point on the circumference represents the characteristics of an entrepreneur (type of project, technology, geographical position, industry, . . .) at this location; two close points mean that the entrepreneurs in those locations are similar. Entrepreneurs' characteristics are uniformly distributed along the city.

The economy has two types of lenders: banks and a fintech firm (called "fintech" hereafter). Banks are located *equidistantly* around the city. If the number of banks is equal to $N \geq 2$ then the arc-distance between two adjacent banks is $1/N$. This assumption means that a bank is closer to some entrepreneurs than to others. For example, banks are specialized in different sectors of the economy (see Paravisini et al., 2021 for export-related lending and Duquerroy et al., 2022 for SME lending). Throughout the paper, we use bank i to denote an arbitrary bank on the circle, and bank $i+1$ to represent the bank that is to the right of and adjacent to bank i. On the arc between banks i and $i+1$, we say that an entrepreneur is located at (location) z_i if the arc-distance between the entrepreneur and bank i is z_i. As a result, the arc-distance between an entrepreneur at z_i and bank $i+1$ is $1/N - z_i$ if the number of banks is N. At each location (e.g., location z_i), there is a mass 1 of entrepreneurs.

Different from banks, the fintech is located at the center of circle and thus equidistant from all entrepreneurs. This assumption captures the idea that the fintech has the same expertise/ability in dealing with all entrepreneurs. In a physical interpretation the fintech connects digitally with entrepreneurs; in a characteristics interpretation, the fintech has a uniform ability to reach entrepreneurs due to its information collection and processing capabilities (big data with AI and machine learning techniques). Figure 1 gives a graphic illustration of the economy.

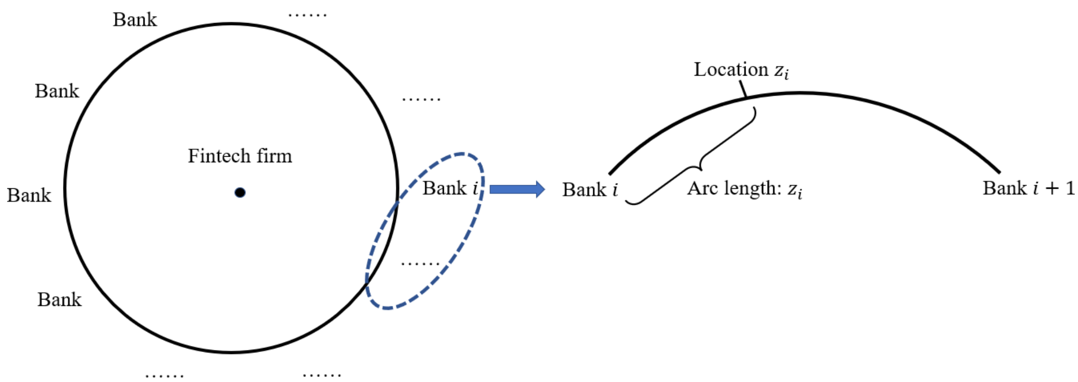

Figure 1: The Economy

A second difference is that fintech lenders, by adopting information technology more rapidly, can price more flexibly than banks. To capture this difference, we assume that a bank must offer a uniform loan rate to all locations it serves; however, the fintech's loan rates can be contingent on entrepreneurs' locations. Specifically, we denote the fintech's loan rate by $r_F(z_i)$ (which is a function of z_i). In Section 5 we allow banks to price discriminate to see how results will change.

Entrepreneurs and monitoring intensity. An entrepreneur has no initial capital but is endowed with a risky investment project that requires a unit of funding. To undertake projects, entrepreneurs require funding from lenders, which can be a bank or the fintech. The investment project of an entrepreneur at z_i yields the following risky return:

$$\tilde{R}(z_i) = \begin{cases} R & \text{with probability } \; m(z_i), \\ 0 & \text{with probability } \; 1 - m(z_i). \end{cases}$$

In case of success (resp. failure), the entrepreneur's investment yields R (resp. 0). The probability of success is $m(z_i) \in [0, 1]$, which represents how intensely the entrepreneur is monitored by the lender that provides the loan; we call $m(z_i)$ the "monitoring intensity" of the lender. More specifically, the project of an entrepreneur (monitored with intensity $m(z_i)$) succeeds if and only if

$$\theta \geq 1 - m(z_i), \tag{1}$$

where θ is a random variable (or say, risk factor) that is uniformly distributed over the interval $[0, 1]$; hence the event $\theta \geq 1 - m(z_i)$ happens exactly with probability $m(z_i)$. The random variable θ is the same across all entrepreneurs; that is, θ is a common risk factor that can be viewed as a measure of economic conditions.

An entrepreneur (at z_i) who borrows from a lender with loan rate r will receive a residual payoff of $R - r$ (resp. 0) from the investment when her project succeeds (resp. fails). If the entrepreneur is monitored with intensity $m(z_i)$, then its expected utility (i.e., profit) is:

$$m(z_i)(R - r); \tag{2}$$

that is, entrepreneurs are risk-neutral and hence care about their expected net return.

The funding costs of lenders. For simplicity, we assume that lenders have no initial capital and therefore must raise funds to finance their loans. Banks raise funds from risk-neutral depositors who are protected by a deposit insurance scheme; whenever bank i cannot fully repay depositors, a deposit insurance fund (DIF) would intervene and ensure that depositors are fully paid. The funding supply of depositors is perfectly elastic when the insured deposit rate is no less than ι_B. In exchange for the DIF's service, bank i must pay a fraction τ_i of its monetary profit to the DIF if the bank is still solvent after paying depositors.[5] We assume that τ_i is fairly determined and so based on bank i's risk (i.e., on bank i's monitoring intensity); this means bank i's expected payment to the DIF is always equal to the DIF's expected payment to depositors no matter how the bank chooses its monitoring intensity for entrepreneurs.

The fintech does not have access to depositors' funding for regulatory reasons; instead, the fintech's funding is from investors who require an expected return ι_F. The monitoring intensity of the fintech is observable to those investors, so the fintech's expected return to a unit of investors' funds is no less than ι_F regardless of how intensely the fintech monitors its entrepreneurs.

Monitoring cost. Non-pecuniary costs will be incurred when lenders monitor en-

[5]If the loan repayment a bank receives from entrepreneurs can cover its promised payment to depositors, then the bank's monetary profit is the loan repayment minus the promised deposit payment; otherwise, the bank's monetary profit is zero.

trepreneurs. Specifically, if a bank monitors an entrepreneur at z_i (on the arc between banks i and $i+1$) with intensity $m(z_i)$, then the (non-pecuniary) monitoring cost the bank needs to incur is:

$$C_B\left(m(z_i), d\right) = \frac{c_B}{2\left(1-qd\right)}(m(z_i))^2,$$

with $c_B > R$, $R \geq \sqrt{2c_B\iota_B}$, $q > 0$ and $d \geq 0$. Variable d is the arc-distance between the bank and the monitored entrepreneur (for bank i /resp. bank $i+1$, $d = z_i$ /resp. $d = 1/N - z_i$). Parameters c_B and q are inverse measures of the efficiency of banks' monitoring technology. Parameter c_B is the slope of marginal monitoring costs when bank-borrower distance $d = 0$ is zero. Parameter q measures the negative effect of bank-borrower distance on banks' monitoring efficiency. The cost function $C_B\left(m(z_i), d\right)$ reflects the fact that a bank must expend more effort to monitor entrepreneurs who are more distant from the bank's expertise or geographic location. The constraint $R \geq \sqrt{2c_B\iota_B}$ must hold to guarantee that banks are willing to provide loans to some entrepreneurs in the market. The constraint $c_B > R$ ensures that a bank's monitoring intensity - which is equal to the success probability of monitored entrepreneurs - is always smaller than 1.

If the fintech monitors an entrepreneur at z_i with intensity $m(z_i)$, then the (non-pecuniary) monitoring cost it incurs is:

$$C_F\left(m(z_i)\right) = \frac{c_F}{2}(m(z_i))^2,$$

where $c_F > R$ is the slope of marginal monitoring costs, which inversely measures the monitoring efficiency of the fintech. Note that $C_F\left(m(z_i)\right)$ is not affected by the location of the monitored entrepreneur for a given $m(z_i)$ as it corresponds to its location at the center of the circle as explained above. The constraint $c_F > R$ ensures that the fintech's monitoring intensity is always smaller than 1.

Interpretation of monitoring. Lenders can collect entrepreneurs' data and assess whether those borrowers are acting appropriately to return their loans – This activity disciplines entrepreneurs and improves their success probability. Monitoring benefits not only lenders but also entrepreneurs; hence we can view it as lenders' expertise-based advising, mentoring or/and information production that is helpful for entrepreneurs. There is evidence that borrowers do value the expertise of lenders. Paravisini et al. (2021) find that an exporter prefers borrowing from a bank with better expertise in the target market. Duquerroy et al. (2022) document that an SME borrows less if its account is reallocated from a branch with expertise in the SME's industry to one without such expertise.

Monitoring relies on lenders' ability to collect and process information about borrowers and it is facilitated by advancements in lenders' information technology, which is represented by c_B and q for banks and c_F for the fintech. Table 1 provides a summary of technology improvements and the corresponding effects on monitoring efficiency in banks and fintech. Banks traditionally have dealt with soft information, which is at the basis of relationship banking. Physical bank-borrower distance impairs relationship banking, but communication technology (like videoconferencing) can facilitate reducing such impairment (i.e., decreasing q in the model). Improvements in processing information (big data, machine learning, or credit scoring) help codify soft information into hard information, which decreases the importance of expertise for banks (i.e., decreases q in the model) and increases the overall monitoring efficiency for both banks and fintechs (i.e., decreases c_B and c_F in the model).[6]

Table 1: Technology Improvements and Monitoring Efficiency.

Improvement of efficiency	Related technology
Decreasing c_B and c_F (improvement in processing information)	AI, ML with big/unconventional data advances in cloud storage and computing, information management software
Decreasing q (physical distance friction) (improvement in communication)	diffusion of internet, video conferencing, smart phone, mobile apps, social media
Decreasing q (expertise friction) (extending competence of human capital/ hardening soft information)	AI, ML with big/unconventional data, credit scoring, remote learning and code sharing

Fintech as a new entrant. Banks are traditional credit providers in the loan market, while fintechs are relatively new and thriving in recent years. In our model we view banks as incumbents and the fintech as a new entrant; this allows us to study (a) the entry condition of the fintech and (b) how the emergence of fintech technology changes the lending market equilibrium.

Timeline. The lending game consists of 4 periods. At $t = 0$, there are $N^0 \geq 3$ banks (incumbents) in the lending market. Those N^0 banks come from a reserve pool of $\overline{N}$ ($> N^0$) potentials banks. The difference between N^0 and $\overline{N}$ is not modeled (it could be because regulatory or other barriers to entry). Throughout the paper, whenever we say N^0 increases (resp. decreases), it means that some banks taken at random from the

[6]In Vives and Ye (2021) we provide a more comprehensive discussion of information technology improvements.

reserve pool enter the market (resp. some banks taken at random from incumbents are taken out) at $t = 0$.

At $t = 1$, there is an unanticipated event that a fintech emerges and can offer loans. At $t = 2$, realizing the potential fintech entry, the incumbent N^0 banks decide whether or not to stay in the market. If bank i chooses to leave the market, it can recover a salvage (liquidation) value of $\lambda(i)L$ $(i = 1, 2, ..., N^0)$. Parameter L measures the general magnitude of salvage values for banks while $\lambda(i)$ varies across different i's, which means that different banks have different salvage values. For convenience, we assume that $\lambda(i)$ is weakly increasing in i. We assume that no matter how many banks enter the market from the reserve pool, $\lambda(N^0)L > 0$ is smaller than the lending profit a bank could earn if there were no fintech technology shock; this assumption implies that no banks would leave the market if the fintech technology was not present. We assume also that $\lambda(2)L$ is sufficiently small such that at least two banks will stay in the market after the fintech technology shock; this assumption guarantees the existence of two adjacent banks (e.g., banks i and $i + 1$) and the arcs between them. The number of banks adjusts from N^0 to N after banks make their "leave-or-stay" decisions at $t = 2$; banks that stay in the market adjust to symmetric locations.

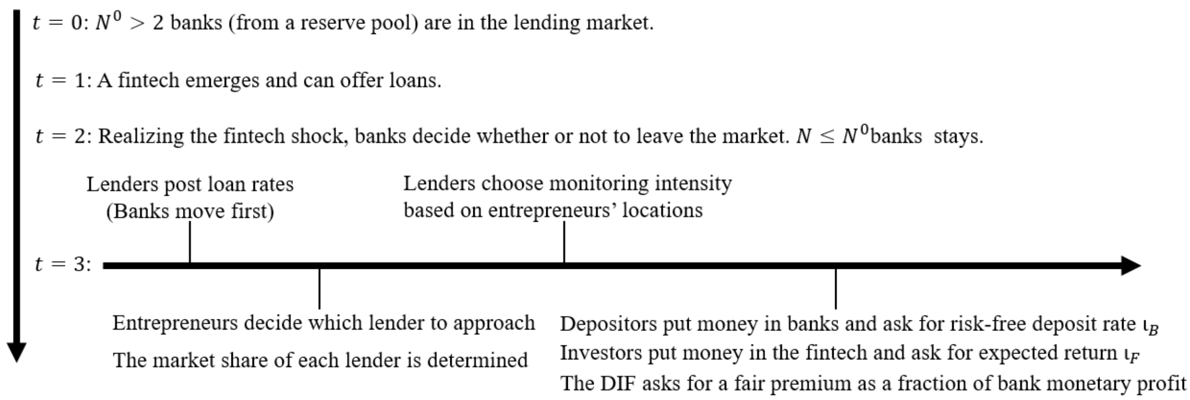

Figure 2: Timeline.

At $t = 3$ lending competition occurs with the following events taking place in sequence. First, lenders (i.e., banks and the fintech) post their loan rates. The incumbent banks post their uniform loan rates first and the fintech moves second posting its discriminatory loan rates after observing banks' loan rates.[7] Second, after lenders' loan rates are chosen and hence observable, entrepreneurs decide which lender to approach for funding.

[7]As in Thisse and Vives (1988) a pure-strategy equilibrium may not exist if a uniform-pricing firm and a price-discriminating one simultaneously post prices.

Given entrepreneurs' decisions and lenders' loan rates, each lender chooses its optimal monitoring intensity as a function of entrepreneurs' locations. A lender can determine its monitoring intensity based on the locations of entrepreneurs for two reasons: First, monitoring is by nature a customized service that relies on collecting and processing borrower-specific information. Second, there is little regulation on how lenders should allocate their monitoring effort among borrowers. After observing the banks' monitoring intensity, the deposit insurance fund determines τ_i (i.e., the fraction of bank's monetary profit that belongs to the DIF) for bank i, ensuring that the deposit insurance is fairly priced. Finally, depositors (resp. investors) put their money into banks (resp. the fintech) and ask for an expected return ι_B (resp. ι_F); investors can observe the fintech's monitoring intensity.

3 Equilibrium regimes

In this section we seek to establish how the fintech technology shock affects lending market equilibrium. We deal with the monitoring choices of the lenders and the decisions of entrepreneurs first, then the different possible equilibrium regimes, and finally the conditions for banks to exit the market.

A standard feature of this class of spatial competition models is that the equilibrium can be fully characterized by assuming that each bank competes only with its neighbors. Hence, it suffices to study the lending competition on the arc between banks i and $i+1$.

3.1 Monitoring intensity and entrepreneurs' decisions

We analyze the equilibrium by backward induction and hence look at lenders' optimal monitoring intensity first.

According to the timeline, an entrepreneur decides which lender to borrow from *before* lenders choose their monitoring intensity. If an entrepreneur at z_i (on the arc between banks i and $i+1$) approaches a bank (say, bank j) whose loan rate is r_B, then the bank's expected profit from financing the entrepreneur can be written as:

$$\pi_B(z_i) \equiv r_B m_B(z_i) - \iota_B - \frac{c_B}{2(1-qd)}(m_B(z_i))^2, \tag{3}$$

where $m_B(z_i)$ is the bank's monitoring intensity at z_i and d is the arc-distance between bank j and location z_i. The first term of $\pi_B(z_i)$ is the expected loan repayment the bank receives from an entrepreneur at z_i, because the entrepreneur repays r_B with probability $m_B(z_i)$.

The second term of $\pi_B(z_i)$ is the bank's expected cost of raising a unit of funding. Because deposits are riskless under the deposit insurance scheme, the bank need only promise a nominal return of ι_B to depositors when raising funds from them. However, the bank can fully repay depositors (and hence stay solvent) only if the total loan repayment it receives from all locations can cover the promised amount to all its depositors. The DIF assumes full repayment to depositors when the bank is insolvent. In exchange for the deposit insurance, the bank must pay the DIF a premium, which is a fraction τ_j of the bank's monetary profit if the bank is still solvent after paying depositors. The DIF fairly determines τ_j such that the bank's expected premium to the DIF exactly equals the DIF's expected payment to the banks' depositors. Therefore, bank's expected cost of raising a unit of funding is ι_B considering its direct payment to depositors and the premium to the DIF.

Finally, the third term represents the non-pecuniary monitoring costs of the bank that monitors the entrepreneur with intensity $m_B(z_i)$.

Reasoning in a similar way, if an entrepreneur at z_i approaches the fintech whose loan rate is $r_F(z_i)$ for this location, then the fintech's expected profit from financing the entrepreneur is:

$$\pi_F(z_i) \equiv r_F(z_i) m_F(z_i) - \iota_F - \frac{c_F}{2}(m_F(z_i))^2,$$

where $m_F(z_i)$ is the fintech's monitoring intensity for entrepreneurs at location z_i. The first term of $\pi_F(z_i)$ is the expected loan repayment the fintech receives from the entrepreneur who repays $r_F(z_i)$ with probability $m_F(z_i)$. The second term of $\pi_F(z_i)$ is the expected cost of raising a unit of funding from investors. The expected funding cost is equal to investors' required expected return ι_F because investors can observe the fintech's risk, which means investors can react according to the fintech's risk to ensure themselves an expected return ι_F. Finally, the third term represents the non-pecuniary monitoring costs of the fintech that monitors the entrepreneur with intensity $m_F(z_i)$.

Taking as given lenders' loan rates and entrepreneurs' decisions, a lender (a bank or the fintech) chooses its monitoring intensity at a location (e.g., location z_i) to maximize its expected profit at this location, which leads to Lemma 1.

Lemma 1. *If a bank's loan rate is r_B, then the bank's optimal monitoring intensity for* *entrepreneurs at* z_i *(on the arc between banks* i *and* $i+1$*) is given by*

$$m_B(z_i) \equiv \frac{r_B}{c_B/(1-qd)},$$

where d *is the arc-distance between the bank and location* z_i*.*

If the fintech offers loan rate $r_F(z_i)$ *to entrepreneurs at location* z_i*, then its optimal monitoring intensity at this location is given by*

$$m_F(z_i) \equiv \frac{r_F(z_i)}{c_F}.$$

According to Lemma 1, a bank's monitoring intensity $m_B(z_i)$ is decreasing in c_B and in q (except if $d = 0$) because in both cases monitoring becomes more costly. Furthermore, $m_B(z_i)$ is decreasing in d because it is more costly for a bank to monitor entrepreneurs that are located farther away from its expertise or geographic location. The slope of the marginal monitoring cost $c_B/(1-qd)$ is an inverse measure of the bank's monitoring efficiency when distance is d. Finally, $m_B(z_i)$ is increasing in the bank's loan rate r_B because a higher r_B implies a larger marginal benefit of increasing entrepreneurs' success probability.

The fintech's monitoring intensity $m_F(z_i)$ is increasing in $r_F(z_i)$ and decreasing in c_F because of similar considerations. The only difference is that for a given loan rate $r_F(z_i)$, the fintech's monitoring intensity $m_F(z_i)$ does not rely on entrepreneurs' locations.

Entrepreneurs' decisions. According to Lemma 1, the monitoring intensities of lenders can be correctly anticipated once their loan rates are observed. An entrepreneur will approach the lender that can provide the highest expected utility after observing the posted loan rates. For example, entrepreneurs at z_i will approach bank j - whose loan rate and (anticipated) monitoring intensity are r_j and $m_j(z_i)$ respectively - for loans if and only if they get the highest expected utility by approaching the bank instead of other lenders:

$$(R - r_j)m_j(z_i) = \max\left\{(R - r_F(z_i))m_F(z_i), (R - r_h)m_h(z_i)\right\}, h = 1, 2, ..., N,$$

where r_h (resp. $m_h(z_i)$) is the loan rate (resp. monitoring intensity) of bank h; $r_F(z_i)$ (resp. $m_F(z_i)$) is the loan rate (resp. monitoring intensity) of the fintech. Both $m_h(z_i)$ and $m_F(z_i)$ follows the rules given in Lemma 1.

Note that increasing a lender's loan rate r at z_i has two competing effects on the expected utility the lender provides at this location: First, the residual payoff $R - r$ will decrease, which reduces entrepreneurs' utility. However, the lender will increase its monitoring intensity, which increases the success probability of entrepreneurs who approach the lender. Therefore, entrepreneurs do not simply choose the lender whose loan rate is lowest. Since a bank's (resp. the fintech's) monitoring intensity is affected by q and c_B (resp. c_F), the monitoring efficiency of lenders is important in determining the expected entrepreneurial utility they can provide.

3.2 Possible equilibria at the lending stage ($t = 3$)

We will discuss three possible cases depending on how the fintech affects the lending market. The following definition presents different types of equilibria depending on the status of fintech entry.

Definition 1. *Fintech entry is* blockaded *if incumbent banks behave as if there is no entry threat. Fintech entry is* prevented *if the fintech does not lend to any entrepreneur because of banks' behavior. Fintech entry is* allowed *if the fintech lends to a positive mass of entrepreneurs.*

In the **blockaded entry case** the fintech cannot make any difference to the lending market and hence banks behave as if the fintech does not exist. Thus banks' pricing strategies are independent of c_F. In the **prevented entry case** banks can prevent the entry of the fintech by modifying their pricing (depending on c_F) to protect their market shares. In the **allowed entry case** banks give up preventing fintech entry and the fintech can lend to a positive mass of entrepreneurs.

We assume that the following inequality holds:

$$\frac{R^2 - 2c_B\iota_B}{qR^2} > \frac{1}{2N^0}. \tag{4}$$

Condition (4) ensures that the arc-distance between two adjacent banks is sufficiently small and banks' monitoring efficiency sufficiently good such that there is effective competition between adjacent banks when fintech entry is blockaded. If Condition (4) does not hold, then (a) there is no effective lending competition in the blockaded entry case and (b) the prevented entry case does not exist because there are entrepreneurs that banks are not willing to compete for. In order to concentrate our analysis on effective lending competition and to ensure the existence of the prevented entry case, throughout the paper we assume Condition (4) holds. The case that Condition (4) does not hold is relegated to Appendix LM.

The following proposition provides the conditions for the three types of equilibria to arise.

Proposition 1. *There exist* $\overline{c}_F$ *and* $\underline{c}_F$ $(< \overline{c}_F)$ *such that:*

(i) If $c_F \geq \overline{c}_F$*, then fintech entry is blockaded; banks' loan rate is denoted by* r_B^{eb}.

(ii) If $\underline{c}_F \leq c_F < \overline{c}_F$*, then fintech entry is prevented; banks' loan rate is* $r_B^{ep} < r_B^{eb}$.

(iii) If $c_F < \underline{c}_F$*, then fintech entry is allowed; banks' loan rate is* $r_B^{ea} < r_B^{eb}$.

According to Proposition 1, which type of equilibrium will arise depends on the monitoring efficiency (i.e., c_F) of the fintech. If the monitoring efficiency of the fintech is low (i.e., if $c_F \geq \overline{c}_F$), borrowing from the fintech implies a low monitoring intensity (i.e., a small a probability of success) for entrepreneurs; hence banks need do nothing to prevent fintech entry; in this case, fintech entry is blockaded. If the monitoring efficiency of the fintech is in an intermediate level (i.e., if $\underline{c}_F \leq c_F < \overline{c}_F$), then the fintech will bring effective competitive pressure to banks; the fintech could attract some entrepreneurs if banks did nothing to respond to the fintech threat. In this case, banks have to decrease their loan rate (from r_B^{eb} to r_B^{ep}) to protect market shares and prevent fintech entry. However, preventing fintech entry is costly for banks because they must decrease the loan rate to the extent that the fintech is not able to attract entrepreneurs at *any* location of the city. Therefore, if the monitoring efficiency of the fintech is sufficiently good (i.e., if $c_F < \underline{c}_F$), banks will allow the fintech to attract entrepreneurs, instead of preventing fintech entry by posting quite low a loan rate. When fintech entry is allowed, banks' loan rate r_B^{ea} is lower than r_B^{eb} because fintech entry increases the competitive pressure faced by banks. Figure 3 graphically illustrates how the equilibrium type and its basic properties are determined by fintech monitoring efficiency.

Figure 3: Fintech Entry and the Type of Equilibrium.

The following corollary provides comparative statics for $\overline{c}_F$ and $\underline{c}_F$.

Corollary 1. *Monitoring efficiency thresholds* $\overline{c}_F$ *and* $\underline{c}_F$ *are increasing in* c_B*,* q *and* ι_B.

As c_B and/or q decrease, the monitoring efficiency of banks increases; hence banks can raise entrepreneurs' success probabilities with lower costs. This efficiency improvement increases banks' ability to provide higher expected utility to entrepreneurs, raising the competitive advantage of banks and hence making it easier for them to maintain the blockaded or prevented fintech entry regime (i.e., making $\overline{c}_F$ and $\underline{c}_F$ lower).

As the funding cost ι_B of banks decreases, the expected profit of a bank at a given location will increase for a given loan rate; this increases the bank's marginal benefit of extending its market share (by reducing its loan rate).[8] As a result, a lower ι_B provides banks with a higher incentive to decrease their loan rates, which increases banks' competitiveness and hence decreases $\overline{c}_F$ and $\underline{c}_F$.

3.3 Bank exit

Since a bank (say bank i) has the option to leave the market and recover the salvage value $\lambda(i)L$ at $t = 2$, we can expect that fintech entry will affect the number of banks N unless blockaded. The following proposition shows that bank exit will occur when fintech technology is good enough.

Proposition 2. *If $L > 0$, then there exists $c_F^0 < \overline{c}_F$ such that $N^0 = N$ (resp. $N^0 > N$) holds if and only if $c_F \geq c_F^0$ (resp. $c_F < c_F^0$).*

If $L = 0$, leaving the market will bring a bank zero salvage value, so all banks will choose to stay in the market, leading to $N = N^0$.

Consider the case $L > 0$. Because of the assumption that no bank will leave the market if there is no fintech technology shock, $N^0 = N$ must hold if fintech entry is blockaded (i.e., if $c_F \geq \overline{c}_F$). If fintech entry is prevented or allowed, then banks will face additional competitive pressure from the fintech. Such competitive pressure is stronger if the fintech monitoring efficiency is higher (i.e., if c_F is lower); that is, a bank's profit is increasing in c_F for a given N. When c_F is sufficiently low (i.e., when $c_F < c_F^0$ holds), some bank(s) will find it optimal to leave the market and recover the salvage value(s), in which case N is smaller than N^0. Panel 2 of Figure 6 illustrates how fintech entry affect the number of banks N.

The following corollary shows how the number of banks N at $t = 3$ is affected by relevant parameters.

[8] The marginal cost of decreasing the loan rate of the bank is that it will reduce its profits from all served locations.

Corollary 2. *If $L > 0$ and $c_F < c_F^0$, then the number of banks N is weakly decreasing in c_B, q, ι_B and L, and weakly increasing in c_F.*

Since the number of banks is an integer, the effect of a parameter change on N is discontinuous. Therefore in Corollary 2 the number of banks N is only "weakly", rather than "strictly", affected by a parameter change.

If a parameter change decreases bank profit at $t = 3$, then weakly more banks will leave the market at $t = 2$, leading to a weakly smaller N. When fintech entry is prevented or allowed, a higher c_B, q or ι_B will increase the monitoring or funding costs of banks and so decrease their competitive advantage over the fintech, which reduces a bank's profit for a given N. Consequently, the number of banks will weakly decrease as c_B, q or ι_B increases.

A higher c_F will decrease the monitoring efficiency and hence the competitive advantage of the fintech. Therefore, an increase in c_F will raise a bank's lending profit (for a given N) when fintech entry is not blockaded, leading to a weakly higher N.

The effect of L is relatively simple. A higher L increases the value of a bank's option to leave the market. Therefore, the threat of fintech entry will induce (weakly) more banks to leave the market as L increases.

Taking some bank(s) out of (or adding more bank(s) into) the lending market at $t = 0$ will also affect the the number of banks finally staying in the market after realizing the fintech threat, which is characterized by the following proposition.

Proposition 3. *The number of banks N is weakly increasing in N^0 (that is, weakly more (resp. less) banks will stay in the market after realizing the fintech threat if some banks taken at random from the reserve pool enter the market (resp. some banks taken at random from incumbents in the market are taken out) at $t = 0$).*

Two cases may arise if some new banks (taken at random from the reserve pool) enter the market. If (all of) the new banks have quite high salvage values, then adding them to the market will not affect N. The reason is that adding banks (with high salvage values) to the market will not decrease the number of banks with sufficiently low salvage values. Banks staying in the market before new banks' entry will still stay after that, while the other banks (including the new ones) will exit because they do not have sufficiently low salvage values. If (some of) the new banks have quite low salvage values, then N will weakly increase. The reason is that the entry of new banks with quite low salvage values potentially enlarges the group of banks who have sufficiently low salvage values and hence are willing to stay. Overall, adding banks into the market will never decrease the number of banks staying in the market, while may increase it sometimes.[9]

Reasoning symmetrically, taking out incumbent banks at random will not affect N if the banks taken out have quite high salvage values while those with sufficiently low salvage values are not affected. However, if banks with sufficiently low salvage values are taken out, then N will weakly decrease.

4 Characterizing equilibria

In the section we characterize the three types of equilibria that may arise depending on the monitoring efficiency of the fintech.

4.1 Fintech entry is blockaded

First we look at the case that fintech entry is blockaded (i.e., when $c_F \geq \overline{c}_F$). The following proposition provides the basic properties of the equilibrium in this case.

Proposition 4. *In the blockaded entry equilibrium, $N = N^0$; banks' loan rate r_B^{eb} is smaller than R. On the arc between banks i and $i+1$, bank i (resp. bank $i+1$) serves locations $z_i \in [0, 1/(2N^0)]$ (resp. $z_i \in (1/(2N^0), 1/(N^0)]$).*

In the blockaded entry case, the fintech technology puts no threat on banks and no banks will leave the market, so $N = N^0$. Since a bank's monitoring efficiency is decreasing in bank-borrower distance, in equilibrium each bank will serve the market area in which it has better monitoring efficiency than rival banks (e.g., bank i will specialize in entrepreneurs at $z_i \in [0, 1/(2N^0)]$).

Banks' loan rate r_B^{eb} is smaller than R because Condition (4) ensures that there is effective competition between adjacent banks. If Condition (4) does not hold, then a "local monopoly equilibrium" will arise, in which case a bank will set its loan rate to R to extract the entire value of a financed project, leaving zero profit to entrepreneurs. The local monopoly blockaded entry equilibrium is discussed in Appendix LM.

[9] Even if the newly added banks have quite low salvage values, the number of banks finally staying in the market will increase only *weakly*, rather than *strictly*. The reason is that a bank that is willing to stay before new banks' entry may exit if the number of remaining banks N increases. Such a bank will be crowed out if a new bank with low salvage value enters the market, in which case N remains the same.

4.2 Fintech entry is prevented

In this section we look at the prevented entry case (i.e., with $\underline{c}_F \leq c_F < \overline{c}_F$). Then banks can no longer ignore the threat of the fintech. The competitiveness of the fintech is reflected by the entrepreneurial utility it can provide, which is characterized in the following lemma.

Lemma 2. *At any location, the fintech's loan rate that maximizes entrepreneurs' expected utility is given by*

$$\overline{r}_F \equiv \max\left\{\frac{R}{2}, \sqrt{2c_F\iota_F}\right\},$$

which implies the following utility for an entrepreneur:

$$\overline{U}_F \equiv \underbrace{\frac{\overline{r}_F}{c_F}}_{\textit{monitoring intensity}} \times \underbrace{(R-\overline{r}_F)}_{\textit{return from success}}.$$

*We call $\overline{r}_F$ the "**best loan rate**" of the fintech.*

We can best explain Lemma 2 by proving it here. The expected utility of an entrepreneur at z_i is equal to

$$U_F(z_i) \equiv m_F(z_i)(R - r_F(z_i))$$

if she approaches the fintech whose loan rate (resp. monitoring intensity) is $r_F(z_i)$ (resp. $m_F(z_i)$). By Lemma 1, we know $m_F(z_i) = r_F(z_i)/c_F$; hence if the fintech maximizes $U_F(z_i)$ by choosing $r_F(z_i)$, the resulting loan rate is exactly $R/2$. However, $R/2$ may not be feasible for the fintech because the fintech must ensure that its expected profit from serving location z_i is non-negative. The non-negative profit requirement implies the following condition:

$$\pi_F(z_i) = r_F(z_i)\, m_F(z_i) - \iota_F - \frac{c_F}{2}(m_F(z_i))^2 \geq 0,$$

which is equivalent to $r_F(z_i) \geq \sqrt{2c_F\iota_F}$. Hence the feasible fintech loan rate that maximizes entrepreneurs' utility is $\overline{r}_F$; the corresponding maximum entrepreneurial utility is $\overline{U}_F$. Note that $\overline{U}_F$ is not a function of z_i because the fintech is equidistant from all locations.

The following proposition provides the basic properties of the prevented entry equilibrium.

Proposition 5. *When fintech entry is prevented, bank i (resp. bank $i+1$) serves locations $z_i \in [0, 1/2N]$ (resp. $z_i \in (1/2N, 1/N]$) on the arc between banks i and $i+1$. In this equilibrium, the expected utility of an entrepreneur at $z_i = 1/(2N)$ is equal to $\overline{U}_F$, that is:*

$$\frac{r_B^{ep}(1 - \frac{q}{2N})(R - r_B^{ep})}{c_B} = \overline{U}_F, \tag{5}$$

where r_B^{ep} is banks' loan rate in the prevented entry equilibrium.

In the prevented entry equilibrium, the lending market is served only by banks. Since a bank's monitoring efficiency is decreasing in bank-borrower distance, in equilibrium each bank will serve the market area in which it has better monitoring efficiency than rival banks (e.g., bank i will specialize in entrepreneurs at $z_i \in [0, 1/(2N)]$).

Although the fintech does not serve any entrepreneur in such an equilibrium, it does affect banks' behavior. For a given banks' loan rate r_B^{ep}, entrepreneurial utility is lowest when bank-borrower distance reaches the maximum value $1/(2N)$ (e.g., at location $z_i = 1/(2N)$). To successfully prevent the fintech from serving any entrepreneurs, r_B^{ep} must be sufficiently low such that the entrepreneurial utility provided by banks is at least $\overline{U}_F$ even if bank-borrower distance is $1/(2N)$, which implies Equation (5).

The following proposition provides the comparative statics of banks' loan rate r_B^{ep} in the prevented entry case.

Proposition 6. *In the prevented entry equilibrium, banks' loan rate r_B^{ep} is increasing in c_F, decreasing in c_B and q, weakly increasing in N^0 and weakly decreasing in ι_B and L.*

First we look at the effect of L. According to Corollary 2, a higher L will weakly decrease the number of banks N. As N decreases, the maximum bank-borrower distance (i.e., $1/(2N)$) will increase in the prevented entry equilibrium, which makes it harder for banks to prevent fintech entry because a bank's monitoring efficiency is decreasing in bank-borrower distance. To successfully prevent fintech entry, banks must decrease their loan rate r_B^{ep}, ensuring that Equation (5) holds. The intuition underlying the effect of L also applies to the effect of N^0. Increasing N^0 will weakly raise banks' loan rate because it weakly increases N (Proposition 3).

Increasing c_F has two effects. First, the direct effect is that monitoring becomes more costly for the fintech; this outcome reduces the fintech's competitiveness and hence allows banks to prevent fintech entry with a higher r_B^{ep}. Second, there is an indirect effect that weakly increases N (Corollary 2); a higher N will decrease the maximum bank-borrower distance (i.e., $1/(2N)$) in the prevented entry equilibrium, making it easier for banks to prevent fintech entry. The direct and indirect effects work in the same direction, so r_B^{ep} is increasing in c_F. Panel 1 of Figure 6 gives a graphic illustration.

Reasoning in the same way, a higher c_B and/or q will reduce the competitive advantage of banks. Meanwhile N will (weakly) decrease as c_B and/or q increase. Both effects cause banks to decrease their loan rate to prevent fintech entry.

Increasing ι_B has no direct effect on r_B^{ep} according to Equation (5). However, a higher ι_B implies a weakly lower N (Corollary 2). If N decreases, r_B^{ep} must also decrease based on our analysis above. Hence r_B^{ep} is weakly decreasing in ι_B.

In the prevented entry equilibrium, the N banks serve the entire lending market, so the market share of a bank is simply $1/N$, which can also be viewed as the concentration of the banking sector. The following corollary characterizes the market share of a bank in such an equilibrium.

Corollary 3. *In the prevented entry equilibrium, a bank's market share* $1/N$ *is weakly decreasing in* c_F *and* N^0*, while weakly increasing in* c_B*,* q*,* ι_B *and* L*.*

In the prevented entry equilibrium a bank's market share will increase if N becomes smaller, which can happen when c_F and N^0 are lower or when c_B, q, ι_B and L are higher. The implication of Corollary 3 is that an increased threat of fintech entry (e.g with lower c_F) will increase bank concentration in the prevented entry case, although the profitability of the banking sector decreases. Table 2 summarizes the comparative statics result when fintech entry is prevented.

Table 2: Summary of Comparative Statics When Fintech Entry is Prevented

	q	c_B	c_F	ι_B	L	N^0
A bank's market share ($1/N$)	↑	↑	↓	↑	↑	↓
Banks' loan rate	↓	↓	↑	↓	↓	↑

This table summarizes how endogenous variables (in the first column) is affected by parameters (in the first row) when fintech entry is prevented. "↑" (resp. "↓") means an endogenous variable is increasing or weakly increasing (resp. decreasing or weakly decreasing) in the corresponding parameter.

4.3 Fintech entry is allowed

Next we look at the equilibrium where fintech entry is allowed (i.e., the case $c_F < \underline{c}_F$). Before proceeding we assume that the following inequality holds for the rest of the paper:

$$\overline{U}_F < \frac{\overline{r}_B(0)(R - \overline{r}_B(0))}{c_B}, \tag{6}$$

where $\overline{r}_B(0) \equiv max\{\frac{R}{2}, \sqrt{2c_B\iota_B}\}$ is a bank's "best loan rate" at zero distance; that is, the bank's loan rate that maximizes the entrepreneurial utility when bank-borrower distance is zero (a similar concept is the fintech's best loan rate, Lemma 2). A bank's best loan rate at general distance d will be characterized in Lemma 4 (Section 5).

Condition (6) implies that bank i can provide entrepreneurs with higher expected utility at $z_i = 0$ than the fintech, which ensures that banks still have positive market shares after fintech entry. If Condition (6) does not hold, then the fintech will completely drive banks out of the market. In reality, the banking sector still plays an important role in the lending market, so we focus on the more interesting and realistic case that fintech entry does not drive out banks.

Proposition 7 characterizes the allowed entry equilibrium.

Proposition 7. *In the allowed entry case (i.e., if $c_F < \underline{c}_F$), there exists an $x^{ea} \in (0, 1/(2N))$ such that the fintech serves entrepreneurs at $z_i \in [x^{ea}, 1/N - x^{ea}]$ on the arc between banks i and i_{+1}, while bank i (resp. bank i_{+1}) serves entrepreneurs at $z_i \in [0, x^{ea})$ (resp. $z_i \in (1/N - x^{ea}, 1/N]$).*

A banks' monitoring efficiency is decreasing in bank-borrower distance, while the fintech's monitoring efficiency is the same for all locations. The fintech thus has a competitive advantage at locations where entrepreneurs are distant from all banks when the entry is allowed. Specifically, on the arc between banks i and $i+1$ the fintech serves entrepreneurs in the middle region (i.e., at $z_i \in [x^{ea}, 1/N - x^{ea}]$) where entrepreneurs are far away from both banks i and $i+1$, while bank i (resp. bank $i+1$) attracts its nearby entrepreneurs at $z_i \in [0, x^{ea})$ (resp. $z_i \in (1/N - x^{ea}, 1/N]$). The point $z_i = x^{ea}$ (resp. $z_i = 1/N - x^{ea}$) is the "indifference location" where approaching bank i (resp. bank $i+1$) for a loan brings the same utility to an entrepreneur as approaching the fintech does. Figure 4 graphically illustrates the three regions served respectively by the fintech and banks i and $i+1$.

Note that the interaction between adjacent banks is cut off when fintech entry is allowed. Specifically, bank i (resp. bank $i+1$) competes with the fintech at $z_i \in [0, 1/(2N)]$

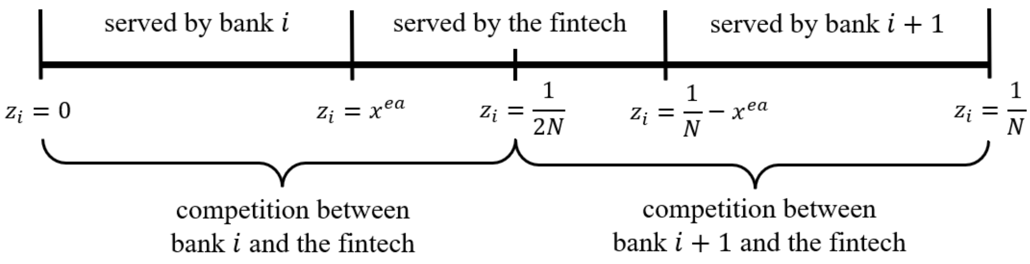

Figure 4: Competition on the Arc between Banks i and $i+1$ (Entry Allowed).

(resp. $z_i \in (1/(2N), 1/N])$ on the arc between banks i and $i+1$; in contrast, bank i no longer faces competitive pressure from bank $i+1$ because the expected entrepreneurial utility provided by the latter bank must be lower than $\overline{U}_F$ at $z_i \in [0, 1/(2N)]$ if the fintech can attract entrepreneurs at $z_i \in [x^{ea}, 1/N - x^{ea}]$.

The following corollary describes how the fintech's loan rate $r_F(z_i)$ varies with location z_i.

Corollary 4. *In the allowed entry case, the fintech's loan rate at z_i, $r_F(z_i)$, is increasing (resp. decreasing) in z_i if $z_i \in [x^{ea}, 1/(2N)]$ (resp. $z_i \in (1/(2N), 1/N - x^{ea}]$) on the arc between banks i and $i+1$. At the indifference location $z_i = x^{ea}$ (or $z_i = 1/N - x^{ea}$), $r_F(z_i) = \overline{r}_F$.*

We focus on the region $[x^{ea}, 1/(2N)]$ when explaining the corollary. In this region, the fintech need only consider the threat of bank i because bank $i+1$ is less attractive than bank i from the perspective of entrepreneurs. As z_i increases in $[x^{ea}, 1/(2N)]$, the utility an entrepreneur can derive by approaching bank i will decrease because the bank's monitoring efficiency becomes lower; hence the fintech's competitive advantage will increase, which allows the fintech to raise $r_F(z_i)$. The fintech cannot attract entrepreneurs at $z_i \in [0, x^{ea})$ because its loan rate has reached $\overline{r}_F$ – the lower bound of the fintech's loan rate – at the indifference location $z_i = x^{ea}$.[10] Note that $r_F(z_i)$ reaches its maximum at $z_i = 1/(2N)$ where the fintech's competitive advantage over the banks i and $i+1$ is highest (see Figure 5). Corollary 4 is consistent with Butler et al. (2017) who find that borrowers with better access to bank financing can request loans at lower interest rates on a fintech platform.

What makes fintech entry allowed? Proposition 8 sheds lights on the question.

[10] Reasoning symmetrically, as z_i increases in the region $(1/(2N), 1/N - x^{ea}]$, the fintech's competitive advantage (over bank $i+1$) will decrease, which forces the fintech to reduce $r_F(z_i)$. At the indifference location $z_i = 1/N - x^{ea}$, $r_F(z_i)$ reaches its lower bound $\overline{r}_F$, so the fintech has to give up entrepreneurs in $(1/N - x^{ea}, 1/N]$.

Proposition 8. *In the allowed entry case, if $\iota_B = \iota_F$, then the following inequalities hold:*

$$\frac{c_B}{1 - qx^{ea}} < c_F \text{ and } r_B^{ea} > r_F(x^{ea}).$$

The condition $\iota_B = \iota_F$ means no lender has advantage in funding cost. Under this condition, the inequality $c_B/(1 - qx^{ea}) < c_F$ in Proposition 8 is equivalent to $C_B(m, x^{ea}) < C_F(m)$ for a given m; this implies that the fintech's market share does not solely result from the fintech's superior monitoring technology, because at the indifference location $z_i = x^{ea}$ it is bank i that has better monitoring efficiency.

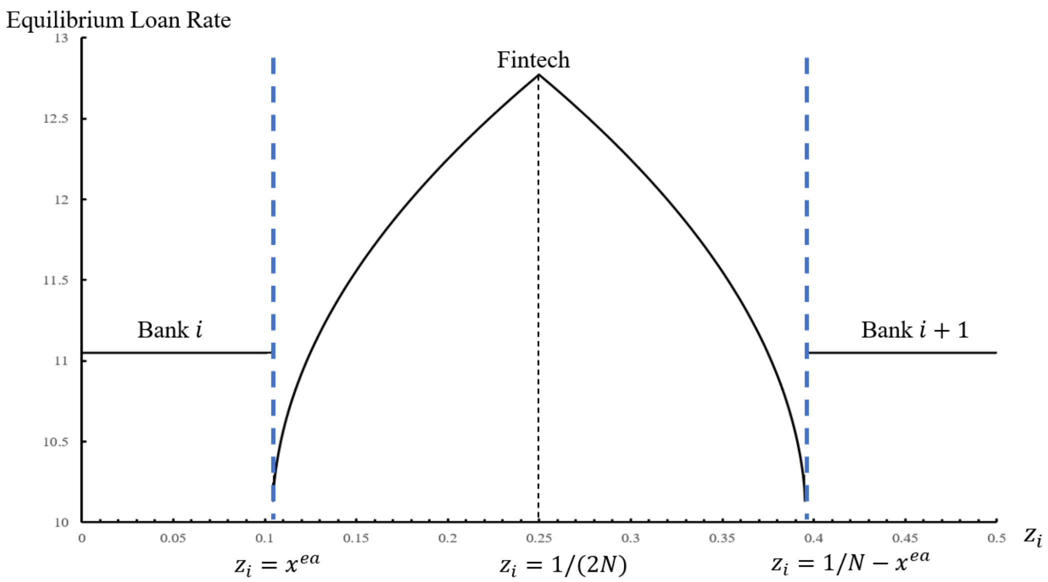

Figure 5: Equilibrium Loan Rates on the Arc between Banks i and $i+1$ (Entry Allowed). This figure plots the equilibrium loan rate against the entrepreneurial location on the arc between banks i and $i+1$ when fintech entry is allowed. The fintech can price discriminate but banks cannot. The parameter values are $R = 20$, $\iota_B = \iota_F = 1$, $c_B = 30$, $c_F = 32$, $q = 0.5$, $N^0 = N = 2$, $L = 0$.

Proposition 8 follows because the fintech can price discriminate, while banks cannot. When the fintech competes with bank i for entrepreneurs at z_i, the fintech's loan rate $r_F(z_i)$ can range from R to $\overline{r}_F$ depending on the competitiveness of the bank, because the fintech need not worry that a lower $r_F(z_i)$ would hurt its profits from other locations. As a consequence, the fintech will offer its best loan rate (i.e., $\overline{r}_F$) at the indifference location $z_i = x^{ea}$. In contrast, bank i must consider that decreasing r_B^{ea} will reduce its profits from all locations it serves. Therefore, at the indifference location bank i still maintains a relatively high loan rate compared with the best loan rate of the fintech, which is reflected by the inequality $r_B^{ea} > r_F(x^{ea})$. Entrepreneurs at $z_i = x^{ea}$ are indifferent between bank i

and the fintech because the bank has superior monitoring efficiency, which implies higher monitoring intensity and hence success probability, while the fintech offers a lower loan rate at this location.

Figure 5 graphically shows how the equilibrium loan rate varies with locations on the arc between banks i and $i+1$ when fintech entry is allowed and $\iota_B = \iota_F$ holds. In the region served by banks, the equilibrium loan rate is the same for all locations because banks cannot discriminate. At indifference locations, banks' loan rate is higher than the fintech's for the reason explained after Proposition 8.

Since bank i has both a higher loan rate and better monitoring efficiency at the indifference location $z_i = x^{ea}$, the monitoring intensity of bank i must be higher than that of the fintech at this location; that is:

$$m_B(x^{ea}) = \frac{r_B^{ea}(1 - qx^{ea})}{c_B} > m_F(x^{ea}) = \frac{r_F(x^{ea})}{c_F}, \tag{7}$$

where $m_B(x^{ea})$ (resp. $m_F(x^{ea})$) is bank i's (resp. the fintech's) monitoring intensity at $z_i = x^{ea}$ according to Lemma 1. Around the indifference location $z_i = x^{ea}$, bank borrowers and fintech borrowers have similar characteristics because their locations are almost the same; hence Inequality (7) implies that bank borrowers have higher success probabilities than fintech borrowers who have similar characteristics. This result is consistent with Di Maggio and Yao (2021) who find that fintech borrowers are more likely to default than bank borrowers after controlling for observable characteristics.[11] Proposition 8 directly leads to the following corollary, which shows how the fintech's ability to price discriminate facilitates fintech entry.

Corollary 5. *Fintech entry can be allowed even if the fintech has no advantage in either monitoring efficiency or funding cost (i.e., even if both* $\frac{c_B}{1-\frac{1}{2N}q} < c_F$ *and* $\iota_B < \iota_F$ *hold).*

For simplicity we focus on the arc between banks i and $i+1$ when explaining the result. Note that $\frac{c_B}{1-\frac{1}{2N}q}$ inversely measures bank i's (or bank $i+1$'s) monitoring efficiency at the mid location $z_i = 1/(2N)$, which is the place that the fintech will penetrate first when its entry is allowed (note that in the limiting case $x^{ea} \to 1/(2N)$, the fintech serves only entrepreneurs at $z_i = 1/(2N)$). Therefore, Corollary 5 states that the fintech can attract

[11] Chava et al. (2021) provide a similar evidence that consumers who borrow from marketplace lending platforms (MPL) have higher default rates than those borrowing from traditional banks. Beaumont et al. (2021) also document that fintech borrowers are more likely than bank borrowers to enter a bankruptcy procedure.

entrepreneurs at $z_i = 1/(2N)$ even if its monitoring efficiency (resp. funding cost) is lower (resp. higher) than that of banks i and $i+1$ at this location.

The intuition for the result directly follows that of Proposition 8. The discrimination ability of the fintech allows it to offer its best loan rate $\overline{r}_F$ to penetrate the lending market, but banks cannot offer too low a loan rate to prevent fintech entry. Therefore, the fintech's ability to discriminate is a competitive advantage that can potentially compensate for the fintech's disadvantage in monitoring efficiency or funding cost.

Comparative statics when fintech entry is allowed. First, we look at how x^{ea}, which measures a bank's market share, varies with different parameters.

Proposition 9. *In the allowed entry case, bank i's market share (measured by x^{ea}) is decreasing in c_B, q and ι_B, increasing in c_F, and independent of N^0 and L.*

As c_F increases, monitoring becomes more costly for the fintech, so the maximum utility it can provide to entrepreneurs will decrease (i.e., $\overline{U}_F$ will decrease. See Lemma 2). In other words, the fintech's competitive advantage will decrease as c_F increases. Consequently, bank i can maintain a higher market share when c_F is higher. Reasoning symmetrically, as c_B, q and/or ι_B increase, monitoring and/or funding will become more costly for banks, which decreases banks' competitiveness in the bank-fintech competition; hence bank i's market share will shrink.

As L or N^0 changes, the number of banks N will be weakly affected (Corollary 2 and Proposition 3). If N decreases, the arc-distance between two adjacent banks will increase. However, the competitiveness of the fintech is determined by $\overline{U}_F$, which does not vary with location z_i, so the competitive advantage of a bank (e.g., bank i) over the fintech will not be affected by the distance between banks i and $i+1$. As a result, in the allowed entry equilibrium x^{ea} will not change even if N is affected by L or N^0.

Although x^{ea} (i.e., the market share of a bank) is not affected by L or N^0, the fintech's market share, which is measured by $1 - Nx^{ea}$, will be affected as N varies with L and N^0, leading to the following corollary.

Corollary 6. *In the allowed entry case, the fintech's market share (measured by $1-Nx^{ea}$) is increasing in c_B, q and ι_B, decreasing in c_F, weakly decreasing in N^0, and weakly increasing in L.*

A decrease in N^0 (or an increase in L) has no effect on x^{ea} but will weakly decrease N, which weakly increases the arc-distance between two adjacent banks and hence widen the region where the fintech has a competitive advantage over banks. This result is consistent with Claessens et al. (2018) and Frost et al. (2019) who find that the FinTech/BigTech platforms lend more in economies with a less competitive banking system.[12]

As c_F increases, there are two effects causing the fintech's market share to decrease. First, a bank's market share x^{ea} will increase based on Proposition 9; second, the number of banks N will weakly increase according to Corollary 2. This result is consistent with Babina et al. (2022) who document that open banking policy – which can be viewed as a decrease in c_F because customer data availability improves for fintechs – significantly enlarges venture capital investment in fintechs.

Reasoning similarly, as c_B, q and/or ι_B increase, the fintech's market share will increase because x^{ea} (resp. N) will decrease (resp. weakly decrease).

Next we analyze how banks' loan rate is affected by the model's parameters.

Proposition 10. *In the allowed entry case, banks' loan rate (i.e., r_B^{ea}) is increasing in c_F and ι_B, decreasing in c_B, and independent of N^0 and L.*

As c_F increases, the competitive advantage of the fintech decreases, which incentivizes banks to increase their loan rate (see Panel 1 of Figure 6 for illustration). Reasoning similarly, banks will decrease their loan rate as c_B increases because banks' competitive advantage is decreasing in c_B. Note that a bank will specialize in a smaller area (i.e., x^{ea} will decrease) and meanwhile offer a lower loan rate when the fintech's monitoring efficiency improves (by decreasing c_F); this is in line with Blickle et al. (2021) who document that bank specialization is associated with more favorable loan rates, especially when the threat of non-banks or other sources of funding is high.[13]

Changing L or N^0 will weakly affect N, which has no effect on a bank's loan rate r_B^{ea} because in the allowed entry equilibrium banks' competitive advantage over the fintech is not affected by the distance between two adjacent banks (see the explanation of Proposition 9).

As ι_B increases, a bank's expected profit at each location will decrease for a given loan rate r_B^{ea}; this outcome will reduce a bank's marginal benefit of extending the market

[12]Similarly, Hau et al. (2021) document that Ant Financial extends more credit lines in rural areas of China with less banks. Avramidis et al. (2021) and Gisbert (2021) find that merger-induced bank closings, which can be viewed as a decrease in N^0, lead to an increase in fintech lending volume.

[13]Increasing q has two competing effects on banks' loan rate r_B^{ea}. First, a higher q decreases banks' competitive advantage, which should incentivize banks to decrease their loan rate. However, a higher q also implies a larger distance friction, which makes it harder for a bank to extend market share; hence x^{ea} becomes less sensitive to r_B^{ea}, thereby reducing a bank's incentive to extend market share by posting a lower loan rate. The two competing effects offset each other, so r_B^{ea} is independent of q.

share by offering a low loan rate. Therefore, banks will set a higher loan rate to rebalance their marginal benefit and cost.

According to Lemma 1, bank i's borrowers at location $z_i \in [0, x^{ea})$ will succeed with probability $r_B^{ea}(1 - qz_i)/c_B$, so we can define the average loan quality of bank i in the allowed entry case as follows:

$$\frac{\int_0^{x^{ea}} r_B^{ea}(1 - qz_i)/c_B dz_i}{x^{ea}}, \tag{8}$$

which is characterized in the following corollary.

Corollary 7. *In the allowed entry case, the average loan quality of bank i is increasing in ι_B.*

Corollary 7 states that an increase in banks' funding cost will improve the average loan quality of banks when fintech entry is allowed. Two reasons contribute to this seemingly counter-intuitive result: First, as ι_B increases, banks will increase their loan rate according to Proposition 10, which gives them incentive to increase monitoring intensity and hence improve loan quality. Second, according to Proposition 9, a bank's market share x^{ea} will shrink as ι_B increases, which allows the bank to specialize in a smaller region where entrepreneurs are less costly to monitor; this specialization also increases banks' average loan quality.

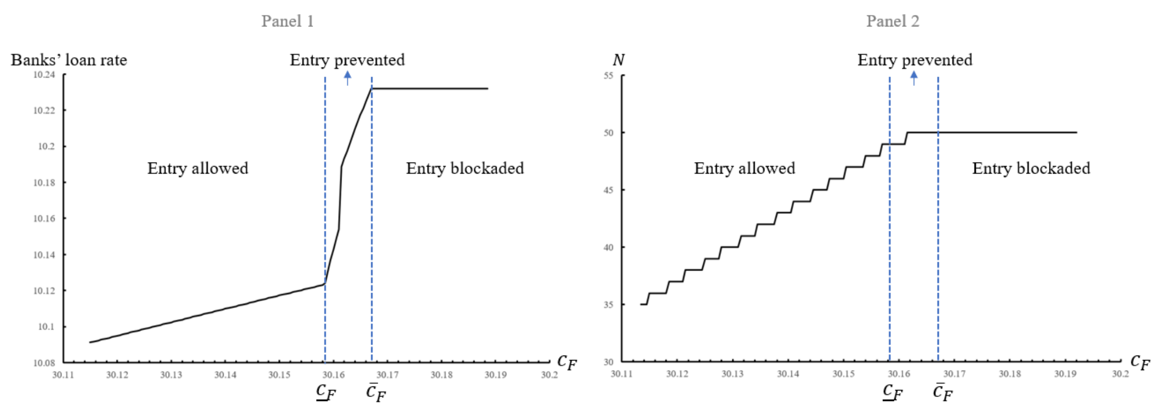

Figure 6: Fintech Entry and Banks' Behavior. This figure plots how the type of the equilibrium, banks' equilibrium loan rate and the number of bank N vary with c_F. The parameter values are $R = 20$, $\iota_B = \iota_F = 1$, $c_B = 30$, $q = 0.5$, $N^0 = 50$, $L = 0.0148$ and $\lambda(i)$ satisfies Equation (12).

Figure 6 illustrates how fintech entry affects banks' behavior from a broader perspective. When fintech monitoring efficiency is low, banks will ignore the existence of the fintech, so decreasing c_F has no effect on banks' behavior in this blockaded entry case. If fintech monitoring efficiency is at an intermediate level ($\underline{c}_F \leq c_F < \bar{c}_F$), then banks can no longer ignore the threat of the fintech and hence have to lower their loan rate to prevent fintech entry as c_F decreases. Decreasing the loan rate reduces the profitability of banks, so some banks may leave the market to recover their salvage values (Panel 2 of Figure 6). To prevent fintech entry, banks must ensure that the lowest entrepreneurial utility they provide is at least $\overline{U}_F$, which requires them to reduce their loan rate by a large extent in response to a small decrease in c_F. Therefore the slope of banks' loan rate with respect to c_F is quite high when fintech entry is prevented (Panel 1 of Figure 6). As c_F further decreases below $\underline{c}_F$, preventing fintech entry will be too expensive for banks, so they have to allow the fintech to serve some entrepreneurs. Since there is no need to prevent fintech entry, the slope of banks' loan rate with respect to c_F is not so high when $c_F < \underline{c}_F$. When fintech entry is allowed, decreasing c_F will reduce the profitability of banks by lowering their loan rate and eroding their market share, so weakly more and more banks will leave the market as c_F decreases.

Finally, we look at the fintech's loan rate $r_F(z_i)$. Since the fintech's loan rate varies with location z_i, we focus on the average fintech loan rate on the arc between banks i and $i+1$, which is defined as $\int_{x^{ea}}^{1/N-x^{ea}} r_F(z_i)/(1/N - 2x^{ea})dz_i$ since the fintech serves locations $z_i \in [x^{ea}, 1/N - x^{ea}]$. The following proposition characterizes the average fintech loan rate.

Proposition 11. *In the allowed entry case, the average fintech loan rate is increasing in c_B, q, ι_B, weakly increasing in L, and weakly decreasing in N^0.*

A higher c_B, q or ι_B decreases banks' competitive advantage, so the fintech can increase its loan rate to make a higher profit. The other effect of increasing c_B, q or ι_B is to weakly decrease N (Corollary 2); a smaller N implies that banks i and $i+1$ are more distant from the mid location $z_i = 1/(2N)$, around which the fintech can raise its loan rate. For the same reason, decreasing N^0 or increasing L will weakly increase the average fintech loan rate by weakly decreasing N.

Following the intuition underlying (8), we can define the average fintech loan quality as follows:

$$\frac{\int_{x^{ea}}^{1/N-x^{ea}} r_F(z_i)/c_F dz_i}{1/N - 2x^{ea}},$$

which has the following property:

Corollary 8. *In the allowed entry case, the average fintech loan quality is weakly increasing in L and weakly decreasing in N^0.*

A decrease in N^0 (or an increase in L) will weakly increase the average fintech loan rate (Proposition 11), which implies weakly higher average loan quality according to Lemma 1. This result is consistent with Avramidis et al. (2021) who document that the overall quality of fintech borrowers increased after an exogenous merger-induced bank closings, which can be viewed as a decrease in N^0. Table 3 summarizes the comparative statics result when fintech entry is allowed.

Table 3: Summary of Comparative Statics When Fintech Entry is Allowed

	q	c_B	c_F	ι_B	L	N^0
An individual bank's market share	↓	↓	↑	↓	/	/
The number of banks (N)	↓	↓	↑	↓	↓	↑
Fintech market share	↑	↑	↓	↑	↑	↓
Banks' loan rate	/	↓	↑	↑	/	/
Average fintech loan rate	↑	↑	ambiguous	↑	↑	↓
Fintech loan quality	↑	↑	ambiguous	↑	↑	↓

This table summarizes how endogenous variables (in the first column) is affected by parameters (in the first row) when fintech entry is allowed. "↑" (resp. "↓") means an endogenous variable is increasing or weakly increasing (resp. decreasing or weakly decreasing) in the corresponding parameter. "/" means an endogenous variable is independent of the corresponding parameter. "Ambiguous" means the effect of a parameter cannot be determined with theoretical methods.

Remark: local monopoly blockaded entry equilibrium. In Appendix LM we assume that Condition (4) does not hold; in this case banks do not compete with each other and hence will offer the loan rate R to extract entire project values when fintech entry is blockaded. Fintech entry will be allowed if and only if $\overline{U}_F \geq 0$ because there exist locations where banks cannot provide positive utility to entrepreneurs when Condition (4) does not hold. At locations where providing loans is unprofitable for banks, entrepreneurs cannot secure funding in the blockaded entry equilibrium; however, the fintech will provide funding to those previously unserved entrepreneurs when its entry is allowed because the fintech monitoring efficiency does not rely on entrepreneurs' locations. Therefore, fintech entry (allowed) on the one hand substitutes bank lending by eroding banks' market share, but on the other hand complements bank lending by meeting the funding demand of entrepreneurs that are not covered by banks.[14]

[14]Tang (2019) finds that fintech lending is a substitute for bank lending in terms of serving infra-

5 Price-discriminating banks

In this section, we consider the case that both the fintech and banks can price discriminate to analyze how the properties of equilibria depend on banks' ability to discriminate. Only in this section we assume that bank i's loan rate can also be a function of location z_i.

Types of equilibria. The following lemma presents the types of equilibria that may arise when banks can price discriminate.

Lemma 3. *There exist $\widetilde{c}_F$ and $\underset{\sim}{c}_F$ ($< \widetilde{c}_F$) such that:*

(i) If $c_F \geq \widetilde{c}_F$, then fintech entry is blockaded.

(ii) If $\underset{\sim}{c}_F \leq c_F < \widetilde{c}_F$, then fintech entry is prevented.

(iii) If $c_F < \underset{\sim}{c}_F$, then fintech entry is allowed. In this case, there exists an $\hat{x}^{ea} \in (0, 1/(2N))$ such that the fintech serves entrepreneurs at $z_i \in [\hat{x}^{ea}, 1/N - \hat{x}^{ea}]$ on the arc between banks i and $i+1$; banks i (resp. bank $i+1$) serves entrepreneurs at $z_i \in [0, \hat{x}^{ea})$ (resp. $z_i \in (1/N - \hat{x}^{ea}, 1/N]$).

When banks can price discriminate, there also exit three types of equilibria based on the fintech's monitoring efficiency: entry blockaded, prevented and allowed. This result is consistent with Proposition 1.

The intuition underlying Lemma 3 is quite similar to that of Proposition 1. If the monitoring efficiency of the fintech is too low (i.e., if $c_F > \widetilde{c}_F$), borrowing from the fintech implies too low a probability of success for entrepreneurs; hence banks need do nothing to prevent fintech entry. In this case, fintech entry is blockaded. If the monitoring efficiency of the fintech is in an intermediate level (i.e., if $\underset{\sim}{c}_F \leq c_F < \widetilde{c}_F$), then the fintech will bring effective competitive pressure to banks because $\overline{U}_F$ is higher than the lowest utility an entrepreneur could derive in the blockaded entry equilibrium. In this case, banks have to decrease their loan rate at some locations to protect market shares; fintech entry will be prevented after banks set lower loan rates for locations where the fintech brings competitive pressure. However, preventing fintech entry will become impossible if the fintech's monitoring efficiency is sufficiently good (i.e., if $c_F < \underset{\sim}{c}_F$); this case will arise if banks cannot provide entrepreneurs with utility that is as high as $\overline{U}_F$ at all locations.

When fintech entry is allowed, the fintech will serve the middle region $z_i \in [\hat{x}^{ea}, 1/N - \hat{x}^{ea}]$ on the arc between banks i and $i+1$ because it has competitive advantage at locations that are far away from both banks i and $i+1$; the mid location $z_i = 1/(2N)$ is the place that the fintech will penetrate first when entry is allowed (Note that in the limiting

marginal bank borrowers, yet complements bank lending with respect to small loans.

case $\hat{x}^{ea} \to 1/(2N)$, the fintech serves only entrepreneurs at $z_i = 1/(2N)$). This result is consistent with Proposition 7.

What changes when banks can discriminate? Before answering the question, we present the following lemma that characterizes the highest utility a bank can provide to an entrepreneur at location z_i.

Lemma 4. *At location z_i, a bank's loan rate that maximizes entrepreneurs' expected utility is given by*

$$\overline{r}_B(d) \equiv \max\left\{\frac{R}{2}, \sqrt{\frac{2c_B \iota_B}{1-qd}}\right\},$$

where d is the arc-distance between the bank and location z_i. If the bank serves location z_i with loan rate $\overline{r}_B(d)$, then an entrepreneur at this location will derive the expected utility $\overline{U}_B(d)$ by approaching the bank, where:

$$\overline{U}_B(d) \equiv \underbrace{\frac{(1-qd)\,\overline{r}_B(d)}{c_B}}_{\text{success probability}} \times \underbrace{(R - \overline{r}_B(d))}_{\text{utility from success}}.$$

*We call $\overline{r}_B(d)$ the "**best loan rate**" of the bank at location z_i.*

The intuition of Lemma 4 is almost the same as that of Lemma 2. A bank's best loan rate should be $R/2$ if it can ensure the bank a non-negative profit; if not, then the bank's best loan rate is the zero-profit loan rate, which is equal to $\sqrt{\frac{2c_B\iota_B}{1-qd}}$ when bank-borrower distance is d. Different from the fintech's zero-profit loan rate (i.e., $\sqrt{2c_F\iota_F}$), a bank's zero-profit loan rate is increasing in the bank-borrower distance d because it is more costly for a bank to monitor a more distant entrepreneur. According to Lemma 1, the monitoring intensity of a bank at z_i is $(1-qd)\,\overline{r}_B(d)/c_B$ if the arc-distance between the bank and location z_i is d and if the bank's loan rate is $\overline{r}_B(d)$; the corresponding entrepreneurial utility at z_i is $\overline{U}_B(d)$.

The following Proposition compares the monitoring efficiency and loan rate of bank i with those of the fintech in the allowed entry equilibrium.

Proposition 12. *In the allowed entry case, if $\iota_B = \iota_F$, then the following equations hold:*

$$\frac{c_B}{1-q\hat{x}^{ea}} = c_F \text{ and } \hat{r}_B^{ea}(\hat{x}^{ea}) = \hat{r}_F(\hat{x}^{ea}) = \overline{r}_F = \overline{r}_B(\hat{x}^{ea}), \tag{9}$$

where $\hat{r}_B^{ea}(\hat{x}^{ea})$ (resp. $\hat{r}_F(\hat{x}^{ea})$) is bank i's (resp. the fintech's) loan rate at location $z_i = \hat{x}^{ea}$ when fintech entry is allowed.

Banks' ability to price discriminate in this section causes the difference between Propositions 12 and 8. With the ability to price discriminate, bank i's pricing at a location will not affect its profit from other locations, so both bank i and the fintech will offer their best loan rates at the indifference location $z_i = \hat{x}^{ea}$; meanwhile, entrepreneurs at $z_i = \hat{x}^{ea}$ are indifferent about bank i and the fintech. Under the condition $\iota_B = \iota_F$ (i.e., no lender has advantage in funding cost), this can happen only if bank i and the fintech have the same monitoring efficiency at $z_i = \hat{x}^{ea}$, implying Equation (9).

If we do not restrict $\iota_B = \iota_F$, then Proposition 12 leads to the following corollary.

Corollary 9. *If* $\frac{c_B}{1-\frac{1}{2N}q} < c_F$ *and* $\iota_B < \iota_F$ *both hold, then fintech entry is not allowed.*

Corollary 9 states that Corollary 5 will be completely flipped if banks can price discriminate. When banks cannot price discriminate, then the fintech's ability to discriminate contributes to the fintech's competitive advantage over banks. When banks can also discriminate, however, such ability is no longer part of the fintech's competitive advantage. Therefore fintech entry is allowed if and only if the fintech has advantage in monitoring efficiency at some locations or/and in funding cost.

Comparing Propositions 12 and 8 can yield following corollary about a bank's market share in the allowed entry case.

Corollary 10. *In the allowed entry case,* $x^{ea} < \hat{x}^{ea}$ *holds.*

Corollary 10 states that in the allowed entry equilibrium a bank will gain a higher market share when it can price discriminate than when it cannot. The intuition is simple. The ability to price discriminate enables the bank to offer its best loan rate to compete with the fintech, which increases the competitive advantage of the bank and hence enlarges its market share.

Finally, we look at how allowing banks to price discriminate will affect the number of banks N. The following proposition gives a relevant result.

Proposition 13. *In the allowed entry case, the number of banks* N *is weakly larger when banks can price discriminate than when they cannot.*

The intuition is simple. In the bank-fintech competition, the profit of banks will be higher if they can price in a more flexible way; hence fintech entry, when it is allowed, will cause a weakly smaller reduction in the number of banks if banks can price discriminate.

Summary: When banks can also price discriminate, the fundamental change is that the ability to price discriminate is no long the fintech's competitive advantage over banks.

As a result, fintech entry can be allowed if and only if the fintech has advantage in funding cost or/and in monitoring efficiency at some locations (Corollary 9); this result is exactly opposite to Corollary 5, which states that fintech entry can be allowed even if the fintech has neither better monitoring efficiency nor lower funding cost when banks cannot price discriminate.

If fintech entry is allowed, allowing banks to price discriminate increases banks' competitive advantage (relative to the fintech) because a bank can offer its best loan rate to compete with the fintech without worrying that reducing the loan rate at one location will decrease the bank's profit from other locations. Consequently, everything else being equal, allowing banks to price discriminate implies a larger market share for each bank, a higher bank profit and hence a weakly larger N (i.e., a weakly smaller reduction in the number of banks) when fintech entry is allowed.

6 Bank stability

In this section we analyze how fintech entry will affect bank stability. Since the status of fintech entry depends on fintech monitoring efficiency (i.e., c_F), we will also look at how c_F affects bank stability. The stability of a bank is inversely measured by its probability of default on depositors.

We denote bank i's default probability by θ^*, which can be pinned down as described in Lemma 5.

Lemma 5. *If bank i serves entrepreneurs with loan rate r_B at locations $z_i \in [0, \tilde{x}]$ on the arc between banks i and $i+1$, then the bank's default probability θ^* is determined by the following equation:*

$$\int_0^{\tilde{x}} r_B 1_{\{1-m_B(z_i)\leq\theta^*\}} dz_i = \tilde{x}\iota_B, \tag{10}$$

where $1_{\{\cdot\}}$ is an indicator function that equals 1 if the condition in $\{\cdot\}$ holds and equals 0 otherwise; $m_B(z_i) = r_B(1-qz_i)/c_B$ is the bank's monitoring intensity for location z_i.

To see what is behind Lemma 5, we prove it here. Bank i defaults if and only if the total loan repayment it receives from entrepreneurs cannot cover its promised payment to depositors. To provide loans to entrepreneurs at locations $z_i \in [0, \tilde{x}]$, the bank must raise $\tilde{x}$ units of funding from depositors; hence the amount bank i promises to depositors is $\tilde{x}\iota_B$ because deposits are riskless under the protection of fair deposit insurance. According to (1), the total loan repayment bank i can receive from entrepreneurs is determined by the common risk factor θ. For a given θ, entrepreneurs at z_i will repay r_B (resp. 0) if $1 - m_B(z_i) \leq \theta$ (resp. $1 - m_B(z_i) > \theta$), so the loan repayment at this location can be denoted by $r_B 1_{\{1-m_B(z_i)\leq\theta\}}$. Integrating entrepreneurs' loan repayment from $z_i = 0$ to $z_i = \tilde{x}$ yields the total loan repayment $\int_0^{\tilde{x}} r_B 1_{\{1-m_B(z_i)\leq\theta\}} dz_i$ (for a given θ). Therefore, bank i defaults if and only if:

$$\int_0^{\tilde{x}} r_B 1_{\{1-m_B(z_i)\leq\theta\}} dz_i < \tilde{x}\iota_B. \tag{11}$$

Note that the bank's premium to the DIF has no direct effect on Inequality (11); the reason is that the bank pays the premium to the DIF only if it is still solvent after paying depositors.[15] Since the common risk factor θ is assumed to be uniformly distributed on $[0, 1]$, it follows that bank i would default when $\theta < \theta^*$ if the bank's default probability is equal to θ^*. Therefore, if $\theta = \theta^*$ holds, the total loan repayment received by the bank should exactly equal the promised payment to depositors, leading to Equation (10) of Lemma 5.

With Lemma 5, we can analyze how fintech entry affects bank stability. First we consider the case that fintech entry is prevented. In this case, $\tilde{x} = 1/(2N)$ holds.

Proposition 14. *The threat of fintech entry increases bank i's probability of default when it is prevented; in this case, bank i's probability of default is decreasing in c_F.*

Prevented fintech entry has two effects on banks' stability. First, there is a "competition effect": fintech entry threat decreases banks' loan rate (from r_B^{eb} to r_B^{ep}); this reduces bank stability because a lower loan rate will decrease banks' monitoring intensity and meanwhile reduce the loan repayment of an entrepreneur in the event of success. Second, there is a "market area effect": fintech entry, when it is prevented, will weakly increase the market share of a bank, because the number of banks will be weakly decreased by fintech entry (Corollary 2); hence a bank must serve more distant entrepreneurs who are harder to monitor, which should also reduce bank stability. The competition and market area effects work in the same direction when fintech entry is prevented, so bank stability will decrease in this case. Decreasing c_F will enhance both the competition and the market area effects, and so make banks less stable.

[15]The deposit insurance has an indirect effect on Inequality (11). Because of the insurance, deposits are riskless from the perspective of depositors; hence bank i need only promise $\tilde{x}\iota_B$ to depositors for $\tilde{x}$ units of funding. If there were no such insurance, then deposits would be risky, in which case the bank must promise a higher nominal return to depositors.

When fintech entry is allowed (i.e., when $c_F < \underline{c}_F$), the effect of fintech entry on bank stability becomes more complex because the competition effect and the market area effect work in opposite directions. The competitive pressure from the fintech forces banks to decrease their loan rate (from r_B^{eb} to r_B^{ea}), which should reduce bank stability. However, as the fintech erodes banks' market shares, a bank may focus on its nearby entrepreneurs who are easier to monitor, which should potentially enhance bank stability. Our numerical study shows that the competition effect dominates, so fintech entry also decreases bank stability in the allowed entry case; meanwhile, banks becomes less stable as the fintech monitoring technology makes progress (i.e., as c_F decreases). We summarize this numerical result as follows:

Numerical Result 1. [16] *Fintech entry increases bank i's probability of default when it is allowed; in this case, bank i's probability of default is decreasing in* c_F.

Combining Proposition 14 and Numerical Result 1, we draw the conclusion that the threat of fintech entry will decrease bank stability, and that the stability-reducing effect will become larger as the fintech technology progresses (i.e., c_F decreases).

7 Welfare analysis

In this section we analyze how fintech entry affects entrepreneurial utility and social welfare. Since fintech entry has no effect on the lending market if it is blockaded, we look only at the prevented and allowed entry cases. Some analyses adopt numerical methods; in this case we assume that $\lambda(i)$ follows a *non-random uniform distribution*; that is:

$$\lambda(i) = \frac{i-1}{N^0}, \quad \text{where } i = 1, 2, ..., N^0. \tag{12}$$

Social welfare is as follows:

$$W = U_E + N\Pi_B + \Pi_F + 1_{\{N<N^0\}} \cdot \sum_{i=N+1}^{N^0} \lambda(i) L - K\theta^*. \tag{13}$$

The first term U_E of Equation (13) represents the aggregate utility of all entrepreneurs. The second term $N\Pi_B$ is the total lending profits of the N banks that stay in the market at $t = 3$ with Π_B the lending profit of one bank. The third term Π_F represents the

[16] The grid of parameters is as follows: R ranges from 5 to 50; c_B ranges from $2R$ to R; c_F ranges from $\underline{c}_F$ to c_B; q ranges from 0.1 to 0.9; ι_B and ι_F range from 0.8 to 1.2; N^0 ranges from 5 to 30.

fintech's expected profit; if fintech entry is not allowed, then obviously $\Pi_F = 0$. The fourth term $1_{\{N<N^0\}} \cdot \sum_{i=N+1}^{N^0} \lambda(i) L$ measures the total salvage value recovered by banks who leave the market at $t = 2$; $1_{\{N<N^0\}}$ is an indicator function that equals 1 (resp. 0) if $N < N^0$ (resp. $N = N^0$) holds (no value is recovered if no bank leaves the market). If $N < N^0$ holds, then it means banks $N+1$, $N+2$... N^0 leave the market because they have the highest salvage values; in this case the total recovered value is $\sum_{i=N+1}^{N^0} \lambda(i) L$. Finally, K represents the social costs associated with systemic bank failure, which happens with probability θ^* according to Lemma 5.

7.1 Fintech entry is prevented

First we look at the case that fintech entry is prevented (where $\underline{c}_F \leq c_F < \overline{c}_F$). We have the following proposition that characterizes the effect of fintech entry on entrepreneurs' utility.

Proposition 15. *The threat of fintech entry increases entrepreneurs' aggregate utility U_E when it is prevented; in this case U_E is decreasing in c_F.*

Even if fintech entry is prevented, the fintech's threat will bring additional competitive pressure to banks, forcing them to provide higher utility to entrepreneurs. As c_F decreases, the maximum utility (i.e., $\overline{U}_F$) the fintech can provide to an entrepreneur will increase. Therefore banks must offer a more attractive loan rate to ensure that the fintech obtains no market share. Note that N will weakly decrease as c_F decreases (Corollary 2), which brings a utility-reducing effect because a bank (e.g., bank i) must serve more distant locations that are harder to monitor when N is smaller. However, this utility-reducing effect is dominated because $\overline{U}_F$ always becomes higher as c_F decreases; bank i must provide entrepreneurial utility $\overline{U}_F$ at $z_i = 1/(2N)$ to prevent fintech entry (see Equation 5), even if doing so becomes more costly as N decreases.

The effect of fintech entry (prevented) on social welfare is more complex. In the prevented entry equilibrium $\Pi_F = 0$ because the fintech obtains no market share. Therefore the welfare effects of fintech entry depend on how U_E, $N\Pi_B$, $1_{\{N<N^0\}} \cdot \sum_{i=N+1}^{N^0} \lambda(i) L$ and $K\theta^*$ change. The importance of $K\theta^*$ depends on the value of K. If K is large enough, then obviously fintech entry will decrease social welfare by making banks more likely to fail (see Proposition 14 and Numerical Result 1).

We focus on the case with $K = 0$, which means the welfare effect of fintech entry is determined by the interaction among entrepreneurs' utility, banks' profits and recovered salvage value in the prevented entry equilibrium. In this case fintech entry brings two competing effects: an *option value effect* and a *project value effect*.

Lemma 6. ***Option value effect.*** *If Π_B decreases by ε, then the decrease in $N\Pi_B + 1_{\{N<N^0\}} \cdot \sum_{i=N+1}^{N^0} \lambda(i) L$ is weakly smaller than $N\varepsilon$.*

We explain the lemma by proving it here. If banks do not have the option to leave the market (e.g., if $L = 0$, which means $N = N^0$), then total bank profit will decrease by $N\varepsilon$ if the lending profit of one bank decreases by ε. However, if banks have the option to leave the market (e.g., $L > 0$), then a bank will choose to exit whenever the lending profit Π_B is smaller than its salvage value; by doing so, the bank can earn a benefit that is higher than the lending profit from staying at the market. Consequently, the decrease in total lending profit plus total recovered salvage value will be weakly smaller than $N\varepsilon$ if Π_B decreases by ε.

The option value effect means that the effect of decreasing a bank's lending profit Π_B on social welfare will be mitigated by banks' option to leave the market. Because of this option value effect, transferring bank profit to other parties (e.g., to entrepreneurs) will benefit social welfare. To prevented fintech entry, banks must charge a lower loan rate to increase entrepreneurs' utility, which transfers some bank profit to entrepreneurs and thereby generates such welfare-improving option value effect in the prevented entry equilibrium.

Lemma 7. ***Project value effect.*** *If an entrepreneur at z_i is monitored by a bank (resp. by the fintech) with intensity $m_B(z_i)$ (resp. $m_F(z_i)$), then the net value of the entrepreneur's project is $V_B(z_i)$ (resp. $V_F(z_i)$), where:*

$$\begin{aligned} V_B(z_i) &= m_B(z_i) R - \iota_B - C_B(m_B(z_i), d), \textit{with } d \textit{ being the bank-borrower distance;} \\ V_F(z_i) &= m_F(z_i) R - \iota_F - C_F(m_F(z_i)). \end{aligned}$$

If lenders' monitoring intensities satisfy the rule of Lemma 1, then $V_B(z_i)$ (resp. $V_F(z_i)$) is maximized when the bank's (resp. the fintech's) loan rate is R.

First we explain the expression for $V_B(z_i)$. If an entrepreneur is monitored by a bank with intensity $m_B(z_i)$, her project succeeds with probability $m_B(z_i)$. Therefore the expected payoff of the entrepreneur's project is $m_B(z_i) R$. Financing this project incurs an expected funding cost ι_B. Finally, monitoring the entrepreneur with intensity $m_B(z_i)$ costs the bank $C_B(m_B(z_i), d)$ if the arc-distance between the bank and the entrepreneur is d. As a result, the net value of the entrepreneur's project is $V_B(z_i)$. The formula of $V_F(z_i)$ follows similarly.

Lemma 7 states that the net project value (be it $V_B(z_i)$ or $V_F(z_i)$) is highest when the loan rate is equal to R, which means the lender extracts all project payoff, leaving 0 to the entrepreneur. The reason is that the loan rate determines a lender's incentive to monitor entrepreneurs. A higher monitoring intensity can increase the value of a project by raising its success probability; only when a lender can extract the entire project value will it choose the monitoring intensity that maximizes the project value.

Now we can look at the project value effect of the prevented fintech entry. To prevent fintech entry, banks must decrease their loan rate; according to Lemma 7, the decrease in banks' loan rate will reduce the net value of entrepreneurs' projects, which is bad for social welfare.

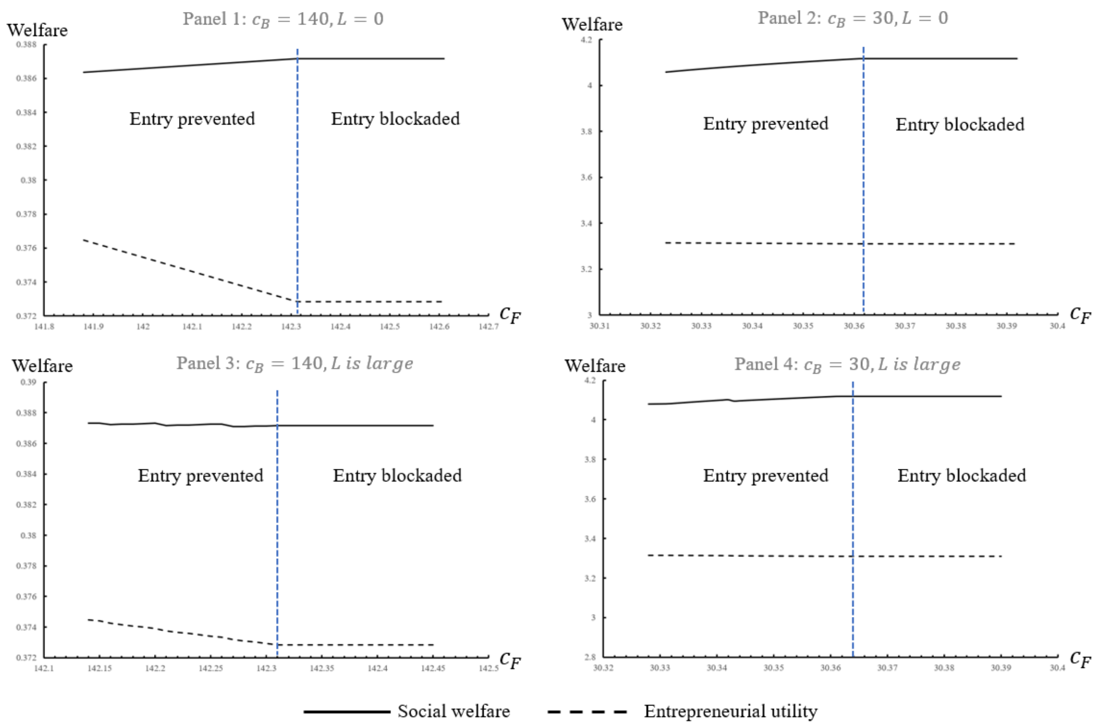

Figure 7: Welfare Effect of c_F (Fintech Entry Blockaded or Prevented). This figure plots social welfare (solid curve) and entrepreneurial utility (dashed curve) against c_F when fintech entry is blockaded or prevented. The parameter values are: $R = 20$, $q = 0.6$ $\iota_B = \iota_F = 1$, $N^0 = 30$.

The net effect depends on which effect (option value v.s. project value effect) dominates. The following proposition characterizes the net effect.

Proposition 16. *Assume that $K = 0$. In the prevented equilibrium, if L is sufficiently small such that N does not vary with c_F, then social welfare is increasing in c_F, which means fintech entry threat decreases social welfare; Numerical Result:*[17] *otherwise, the effects of fintech entry and c_F on social welfare are ambiguous.*

If L is sufficiently small such that N does not vary with c_F, then no banks will leave the market, so there is no option value effect. Then only the project value effect exists in the prevented entry equilibrium. Since banks' loan rate is increasing in c_F, social welfare is increasing in c_F in this case. Hence fintech entry (prevented) decreases social welfare. See Panels 1 and 2 of Figure 7.

If L is not sufficiently small, then banks may leave the market as c_F changes, which generates the option value effect. According to our numerical study, the effect of c_F on social welfare is discontinuous (or say, serrated) if L is not sufficiently small. As c_F decreases, social welfare will decrease for a given N because of the project value effect; however, if N is also decreased by a reduction in c_F, then social welfare will discontinuously jump up because of the option value effect. The interaction between the two effects determines the welfare effect of the prevented fintech entry. When monitoring is very costly for lenders (i.e., when c_F and c_B are very high), the option value effect will dominate because in this case banks' monitoring intensity is very low and hence not sensitive to banks' loan rate, which means the project value effect is weak; hence fintech entry threat increases social welfare after several banks leave the market (Panel 3 of Figure 7). In contrast, if monitoring is sufficiently cheap for lenders (i.e., if c_F and c_B are low), then the project value effect will dominate the option value effect, and so social welfare will be reduced by fintech entry threat (Panel 4 of Figure 7).

7.2 Fintech entry is allowed

Now we look at the case where fintech entry is allowed ($c_F < \underline{c}_F$). The following numerical result shows how entrepreneurial utility is affected by the allowed fintech entry.

Numerical Result 2. [18] *Assume that $K = 0$. In the allowed entry equilibrium, fintech*

[17] The grid of parameters is as follows: R ranges from 10 to 50; c_B ranges from $(3/2)R$ to $8R$; q ranges from 0.1 to 0.8; ι_B and ι_F range from 0.8 to 1.2. N^0 ranges from 10 to 50. L ranges from 0 to the value that equals a bank's lending profit when fintech entry is blockaded.

[18] The grid of parameters is as follows: R ranges from 10 to 50; c_B ranges from $(3/2)R$ to $8R$; q ranges from 0.1 to 0.8; ι_B and ι_F range from 0.8 to 1.2. N^0 ranges from 10 to 50. L ranges from 0 to the value that equals a bank's lending profit when fintech entry is blockaded.

entry increases entrepreneurs' aggregate utility if $L = 0$; If $L > 0$, then fintech entry decreases entrepreneurs' aggregate utility when c_F is sufficiently small relative to c_B.

If $L = 0$, then no banks will leave the market. In this case, the allowed fintech entry decreases the loan rate of banks, which means the intensity of lending competition increases in the market. A higher intensity of lending competition implies that lenders (i.e., banks and the fintech) must offer more attractive loan rates to entrepreneurs, increasing entrepreneurs' utility. See Panels 1 and 2 of Figure 8.

If $L > 0$, the story is different. If c_F is not too low relative to c_B, then fintech entry will not cause many banks to leave the market; in this case fintech entry increases the overall intensity of lending competition and hence benefits entrepreneurs' utility. However, if c_F is sufficiently small relative to c_B, then too many banks will leave the market, which decreases the competitive pressure faced by the fintech. Therefore, fintech entry decreases the overall intensity of lending competition and hence hurts entrepreneurs when $L > 0$ and c_F is sufficiently small relative to c_B. See Panels 3 and 4 of Figure 8.

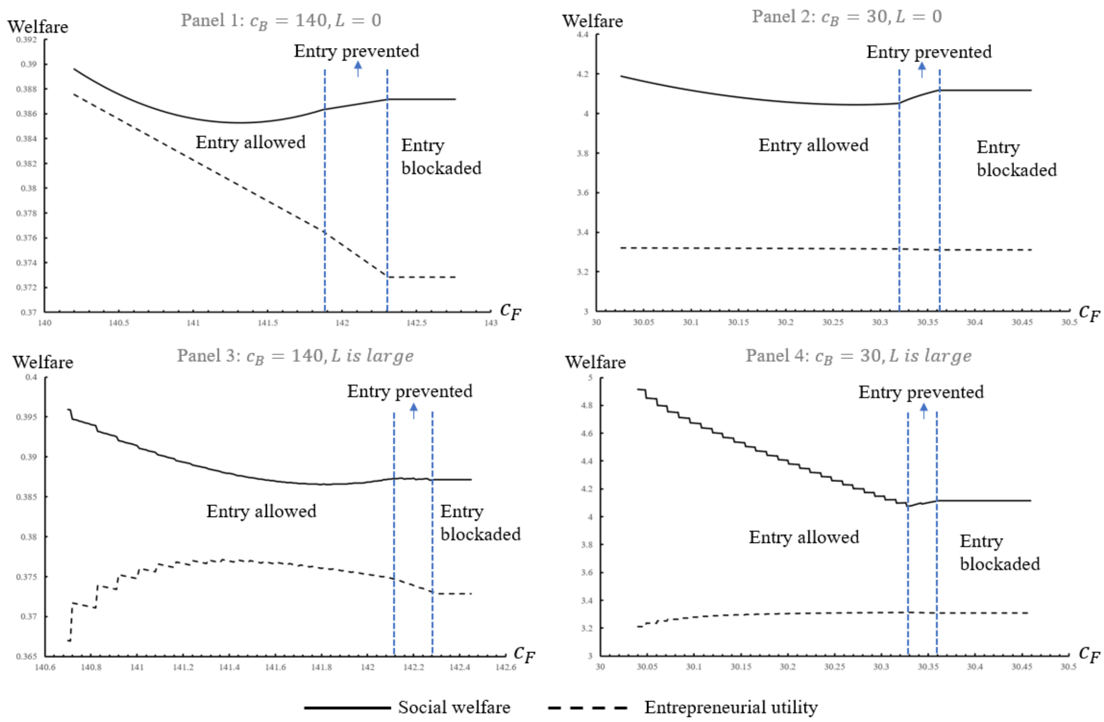

Figure 8: Welfare Effect of c_F. This figure plots social welfare (solid curve) and entrepreneurial utility (dashed curve) against c_F when fintech entry is blockaded, prevented or allowed. The parameter values are: $R = 20$, $q = 0.3$ $\iota_B = \iota_F = 1$ and $N^0 = 30$.

The effect of fintech entry on social welfare in the allowed entry case is given by the following numerical result.

Numerical Result 3. [19] *Assume that $K = 0$. In the allowed entry equilibrium, fintech entry increases social welfare when c_F is sufficiently small relative to c_B; if c_F is not sufficiently small relative to c_B, the welfare effect of fintech entry on social welfare is ambiguous.*

Fintech entry has four effects on social welfare in the allowed entry case. First, the welfare-improving option value effect still works in the allowed entry equilibrium if $L > 0$: As c_F decreases, banks' market share will be eroded by the fintech, so bank profit will decrease while fintech profit will increase. Because of the banks' option to recover their salvage values, the effect of decreasing a bank's lending profit on social welfare is mitigated. Consequently, transferring profit from banks to the fintech should benefit social welfare. However, note that Numerical Result 3 does not rely on $L > 0$, so the option value effect is not the main contributor to the result.

Second, there is a direct welfare-improving cost-saving effect: As c_F decreases, monitoring becomes cheaper for the fintech, so it can serve entrepreneurs with higher monitoring intensity and lower costs, which also improves social welfare.

Third, the project value effect still exists, but its direction is ambiguous when fintech entry is allowed. As c_F decreases, banks' loan rate will decrease, which reduces banks' monitoring intensity and hence causes a welfare-reducing project value effect at locations served by banks. However, the fintech may increase or decrease its loan rates as c_F decreases (see Table 3), which causes an ambiguous project value effect at locations served by the fintech. The overall project value effect depends on the fintech's market share relative to that of banks. If the market share of the fintech is small relative to that of banks, then the overall project value effect of decreasing c_F is welfare-reducing because banks' loan rate decreases. However, if the market share of the fintech is large relative to that of banks, then the overall project value effect is ambiguous.

Finally, there is a welfare-reducing *business stealing* effect as c_F decreases: the fintech can obtain market share by posting low loan rates, even if it has no advantage in either monitoring efficiency or funding cost compared with banks (see Proposition 8 and Corollary 5). Therefore, the allowed fintech entry marginally replaces banks' high profit with the fintech's low profit; that is, if c_F marginally decreases (without changing N), then

[19] The grid of parameters is as follows: R ranges from 10 to 50; c_B ranges from $(3/2)R$ to $8R$; q ranges from 0.1 to 0.8; ι_B and ι_F range from 0.8 to 1.2. N^0 ranges from 10 to 50. L ranges from 0 to the value that equals a bank's lending profit when fintech entry is blockaded.

the corresponding marginal decrease in $N\Pi_B$ is higher than the increase in Π_F, which should have a negative welfare effect.

Our numerical study (Numerical Result 3) finds that the welfare-improving option value and cost-saving effects will dominate other effects when c_F is sufficiently small relative to c_B (i.e., when the fintech's market share is large); in this case social welfare is decreasing in c_F (Figure 8). Consequently, fintech entry increases social welfare when c_F is sufficiently small relative to c_B. The reason is that the cost-saving effect is large when the fintech serves a large share of the market; in this case fintech entry significantly increases the overall monitoring efficiency of the entire lending market, thereby improving social welfare.

Table 4: The Effect of Decreasing c_F on Social Welfare

	fintech entry is prevented	fintech entry is allowed
Option value	+	+
Project value	−	− if fintech market share is small
Cost-saving	null	+
Business-stealing	null	−
Net effect	− if L is small	+ if fintech market share is large

In the table, +/−/null means "welfare-improving"/"welfare-reducing"/"no effect".

When c_F is not sufficiently small relative to c_B (i.e., when the fintech's market share is small), the welfare effect of fintech entry is ambiguous because the net effect of decreasing c_F is ambiguous. In this case, the cost-saving effect is small because the fintech serves only a small region of the market; hence the net effect of decreasing c_F mainly depends on the interaction of the project value effect (which is welfare-reducing when the fintech's market share is small), the option value effect (which exists only when $L > 0$ and is welfare-improving) and the business stealing effects (which is welfare-reducing). We find that the project value and business stealing effects dominate if monitoring is costly for both banks and the fintech (Panels 1 and 3 of Figure 8), because in this case the fintech's best loan rate implies zero profit for the fintech. More specifically, as c_F decreases (without changing N), the marginal decrease in $N\Pi_B$ is significant, but the marginal increase in Π_F is almost zero; this means the welfare-reducing business stealing effect is strong. If monitoring is not costly for lenders, then the welfare-improving option value effect can dominate those welfare-reducing effects when L is large enough because in this case the fintech's best loan rate can bring the fintech a significantly positive profit, which weakens the business stealing effect (Panel 4 of Figure 8). Table 4 summarizes the effects of decreasing c_F on social welfare.

8 Conclusion

Our study shows that three types of equilibria may arise depending on the monitoring efficiency of the fintech: the blockaded entry, the prevented entry, and the allowed entry equilibrium. Fintech entry can be allowed even if the fintech has no advantage in either monitoring efficiency or funding cost compared with banks, because the fintech's exclusive ability to discriminate contributes to the fintech's competitive advantage. However, if banks can also price discriminate, then the fintech's advantage in monitoring efficiency or funding cost is a necessary condition for allowing fintech entry.

When fintech entry is allowed, the fintech's lending volume and loan quality will increase if the concentration of banks is higher (i.e., the number of banks decreases). The fintech has a higher competitive advantage if its monitoring efficiency increases, or if its funding cost decreases, relative to banks. As the fintech becomes more competitive, weakly more banks will leave the market and the banking sector will become less stable. Allowing banks to price discriminate will increase their competitive advantage over the fintech, in which case weakly more banks will stay in the market, reducing the fintech's market share.

The welfare effect of fintech entry is in general ambiguous and depends on the interaction of the four effects: option value, project value, cost-saving, and business stealing. In the prevented entry case, fintech entry will decrease social welfare if bank restructuring is limited. In the allowed entry equilibrium, fintech entry will increase social welfare if the monitoring efficiency of the fintech is sufficiently good relative to that of banks.

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Appendix LM

In this appendix we consider the case that there is no effective competition between adjacent banks when fintech entry is blockaded (in which case $N = N^0$ by assumption); that is, banks enjoy local monopoly in the blockaded entry equilibrium. For convenience we concentrate our analysis on the arc between banks i and $i + 1$.

In the blockaded entry case, the loan rate of banks is obviously R because there is no competition among them. Hence bank i's expected profit from serving an entrepreneur at z_i is

$$\pi_i^{LM}(z_i) \equiv \underbrace{\frac{R(1-qz_i)}{c_B}}_{\text{monitoring intensity}} R - \iota_B - \frac{c_B}{2(1-qz_i)}\left(\frac{R(1-qz_i)}{c_B}\right)^2. \tag{14}$$

The first term of Equation (14) is the expected loan repayment the bank receives from the entrepreneur; note that bank i's monitoring intensity is $R(1-qz_i)/c_B$ when its loan rate is R (Lemma 1). The second term is sum of the bank's expected payment to depositors and the expected premium to the DIF. The third term is the non-pecuniary monitoring cost incurred by the bank when its monitoring intensity is $R(1-qz_i)/c_B$.

Obviously, $\pi_i^{LM}(z_i)$ is non-negative if and only if $z_i \leq (R^2 - 2c_B\iota_B)/qR^2$. Therefore, bank i is willing to serve entrepreneurs at locations $z_i \in [0, (R^2 - 2c_B\iota_B)/qR^2]$ in the blockaded entry case. Reasoning symmetrically, bank $i+1$ is willing to serve entrepreneurs at locations $z_i \in [1/N^0 - (R^2 - 2c_B\iota_B)/qR^2, 1/N^0]$. There is no competition between banks i and $i+1$ if and only if

$$\frac{R^2 - 2c_B\iota_B}{qR^2} \leq \frac{1}{2N^0}, \tag{15}$$

which is exactly the opposite of Condition (4).

In this local monopoly blockaded entry equilibrium, an entrepreneur's expected utility is always equal to 0 because banks extract entire project values. Hence the fintech can affect the equilibrium if it can provide entrepreneurs with utility that is no less than 0. This implies the following proposition.

Proposition 17. *Assume that Inequality (15) holds. fintech entry is allowed (resp. blockaded) if and only if*

$$\overline{U}_F \geq 0 \text{ (resp. } \overline{U}_F < 0\text{).}$$

If fintech entry is allowed, then there exists an $x^{ea} \in (0, 1/(2N)]$ such that the fintech serves entrepreneurs at $z_i \in [x^{ea}, 1/N - x^{ea}]$ on the arc between banks i and i_{+1}, while *bank i (resp. bank i_{+1}) serves entrepreneurs at $z_i \in [0, x^{ea})$ (resp. $z_i \in (1/N - x^{ea}, 1/N]$).*

If banks enjoy local monopoly in the blockaded entry equilibrium, there must exist a location (e.g. location $z_i = 1/(2N^0)$) where banks make non-positive profit even if their loan rate is R. To attract entrepreneurs at this location, the fintech need only provide them with non-negative utility (i.e., $\overline{U}_F \geq 0$). Recall that $\overline{U}_F$ is determined by only c_F and ι_F; hence whether or not fintech entry is allowed depends only on the fintech's own monitoring technology (i.e., c_F) and funding cost (i.e., ι_F). If c_F or/and ι_F is/are sufficiently small such that the fintech can provide entrepreneurs with non-negative utility, then fintech entry is allowed. In the allowed entry case, the fintech serves entrepreneurs that are distant from both banks i and $i+1$ as in Proposition 7.

Note that there does not exist a prevented entry equilibrium if banks enjoy local monopoly in the blockaded entry equilibrium. The reason is that banks can make only non-positive profit at location $z_i = 1/(2N^0)$ even if their loan rate is R, which means banks cannot provide positive utility to entrepreneurs at this location. If $\overline{U}_F \geq 0$ holds, banks cannot prevent the fintech from obtaining entrepreneurs at location $z_i = 1/(2N^0)$; if $\overline{U}_F \geq 0$ does not hold, then the fintech is not more attractive than banks at any location, which means fintech entry is blockaded.

If (15) holds without equality (i.e., if $\frac{R^2 - 2c_B\iota_B}{qR^2} < \frac{1}{2N^0}$ holds), then entrepreneurs at $z_i \in \left(\frac{R^2-2c_B\iota_B}{qR^2}, 1/N^0 - \frac{R^2-2c_B\iota_B}{qR^2}\right)$ will not be served by any bank in the blockaded entry case. However, if fintech entry is allowed (i.e., if $\overline{U}_F \geq 0$), then entrepreneurs at $z_i \in \left(\frac{R^2-2c_B\iota_B}{qR^2}, 1/N^0 - \frac{R^2-2c_B\iota_B}{qR^2}\right)$ will be served by the fintech. Therefore, fintech lending can complement bank lending by meeting the funding demand of entrepreneurs that are not covered by banks.

Appendix: Proofs

Proof of Equation (3). Let Ω_j denote the set of locations served by bank j. If location z_i is served by bank j, then it means $z_i \in \Omega_j$.

Let $s(z_i, j)$ denote the distance between location z_i and bank j. If the bank's loan rate (resp. the bank's monitoring intensity) is r_B (resp. $m_B(z_i)$ at z_i) and if the common risk factor is θ, then the bank's aggregate lending profit from serving locations in Ω_j is

$$(1-\tau_j)\max\left\{\int_{z_i\in\Omega_j} r_B 1_{\{1-m_B(z_i)\le\theta\}}dz_i - \iota_B\int_{z_i\in\Omega_j}dz_i, 0\right\} - \int_{z_i\in\Omega_j}C_B(m_B(z_i), s(z_i,j))dz_i. \tag{16}$$

The term $\int_{z_i\in\Omega_j} r_B 1_{\{1-m_B(z_i)\le\theta\}}dz_i$ represents the bank's loan repayment from all locations in Ω_j when the common risk factor is θ. According to Inequality (1), entrepreneurs at z_i succeed if and only if $1 - m_B(z_i) \le \theta$. Hence the loan repayment from entrepreneurs at $z_i \in \Omega_j$ to bank j is $r_B 1_{\{1-m_B(z_i)\le\theta\}}$; the total loan repayment from all locations is $\int_{z_i\in\Omega_j} r_B 1_{\{1-m_B(z_i)\le\theta\}}dz_i$. The term $\iota_B \int_{z_i\in\Omega_j} dz_i$ is bank j's total promised payment to depositors. To provide loans to all entrepreneurs at $z_i \in \Omega_j$, the bank must raise $\int_{z_i\in\Omega_j} dz_i$ units of funds from depositors. The promised per-unit return to depositors is ι_B because deposits are riskless under the protection of the insurance. Therefore, if the common risk factor is θ, then the monetary profit of bank j is

$$\varphi_j(\theta) \equiv \max\left\{\int_{z_i\in\Omega_j} r_B 1_{\{1-m_B(z_i)\le\theta\}}dz_i - \iota_B\int_{z_i\in\Omega_j}dz_i, 0\right\}.$$

Note that $\varphi_j(\theta) = 0$ if the total loan repayment cannot cover the total promised payment to depositors, because the bank is protected by limited liability. If $\varphi_j(\theta) > 0$, then the bank must pay $\tau_j\varphi_j(\theta)$ to the DIF as the premium for the deposit insurance. Therefore, the first term of (16) is $(1-\tau_j)\varphi_j(\theta)$, which is the residual monetary profit of the bank after paying the premium. The second term of (16) is the total monitoring costs incurred by the bank.

Next we look at how τ_j is fairly determined. The DIF needs to assume the payment to depositors only if the bank's loan repayment cannot cover the promised deposit payment. Therefore the expected payment from the DIF to bank j's depositors equals

$$\begin{aligned} EDI &\equiv E\left[\max\left\{\iota_B \int_{z_i \in \Omega_j} dz_i - \int_{z_i \in \Omega_j} r_B 1_{\{1-m_B(z_i)\leq\theta\}} dz_i, 0\right\}\right] \\ &= \int_0^1 \underbrace{\max\left\{\iota_B \int_{z_i \in \Omega_j} dz_i - \int_{z_i \in \Omega_j} r_B 1_{\{1-m_B(z_i)\leq\theta\}} dz_i, 0\right\}}_{\text{The amount paid by DIF when common risk factor is } \theta.} d\theta. \end{aligned}$$

Since the deposit insurance is fairly priced, we have

$$\tau_j E\left[\varphi_j(\theta)\right] = EDI \Leftrightarrow \tau_j = \frac{EDI}{E\left[\varphi_j(\theta)\right]}.$$

Inserting τ_j back to (16) and calculating the expected value will yield bank j's expected profit from all locations (denoted by Π_j):

$$\begin{aligned} \Pi_j &= \left(1 - \frac{EDI}{E\left[\varphi_j(\theta)\right]}\right) E\left[\varphi_j(\theta)\right] - \int_{z_i \in \Omega_j} C_B(m_B(z_i), s(z_i, j)) dz_i \qquad (17) \\ &= \left(E\left[\varphi_j(\theta)\right] - EDI\right) - \int_{z_i \in \Omega_j} C_B(m_B(z_i), s(z_i, j)) dz_i \\ &= \int_{z_i \in \Omega_j} \left(r_B m_B(z_i) - \iota_B - C_B(m_B(z_i), s(z_i, j))\right) dz_i, \end{aligned}$$

where the last equality holds because

$$\int_0^1 1_{\{1-m_B(z_i)\leq\theta\}} d\theta = \int_{1-m_B(z_i)}^1 d\theta = m_B(z_i).$$

According to Equation (17), bank j's profit from location z_i is given by Equation (3) when $s(z_i, j) = d$.

Proof of Lemma 1. A bank chooses $m_B(z_i)$ to maximize $\pi_B(z_i)$ (see Equation 3), yielding the following first order condition (FOC):

$$r_B - \frac{c_B}{(1-qd)} m_B(z_i) = 0 \Rightarrow m_B(z_i) \equiv \frac{r_B(1-qd)}{c_B}.$$

In the same way, we can show that $m_F(z_i) = r_F(z_i)/c_F$.

Proofs of Propositions 1 and 4. We prove Proposition 4 first. On the arc between banks i and $i+1$, banks i and $i+1$ will compete with each other if and only they are willing to serve location $z_i = \frac{1}{2N}$, which implies that $\pi_B(z_i) > 0$ when $d = \frac{1}{2N}$, $r_B = R$ and $m_B(z_i) = r_B(1 - qd)/c_B$ hold; the resulting inequality is Condition (4) when $N = N^0$; by assumption no banks will leave the market if there is no fintech threat, so $N = N^0$ indeed holds in the blockaded entry equilibrium.

Next we consider the case Condition (4) holds. Assume that bank i offers the loan rate r_i while bank $i+1$ offers r_{i+1}. The indifference location x^{eb} on the arc between banks i and $i+1$ is determined by

$$m_i(x^{eb})(R - r_i) = m_{i+1}(x^{eb})(R - r_{i+1}),$$

where $m_i(x^{eb}) = r_i\left(1 - qx^{eb}\right)/c_B$ while $m_{i+1}(x^{eb}) = r_{i+1}\left(1 - q(\frac{1}{N} - x^{eb})\right)/c_B$. Then bank i's profit is equal to

$$\Pi_i = \int_0^{x^{eb}} \left(\frac{(r_i)^2(1 - qz_i)}{2c_B} - \iota_B \right) dz_i,$$

which yields the following FOC wrt r_i:

$$f^{eb}(r_i) \equiv \underbrace{\int_0^{x^{eb}} \frac{\partial\left(\frac{(r_i)^2(1-qz_i)}{2c_B} - \iota_B\right)}{\partial r_i} dz_i + \left(\frac{(r_i)^2\left(1 - qx^{eb}\right)}{2c_B} - \iota_B \right) \frac{\partial x^{eb}}{\partial r_i}}_{r_i = r_{i+1} \text{ and } x^{eb} = 1/(2N) \text{ hold in the symmetric equilibrium}} = 0. \tag{18}$$

In the symmetric equilibrium, we have $r_i = r_{i+1} = r_B^{eb}$, which means $x^{eb} = 1/(2N)$ and

$$\left.\frac{\partial x^{eb}}{\partial r_i}\right|_{r_i = r_{i+1} = r_B^{eb}} = \frac{(2N - q)\left(R - 2r_B^{eb}\right)}{4Nq\left(R - r_B^{eb}\right) r_B^{eb}}. \tag{19}$$

Then the FOC (18) then can be reduced to

$$\frac{2q\left(R - r_B^{eb}\right)\left(r_B^{eb}\right)^2\left(1 - \frac{q}{4N}\right)}{c_B} + \left(\frac{\left(r_B^{eb}\right)^2\left(1 - \frac{1}{2N}q\right)}{2c_B} - \iota_B \right)\left(R - 2r_B^{eb}\right)(2N - q) = 0, \tag{20}$$

which has a unique solution r_B^{eb} in the region $\left(\frac{R}{2}, R\right)$. Note that r_B^{eb} cannot be smaller than $\frac{R}{2}$ because then $\frac{\partial x^{eb}}{\partial r_i} > 0$ would hold, which cannot be the equilibrium result. Therefore, the equilibrium loan rate r_B^{eb} is the unique solution of (20) in the region $\left(\frac{R}{2}, R\right)$.

Next we prove Proposition 1. We provide a sketch of the proof first and then give the proof in detail. In the first step, we can show that for given N, there exist $\underline{\underline{c}}_F(N)$

and $\bar{\bar{c}}_F(N)$ $(> \underline{\underline{c}}_F(N))$ such that fintech is blockaded if and only if $c_F \geq \bar{\bar{c}}_F(N)$, that fintech entry is prevented if and only if $\underline{\underline{c}}_F(N) \leq c_F < \bar{\bar{c}}_F(N)$, and that fintech entry is allowed if and only if $c_F < \underline{\underline{c}}_F(N)$. In the second step, we need to show that as c_F decreases, the profit of a bank staying at the market will weakly decrease, hence N will also weakly decrease. Finally, we need to show that if fintech entry is not blockaded (resp. is allowed) for a given N, then fintech entry is still not blockaded (resp. is still allowed) if N decreases. With all the statements above holding, $\bar{c}_F$ and $\underline{c}_F$ will exist.

Now we prove Proposition 1 in detail. First we need to prove the following lemma:

Lemma 8. *For a given N, there exist $\underline{\underline{c}}_F(N)$ and $\bar{\bar{c}}_F(N)$ (which is higher than $\underline{\underline{c}}_F(N)$) such that fintech is blockaded if and only if $c_F \geq \bar{\bar{c}}_F(N)$, that fintech entry is prevented if and only if $\underline{\underline{c}}_F(N) \leq c_F < \bar{\bar{c}}_F(N)$, and that fintech entry is allowed if and only if $c_F < \underline{\underline{c}}_F(N)$.*

Proof of Lemma 8. First we show the existence of $\bar{\bar{c}}_F(N)$. In the blockaded entry equilibrium, entrepreneurial utility is lowest at location $z_i = 1/(2N)$, so fintech is blockaded only if

$$\frac{r_B^{eb}\left(1-\frac{q}{2N}\right)\left(R-r_B^{eb}\right)}{c_B} \geq \overline{U}_F = \frac{\overline{r}_F(R-\overline{r}_F)}{c_F}.$$

Since $\overline{r}_F$ is also a function of c_F, in the proof we sometimes use write $\overline{r}_F$ as $\overline{r}_F(c_F)$ to highlight that $\overline{r}_F$ is not independent of c_F. Obviously, $\overline{r}_F(c_F)$ is weakly increasing in c_F according to Lemma 1.

Therefore $\bar{\bar{c}}_F(N)$ is determined by the following equation:

$$\frac{r_B^{eb}\left(1-\frac{q}{2N}\right)\left(R-r_B^{eb}\right)}{c_B} = \frac{\overline{r}_F\left(\bar{\bar{c}}_F(N)\right)\left(R-\overline{r}_F\left(\bar{\bar{c}}_F(N)\right)\right)}{\bar{\bar{c}}_F(N)}. \tag{21}$$

Therefore, if $c_F < \bar{\bar{c}}_F(N)$, the blockaded entry equilibrium cannot be sustained.

If c_F is smaller than $\bar{\bar{c}}_F(N)$, then there are two possible cases: the allowed entry case and the prevented entry case. Fintech entry must be allowed if

$$c_F < \frac{c_B\overline{r}_F(c_F)\left(R-\overline{r}_F(c_F)\right)}{\overline{r}_B(0)\left(R-\overline{r}_B(0)\right)}, \tag{22}$$

where $\overline{r}_B(0)$, define in Lemma 2, is a bank's loan rate that maximizes an entrepreneur's utility when bank-borrower distance d is 0. When Condition (22) holds, $\overline{U}_F$ is always higher than the the entrepreneurial utility bank i could bring at any location, so banks cannot serve any entrepreneurs. Hence the fintech will serve all entrepreneurs in the lending market if Condition (22) holds.

Next we consider the case $\frac{c_B \overline{r}_F(c_F)(R-\overline{r}_F(c_F))}{\overline{r}_B(0)(R-\overline{r}_B(0))} \leq c_F < \overline{\overline{c}}_F(N)$. If fintech entry is allowed, then it means bank i no longer compete with bank $i+1$. To see this, we assume that bank i offers loan rate r_i^{ea} while bank $i+1$ offers r_{i+1}^{ea} when fintech entry is allowed. Let $z_i = z_F \in \left[0, \frac{1}{N}\right]$ be a location served by the fintech. Then obviously the following relation must hold

$$\overline{U}_F \geq \max\left\{\frac{r_i^{ea}\left(1-qz_F\right)\left(R-r_i^{ea}\right)}{c_B}, \frac{r_{i+1}^{ea}\left(1-q\left(\frac{1}{N}-z_F\right)\right)\left(R-r_{i+1}^{ea}\right)}{c_B}\right\}$$

because at location $z_i = z_F$ it is the fintech that can offer entrepreneurs a weakly higher expected utility. Then for locations $z_i \in [0, z_F]$, the following inequality must hold

$$\overline{U}_F \geq \frac{r_{i+1}^{ea}\left(1-q\left(\frac{1}{N}-z_i\right)\right)\left(R-r_{i+1}^{ea}\right)}{c_B},$$

which means the fintech is more competitive than bank $i+1$ at locations $z_i \in [0, z_F]$. In other words, bank i need only consider the competitive pressure from the fintech at $z_i \in [0, z_F]$. Reasoning symmetrically, bank $i+1$ need only consider the competitive pressure from the fintech at $z_i \in \left[z_F, \frac{1}{N}\right]$. Hence there is no direct competition between banks i and $i+1$ when fintech entry is allowed.

We look at the competition between bank i and the fintech when fintech entry is allowed. Let x^{ea} denote the indifference location where an entrepreneur is indifferent between bank i and the fintech when fintech entry is allowed. Then x^{ea} is determined by

$$\frac{r_i^{ea}\left(1-qx^{ea}\right)\left(R-r_i^{ea}\right)}{c_B} = \overline{U}_F \Leftrightarrow x^{ea} = \frac{\left(1-\frac{c_B\overline{U}_F}{r_i^{ea}\left(R-r_i^{ea}\right)}\right)}{q}. \tag{23}$$

Bank i serves all entrepreneurs at $z_i \in [0, x^{ea}]$ when competing with the fintech. Since banks i and $i+1$ are symmetric, the allowed entry case can arise only if $x^{ea} < \frac{1}{2N}$ holds in the allowed entry equilibrium; otherwise bank i will touch and compete directly with bank $i+1$, which means fintech entry is not allowed.

If fintech entry is allowed, bank i's expected lending profit is

$$\int_0^{x^{ea}} \left(\frac{\left(r_i^{ea}\right)^2\left(1-qz_i\right)}{2c_B} - \iota_B\right) dz_i. \tag{24}$$

The derivative of (24) wrt r_i^{ea} yields:

$$\left(\int_0^{x^{ea}} \frac{\partial\left(\frac{\left(r_i^{ea}\right)^2(1-qz_i)}{2c_B}-\iota_B\right)}{r_i^{ea}} dz_i + \left(\frac{\left(r_i^{ea}\right)^2\left(1-qx^{ea}\right)}{2c_B}-\iota_B\right)\frac{\partial x^{ea}}{\partial r_i^{ea}}\right)$$

$$= \frac{1}{q}\underbrace{\left(\begin{array}{c}\frac{1}{2}\frac{r_i^{ea}}{c_B}\left(1-\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_i^{ea}\left(R-r_i^{ea}\right)}\right)\left(1+\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_i^{ea}\left(R-r_i^{ea}\right)}\right)\\ +\left(\frac{\overline{r}_F(R-\overline{r}_F)r_i^{ea}}{2c_F\left(R-r_i^{ea}\right)}-\iota_B\right)\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_i^{ea}\left(R-r_i^{ea}\right)}\frac{\left(R-2r_i^{ea}\right)}{r_i^{ea}\left(R-r_i^{ea}\right)}\end{array}\right)}_{\text{denoted by } f^{ea}\left(r_i^{ea}\right)} = \frac{1}{q}f^{ea}\left(r_i^{ea}\right).$$

It can be shown that $f^{ea}\left(\frac{R}{2}\right) \geq 0$ and $\lim_{r_i^{ea}\to R} f^{ea}\left(r_i^{ea}\right) < 0$ hold. Meanwhile, it is easy to show that the solution to $f^{ea}\left(r_i^{ea}\right) = 0$ is unique in the interval $\left[\frac{R}{2}, R\right)$; we denote this unique solution in the interval $\left[\frac{R}{2}, R\right)$ as r_B^{ea}. Therefore, the equilibrium bank loan rate in the allowed entry case is r_B^{ea}. Any solution that is smaller than $\frac{R}{2}$ cannot be the equilibrium solution because $\frac{\partial x^{ea}}{\partial r_i^{ea}} > 0$ will hold when $r_i^{ea} < \frac{R}{2}$, which is impossible in an equilibrium.

Next we show that fintech entry cannot be allowed if c_F is smaller than but sufficiently close to $\overline{\overline{c}}_F(N)$. According to the formulae of $\overline{\overline{c}}_F(N)$ and x^{ea} (see Equation 21 and 23), if $c_F = \overline{\overline{c}}_F(N)$ and if fintech entry is allowed, then we can show that $x^{ea} = 1/(2N)$ holds when bank i chooses $r_i^{ea} = r_B^{eb}$. Then we have

$$f^{ea}\left(r_B^{eb}\right)\Big|_{c_F=\overline{\overline{c}}_F(N)} = \underbrace{\left(\int_0^{1/(2N)} \frac{\partial\left(\frac{\left(r_i^{ea}\right)^2(1-qz_i)}{2c_B}-\iota_B\right)}{r_i^{ea}} dz_i + \left(\frac{\left(r_i^{ea}\right)^2\left(1-\frac{q}{2N}\right)}{2c_B}-\iota_B\right)\frac{\partial x^{ea}}{\partial r_i^{ea}}\right)}_{\text{inserting } r_i^{ea}=r_B^{eb} \text{ after taking derivatives wrt } r_i^{ea}}.$$

It is easy to show that

$$\left.\frac{\partial x^{ea}}{\partial r_i^{ea}}\right|_{r_i^{ea}=r_B^{eb},x^{ea}=1/(2N)} = \frac{(2N-q)\left(R-2r_B^{eb}\right)}{2Nq\left(R-r_B^{eb}\right)r_B^{eb}} < \left.\frac{\partial x^{eb}}{\partial r_i}\right|_{r_i=r_{i+1}=r_B^{eb}} < 0,$$

which means

$$f^{ea}\left(r_B^{eb}\right)\Big|_{c_F=\overline{\overline{c}}_F(N)} < f^{eb}\left(r_i\right)\Big|_{r_i=r_{i+1}=r_B^{eb}} = 0 \qquad (25)$$

after comparing $f^{ea}\left(r_B^{eb}\right)\Big|_{c_F=\overline{\overline{c}}_F(N)}$ with FOC (18) in the blockaded entry case. The Inequality (25) means that bank i's loan rate must be lower than r_B^{eb} if $c_F = \overline{\overline{c}}_F(N)$ and if fintech entry is allowed (i.e., $r_B^{ea} < r_B^{eb}$ must hold if $c_F = \overline{\overline{c}}_F(N)$); this means $x^{ea} > 1/(2N)$ must hold in the allowed entry case if $c_F = \overline{\overline{c}}_F(N)$ holds, which contradicts the fact that the allowed entry case can arise only if $x^{ea} < 1/(2N)$ holds. If c_F is smaller than but sufficiently close to $\overline{\overline{c}}_F(N)$, $x^{ea} > 1/(2N)$ must still hold because $f^{ea}(r_i^{ea})$ is a continuous function of r_i^{ea}; as a result, fintech entry cannot be allowed if c_F is smaller than but sufficiently close to $\overline{\overline{c}}_F(N)$.

If c_F is smaller than but sufficiently close to $\overline{\overline{c}}_F(N)$ (i.e., if $x^{ea} > 1/(2N)$), fintech entry is not allowed. Meanwhile, since the blockaded entry equilibrium is not sustained if $c_F < \overline{\overline{c}}_F(N)$ holds, fintech entry must be prevented. In the symmetric prevented entry equilibrium, bank i's loan rate that prevents fintech entry, denoted by $r_B^{ep} \in [R/2, R]$, is given by:

$$\frac{r_B^{ep}\left(1 - \frac{q}{2N}\right)\left(R - r_B^{ep}\right)}{c_B} = \overline{U}_F. \tag{26}$$

Because c_F is sufficiently close to $\overline{\overline{c}}_F(N)$, r_B^{ep} is sufficiently close to r_B^{eb}, which means $f^{ea}(r_B^{ep}) \leq 0$ holds; hence a bank (e.g., bank i) has no incentive to increase its loan rate from r_B^{ep} to allow fintech entry. Meanwhile, the relation $r_B^{ep} < r_B^{eb}$ implies that $f^{eb}(r_i)\big|_{r_i = r_{i+1} = r_B^{ep}} > 0$ hold (recall the FOC $f^{eb}(r_i)\big|_{r_i = r_{i+1} = r_B^{eb}} = 0$ in the blockaded entry case), which means bank i has no incentive to decrease its loan rate from r_B^{ep} to blockade fintech entry and compete only with bank $i+1$.

Now we show the existence of $\underline{\underline{c}}_F(N)$. When $c_F < \overline{\overline{c}}_F(N)$, fintech entry will be allowed if and only if $f^{ea}(r_B^{ep}) > 0$ holds, which is equivalent to $x^{ea} < 1/(2N)$. Therefore, we need only show that $x^{ea} \leq 1/(2N)$ will hold when c_F is sufficiently small and that x^{ea} is increasing in c_F in the allowed entry case. According to our previous analysis (see Inequality 22), $x^{ea} = 0$ must hold if $c_F = \frac{c_B \overline{r}_F (R - \overline{r}_F)}{\overline{r}_B(0)(R - \overline{r}_B(0))}$, so $x^{ea} \leq 1/(2N)$ will indeed hold when c_F is sufficiently small. The fact that x^{ea} is increasing in c_F in the allowed entry case is shown in the proof of Proposition 9. When $c_F = \underline{\underline{c}}_F(N)$, $x^{ea} = 1/(2N)$ must hold, which means $r_B^{ea} = r_B^{ep}$. Thus Lemma 8 is proved.

Next we need to prove the following lemma.

Lemma 9. *For a given N, a bank's lending profit, denoted by $\Pi_B(N, c_F)$, is a continuous function of c_F and is weakly increasing in c_F.*

Proof of Lemma 9. First we show that $\Pi_B(N, c_F)$ is a continuous continuous function of c_F for a given N. According to Lemma 8, we need only show that $\Pi_B(N, c_F)$ is continuous at $c_F = \overline{\overline{c}}_F(N)$ and at $c_F = \underline{\underline{c}}_F(N)$. If $c_F = \overline{\overline{c}}_F(N)$, then fintech entry is blockaded and a bank's loan rate is r_B^{eb}; a bank's lending profit in this case is given by:

$$\Pi_B(N, c_F) = \Pi_B^{eb}(N, c_F) \equiv 2\int_0^{1/(2N)} \left(\frac{\left(r_B^{eb}\right)^2 (1 - qz_i)}{2c_B} - \iota_B \right) dz_i.$$

If $\underline{\underline{c}}_F(N) \leq c_F < \overline{\overline{c}}_F(N)$, then a bank's lending profit in the prevented entry case is

$$\Pi_B(N, c_F) = \Pi_B^{ep}(N, c_F) \equiv 2\int_0^{1/(2N)} \left(\frac{\left(r_B^{ep}\right)^2 (1 - qz_i)}{2c_B} - \iota_B \right) dz_i.$$

Obviously we have $\lim_{c_F \to \overline{\overline{c}}_F(N)} \Pi_B^{ep}(N, c_F) = \Pi_B^{eb}\left(N, \overline{\overline{c}}_F(N)\right)$ because $\lim_{c_F \to \overline{\overline{c}}_F(N)} r_B^{ep} = r_B^{eb}$ holds according to Equation (21) and (26). Hence $\Pi_B(N, c_F)$ is continuous at $c_F = \overline{\overline{c}}_F(N)$.

If $c_F = \underline{\underline{c}}_F(N)$, then a bank's lending profit is $\Pi_B^{ep}\left(N, \underline{\underline{c}}_F(N)\right)$. If $c_F < \underline{\underline{c}}_F(N)$, then a bank's lending profit is

$$\Pi_B(N, c_F) = \Pi_B^{ea}(N, c_F) \equiv 2\int_0^{x^{ea}} \left(\frac{\left(r_B^{ea}\right)^2 (1 - qz_i)}{2c_B} - \iota_B \right) dz_i.$$

$\lim_{c_F \to \underline{\underline{c}}_F(N)} \Pi_B^{ea}(N, c_F) = \Pi_B^{ep}\left(N, \underline{\underline{c}}_F(N)\right)$ because $\lim_{c_F \to \underline{\underline{c}}_F(N)} r_B^{ea} = r_B^{ep}$ and $\lim_{c_F \to \underline{\underline{c}}_F(N)} x^{ea} = 1/(2N)$ hold according to the proof of Lemma 8. Therefore, $\Pi_B(N, c_F)$ is continuous at $c_F = \overline{\overline{c}}_F(N)$ and at $c_F = \underline{\underline{c}}_F(N)$.

Next we show that $\Pi_B(N, c_F)$ is weakly increasing in c_F. If $c_F \geq \overline{\overline{c}}_F(N)$, fintech entry is blockaded, so $\Pi_B(N, c_F)$ is independent of c_F. If $\underline{\underline{c}}_F(N) \leq c_F < \overline{\overline{c}}_F(N)$, fintech entry is prevented, so $\Pi_B(N, c_F)$ is increasing in c_F because r_B^{ep} is increasing in c_F according to Equation (26). If $c_F < \underline{\underline{c}}_F(N)$, fintech entry is allowed; in this case $\Pi_B(N, c_F)$ is increasing in c_F because both x^{ea} and r_B^{ea} are increasing in c_F in the allowed entry case (see the proofs of Propositions 9 and 10). Overall, $\Pi_B(N, c_F)$ is weakly increasing in c_F.

Next we need to prove the following lemma.

Lemma 10. *A bank's lending profit, denoted by $\Pi_B(N, c_F)$, is weakly decreasing in N.*

Proof of Lemma 10. We can ignore the restriction that N must be an integer and show that $\frac{\partial \Pi_B(N,c_F)}{\partial N} \leq 0$ always hold, which is a sufficient condition that ensures Lemma 10. If $c_F \geq \overline{\overline{c}}_F(N)$, then we can show that $\frac{\partial r_B^{ep}}{\partial N} < 0$ holds because of Equation (20). Therefore, $\frac{\partial \Pi_B(N,c_F)}{\partial N} = \frac{\partial \Pi_B^{eb}(N,c_F)}{\partial N} < 0$ holds in the blockaded entry case because of $\frac{\partial r_B^{ep}}{\partial N} < 0$ and $\frac{\partial x^{eb}}{\partial N} < 0$.

If $\underline{\underline{c}}_F(N) \leq c_F < \overline{\overline{c}}_F(N)$, have shown in the proof of Lemma 8 that bank i's optimal loan rate is r_B^{ep}, which is increasing in N according to Equation (26). For convenience, we use $r_B^{ep}(N)$ to represent the value of r_B^{ep} when the number of banks is N. In the prevented entry case, $\frac{\partial \Pi_B^{ep}(N,c_F)}{\partial N} \leq 0$ must hold; otherwise we can find a contradiction. Assume that the number of banks decreases from N to $N-\epsilon$. If $\Pi_B^{ep}(N,c_F) > \Pi_B^{ep}(N-\epsilon,c_F)$ holds, then bank i has incentive to deviate from offering $r_B^{ep}(N-\epsilon)$ after the decrease in bank number; specifically, if bank i deviates from $r_B^{ep}(N-\epsilon)$ to $r_B^{ep}(N)$ while all other banks offer $r_B^{ep}(N-\epsilon)$, then bank i can serve entrepreneurs at $z_i \in [0, 1/(2N)]$. Bank i's lending from after the deviation is exactly $\Pi_B^{ep}(N,c_F)$, which is higher than $\Pi_B^{ep}(N-\epsilon,c_F)$. This result contracts the fact that $r_B^{ep}(N-\epsilon)$ is banks' equilibrium loan rate in the prevented entry case when the number of banks is $N-\epsilon$. Therefore, $\Pi_B^{ep}(N,c_F) \leq \Pi_B^{ep}(N-\epsilon,c_F)$ must hold. As a result, $\frac{\partial \Pi_B^{ep}(N,c_F)}{\partial N} \leq 0$ must hold.

If $c_F < \underline{\underline{c}}_F(N)$, then obviously $\Pi_B(N,c_F)$, which is equal to $\Pi_B^{ea}(N,c_F)$, is independent of N because function $f^{ea}(r_i^{ea})$ is independent of N. Overall, $\Pi_B(N,c_F)$ is weakly decreasing in N.

Next we need to prove the following lemma.

Lemma 11. *Let N_1 and N_2 be two positive integers and $N_1 > N_2$. If fintech entry is allowed (resp. not blockaded) when $N = N_1$, then fintech entry is allowed (resp. not blockaded) when $N = N_2$.*

Proof of Lemma 11. Fintech entry is not blockaded if and only if

$$\frac{r_B^{eb}\left(R - r_B^{eb}\right)\left(1 - \frac{q}{2N}\right)}{c_B} < \overline{U}_F$$

holds. The inequality above still holds if N decreases because $\frac{\partial r_B^{eb}}{\partial N} < 0$ holds according to Equation (20).

Fintech entry is allowed if and only if $x^{ea} < 1/(2N)$ holds according to the proof of Lemma 8. Since $f^{ea}(r_i^{ea})$ is independent of N, x^{ea} is also independent of N. Therefore, if $x^{ea} < 1/(2N)$ holds for a given N, then $x^{ea} < 1/(2N)$ also holds when N decreases.

With Lemmas 8 to 11, we prove Proposition 1. When c_F is high enough (e.g., $c_F \to +\infty$), obviously fintech entry must be blockaded. By assumption, $\lambda(N^0)L$ is smaller than a bank's lending profit if there were no fintech shock (i.e., $\lambda(N^0)L < \Pi_B^{eb}(N^0, c_F)$), hence the number of banks is $N = N^0$ when fintech entry is blockaded. This means $\overline{c}_F$ is determined by the following equation (see Equation 21):

$$\frac{r_B^{eb}\left(1-\frac{q}{2N}\right)\left(R-r_B^{eb}\right)}{c_B}=\frac{\overline{r}_F\left(\overline{c}_F\right)\left(R-\overline{r}_F\left(\overline{c}_F\right)\right)}{\overline{c}_F}, \tag{27}$$

with $N=N^0$. Obviously, $\overline{c}_F=\overline{\overline{c}}_F\left(N^0\right)$ according to Lemma 8.

If $c_F<\overline{c}_F$, then fintech entry cannot be blockaded when $N=N^0$. Since $\Pi_B\left(N^0,c_F\right)$ is a continuous function of c_F (see Lemma 9), $\Pi_B\left(N^0,c_F\right)\geq\lambda\left(N^0\right)L$ must hold when c_F is smaller than but sufficiently close to $\overline{c}_F$, in which case $N=N^0$ still hold and, according to Lemma 8, fintech entry is prevented.

As c_F further decrease, $\Pi_B\left(N^0,c_F\right)<\lambda\left(N^0\right)L$ may hold, so some bank(s) may leave the market because of Lemmas 9 and 10. If some bank(s) leave the market, the number of banks N is determined by the following condition:

$$\Pi_B\left(N,c_F\right)\geq\lambda\left(N\right)L \text{ and } \lambda\left(N+1\right)L>\Pi_B\left(N+1,c_F\right). \tag{28}$$

Since $\Pi_B\left(N,c_F\right)$ is weakly increasing in c_F and decreasing in N (see Lemmas 9 and 10), Condition (28) implies that N is weakly increasing in c_F. Consequently, Lemma 11 ensures that fintech entry is not blockaded when $c_F<\overline{c}_F$.

According to Lemma 11 and the fact that N is weakly increasing in c_F, it is easy to find that if fintech entry is allowed for some c_F, then the entry is still allowed as c_F decreases. Therefore, to show the existence of $\underline{c}_F$, we need only show that there exists a c_F that makes fintech entry allowed. In the proof of Lemma 8, we have shown that $x^{ea}<1/\left(2N\right)$ will indeed hold when c_F is sufficiently small (e.g., when $c_F=\frac{c_B\overline{r}_F(R-\overline{r}_F)}{\overline{r}_B(0)(R-\overline{r}_B(0))}$, $x^{ea}=0$ holds), so indeed there exists a c_F that makes fintech entry allowed. As a result, $\underline{c}_F$ must exist.

Proof of Corollary 1. According to the proof of Proposition 4, $\overline{c}_F$ is determined by the Equation (27). According to FOC (20), $r_B^{eb}\in\left[\frac{R}{2},R\right)$ is increasing in q, c_B and ι_B, which means the left hand side (LHS) of Equation (27) is decreasing in q, c_B and ι_B. To ensure that Equation (27) holds, $\overline{c}_F$ must be increasing in q, c_B and ι_B.

Next we look at $\underline{c}_F$. Fintech entry is allowed if and only if $x^{ea}<1/\left(2N\right)$ holds according to the proof of Proposition 1. This means $\underline{c}_F$ is the lowest value of the c_F that ensures $x^{ea}\geq1/\left(2N\right)$ holds. If q, c_B or ι_B increases, then x^{ea} will decrease (see the proof of 9) while N will weakly decrease (see the proof of Corollary 2), which makes $x^{ea}\geq1/\left(2N\right)$ harder to hold. Therefore, $\underline{c}_F$ will increase as q, c_B or ι_B increases.

Proof of Proposition 2 and Corollary 2. According to the proof of Proposition

1, no banks will leave the the market when $c_F \geq \overline{c}_F$ or when c_F is smaller than but sufficiently close to $\overline{c}_F$. However, a bank's lending profit is weakly increasing in c_F. If c_F is sufficiently small, a bank's lending profit will be small than $\lambda(N^0)L$; for example, as c_F approaches $\frac{c_B \overline{r}_F (R-\overline{r}_F)}{\overline{r}_B(0)(R-\overline{r}_B(0))}$, a bank's profit will approach zero because x^{ea} will approach zero (see Condition 22). Hence $N^0 > N$ holds when c_F is sufficiently small.

Next we look at Corollary 2. The effect of L is simple. A higher L implies a higher $\lambda(N)L$, so the equilibrium number of banks will weakly decrease according to Condition (28).

For the effects of c_B, q, and ι_B, we need only show that a bank's profit (i.e., $\Pi_B(N, c_F)$) is weakly decreasing in c_B, q, and ι_B for a given N when fintech entry is not blockaded; recall that fintech entry is not blockaded when $c_F < c_F^0$ holds.

First we look at the effect of c_B. If fintech entry is prevented, $\Pi_B(N, c_F)$ is decreasing in c_B because r_B^{ep} is decreasing in c_B according to Equation (26). If fintech entry is allowed, then $\Pi_B(N, c_F)$ is decreasing in c_B because both x^{ea} and r_B^{ea} are decreasing in c_B in the allowed entry case (see the proofs of Propositions 9 and 10). Overall, $\Pi_B(N, c_F)$ is decreasing in c_B when fintech entry is not blockaded.

Next we look at the effect of q. If fintech entry is prevented, $\Pi_B(N, c_F)$ is decreasing in q because r_B^{ep} is decreasing in q according to Equation (26). If fintech entry is allowed, then $\Pi_B(N, c_F)$ is decreasing in q because x^{ea} is decreasing in q while r_B^{ea} is independent of q in the allowed entry case (see the proofs of Propositions 9 and 10). Overall, $\Pi_B(N, c_F)$ is decreasing in q when fintech entry is not blockaded.

Finally, we look at the effect of ι_B. If fintech entry is prevented, $\Pi_B(N, c_F)$ is decreasing in ι_B because r_B^{ep} is independent of ι_B according to Equation (26). If fintech entry is allowed, then r_B^{ea} is increasing in ι_B while x^{ea} is decreasing in ι_B (see the proofs of Propositions 9 and 10). In this case $\Pi_B(N, c_F)$ must be weakly decreasing in ι_B; otherwise there is a contradiction. Let ι_{B1} and ι_{B2} ($> \iota_{B1}$) be two values of ι_B and let $r_B^{ea}(\iota_B)$ be a bank's loan rate (i.e., the solution to $f^{ea}(r_B^{ea}) = 0$) when funding cost is ι_B. If

$$\Pi_B(N, c_F)\big|_{\iota_B=\iota_{B2}} > \Pi_B(N, c_F)\big|_{\iota_B=\iota_{B1}},$$

then a bank can offer $r_B^{ea}(\iota_{B2})$ when $\iota_B = \iota_{B1}$; this loan rate will bring the bank a profit that is higher than $\Pi_B(N, c_F)\big|_{\iota_B=\iota_{B2}}$ (and hence is also higher than $\Pi_B(N, c_F)\big|_{\iota_B=\iota_{B1}}$) because $\iota_{B2} > \iota_{B1}$. However this contradicts the fact that the bank's optimal loan rate is $r_B^{ea}(\iota_{B1})$ when $\iota_B = \iota_{B1}$, which implies the optimal profit $\Pi_B(N, c_F)\big|_{\iota_B=\iota_{B1}}$. Overall, $\Pi_B(N, c_F)$ is weakly decreasing in ι_B when fintech entry is not blockaded.

Proof of Proposition 3. First we consider the case that N^0 decreases. In this case it is sufficient to show that N will weakly decrease if one bank is taken out at random. If $\Pi_B(N^0, c_F) \geq \lambda(N^0) L$, then $N = N^0$ will hold in equilibrium if no bank is taken out. In this case, taking out a bank from the initial N^0 banks will decrease N.

Next we consider the case $0 < N < N^0$. Let N^{old} denote the number of banks staying at the market if no incumbent bank is taken out at $t = 0$. Then N^{old} is determined by the following inequalities:

$$\Pi_B\left(N^{old}, c_F\right) \geq \lambda\left(N^{old}\right) L \text{ and } \lambda\left(N^{old}+1\right) L > \Pi_B\left(N^{old}+1, c_F\right). \tag{29}$$

Now consider that a bank is taken out at random at $t = 0$, and let N^{new} denote the number of banks staying at the market in this case. If bank j ($j > N^{old}+1$) is taken out, then $N^{new} = N^{old}$ must hold because Condition (29) still holds (note that banks $1, 2..N^{old}+1$ are not taken out).

If bank j ($j = N^{old}+1$) is taken out, then $N^{new} = N^{old}$ must hold. First, since $\Pi_B\left(N^{old}, c_F\right) \geq \lambda\left(N^{old}\right) L$ holds, the number of banks is at least N^{old}. Meanwhile, since bank j ($j = N^{old}+1$) is taken out, one more bank (besides the N^{old} banks with lowest salvage values) will stay at the market only if $\Pi_B\left(N^{old}+1, c_F\right) \geq \lambda\left(N^{old}+2\right) L$ holds, which is impossible because Condition (29) implies

$$\lambda\left(N^{old}+2\right) L \geq \lambda\left(N^{old}+1\right) L > \Pi_B\left(N^{old}+1, c_F\right). \tag{30}$$

Therefore, $N^{new} = N^{old}$ must hold if bank j ($j = N^{old}+1$) is taken out.

If bank j ($j < N^{old}+1$) is taken out, then $N^{new} \leq N^{old}$ must hold; otherwise (i.e., if $N^{new} > N^{old}$) the following inequality must hold

$$\lambda\left(N^{old}+1\right) L \leq \underbrace{\lambda\left(N^{new}+1\right) L \leq \Pi_B\left(N^{new}, c_F\right)}_{\text{bank } N^{new}+1 \text{ is willing to stay}} \leq \Pi_B\left(N^{old}+1, c_F\right), \tag{31}$$

because bank $N^{new}+1$ must stay to ensure that there are in total N^{new} banks staying at the market; specifically, the N^{new} banks staying in the market are banks $1, 2...j-1, j+1...N^{new}+1$ since bank j ($j < N^{old}+1 \leq N^{new}$) is taken out. However, (31) contradicts (29); hence $N^{new} \leq N^{old}$ must hold. If $N^{new} = N^{old}$ holds, then it means bank $N^{old}+1$ must stay to ensure that there are in total N^{old} banks staying at the market (when bank

j ($j < N^{old} + 1$) is taken out), which means

$$\lambda \left(N^{old} + 1\right) L \leq \Pi_B \left(N^{old}, c_F\right). \tag{32}$$

Condition (32) does not contradict (29) and hence may hold. If it holds, then $N^{new} = N^{old}$; otherwise, $N^{new} < N^{old}$ must hold.

Overall, taking out a bank randomly at $t = 0$ will weakly decrease N. Therefore, decreasing N^0 will weakly reduce N.

Next we consider the case that N^0 increases. Increasing N^0 is actually a mirror case of decreasing N^0. Compared with the "new case" that some banks taken at random from the reserve pool enter the market, the original case without newly added banks can be viewed as taking out some incumbent banks from the new case. Therefore, the original case must have weakly lower N compared with the new case with newly added banks.

Proof of Proposition 5. This proposition has been proven in the proof of Lemma 8. See Equation (26).

Proof of Proposition 6. In the entry prevented case, r_B^{ep} is determined by Equation (26). As c_B or q increases, N will weakly decrease, so the LHS of Equation (26) will decrease. As a result, r_B^{ep} must decrease to ensure Equation (26) holds.

If c_F increases, N will weakly increase, so the LHS of Equation (26) will weakly increase. Meanwhile, the RHS of (26) will decrease. As a result, r_B^{ep} must decrease to ensure Equation (26) holds.

If L increases or N^0 decreases, N will weakly decrease, so the LHS of Equation (26) will weakly decrease. As a result, r_B^{ep} must decrease to ensure Equation (26) holds if N decreases.

Proof of Proposition 7. In the proof of Lemma 8, we have shown that fintech entry is allowed if and only if $x^{ea} < 1/(2N)$ and that bank i serves entrepreneurs at $z_i \in [0, x^{ea})$ in the allowed entry case. Symmetrically, bank $i + 1$ serves serves entrepreneurs at $z_i \in (1/N - x^{ea}, 1/N]$. Therefore, the fintech serves entrepreneurs at $z_i \in [x^{ea}, 1/N - x^{ea}]$.

Proof of Corollary 4. In the allowed entry case, the fintech competes with bank i at locations $z_i \in \left[0, \frac{1}{2N}\right]$. Because the fintech's profit at a location is increasing in its loan rate, $r_F(z_i)$ at $z_i \in \left[x^{ea}, \frac{1}{2N}\right]$ is determined by the following equation:

$$\frac{r_B^{ea}\left(R - r_B^{ea}\right)\left(1 - qz_i\right)}{c_B} = \frac{r_F\left(z_i\right)\left(R - r_F\left(z_i\right)\right)}{c_F} \text{ s.t. } r_F\left(z_i\right) \geq \overline{r}_F. \tag{33}$$

The LHS of Equation (33) is decreasing in z_i, so $r_F(z_i)$ is increasing in z_i. Symmetrically,

$r_F(z_i)$ is decreasing in z_i at locations $z_i \in \left(\frac{1}{2N}, \frac{1}{N} - x^{ea}\right]$.

At the indifference location $z_i = x^{ea}$, $r_F(z_i) = \overline{r}_F$ because of the definition of x^{ea}, which is given by Equation (23).

Proof of Proposition 8 and Corollary 5. First we consider the case $\iota_B = \iota_F$. In the allowed entry case, r_B^{ea} is determined by $f^{ea}(r_B^{ea}) = 0$. Note that

$$f^{ea}(r_B^{ea}) = \left(\int_0^{x^{ea}} \frac{\partial \left(\frac{\left(r_B^{ea}\right)^2 (1-qz_i)}{2c_B} - \iota_B \right)}{r_B^{ea}} dz_i + \left(\frac{\left(r_B^{ea}\right)^2 (1-qx^{ea})}{2c_B} - \iota_B \right) \frac{\partial x^{ea}}{\partial r_B^{ea}} \right).$$

Since $\frac{\partial x^{ea}}{\partial r_B^{ea}} < 0$ holds in equilibrium, it must hold that

$$\frac{\left(r_B^{ea}\right)^2 (1-qx^{ea})}{2c_B} - \iota_B > 0 \Rightarrow r_B^{ea} > \sqrt{\frac{2c_B\iota_B}{1-qx^{ea}}};$$

otherwise $f^{ea}(r_B^{ea}) > 0$ will hold. r_B^{ea} must also be higher than $\frac{R}{2}$ in equilibrium to ensure that $\frac{\partial x^{ea}}{\partial r_B^{ea}} < 0$. Therefore, $r_B^{ea} > \max\left\{\frac{R}{2}, \sqrt{\frac{2c_B\iota_B}{1-qx^{ea}}}\right\}$. Defining $c_{Bx} \equiv \frac{c_B}{1-qx^{ea}}$, we have that $r_B^{ea} > \max\left\{\frac{R}{2}, \sqrt{2c_{Bx}\iota_B}\right\}$. At $z_i = x^{ea}$, we have $r_F(x^{ea}) = \overline{r}_F$. Equation (23) can be simplified as follows:

$$\frac{r_B^{ea}\left(R - r_B^{ea}\right)}{c_{Bx}} = \frac{\overline{r}_F\left(R - \overline{r}_F\right)}{c_F}. \tag{34}$$

Equation (34) means $c_{Bx} < c_F$ and $r_B^{ea} > \overline{r}_F$ must hold because $r_B^{ea} > \max\left\{\frac{R}{2}, \sqrt{2c_{Bx}\iota_B}\right\}$, $\overline{r}_F = \left\{\frac{R}{2}, \sqrt{2c_F\iota_F}\right\}$ and $\iota_B = \iota_F$ hold.

Next we prove Corollary 5. Consider the case that N does not change when $c_F \in (\underline{c}_F - e, \underline{c}_F + e)$, where e is positive and sufficiently small (for example, $L = 0$ belongs to the case because $N = N^0$ always holds). In this case, we have $\lim_{c_F \to \underline{c}_F} x^{ea} = \frac{1}{2N}$ when fintech entry is allowed. Proposition 8 implies that $\frac{c_B}{1-q\frac{1}{2N}} < c_F$ must hold in the allowed entry case if $c_F \to \underline{c}_F$ and if $\iota_B = \iota_F$. If ι_F increases marginally from being equal to ι_B, then fintech entry can still be allowed after c_F decreases slightly, which will not change the relation $\frac{c_B}{1-q\frac{1}{2N}} < c_F$ because $f^{ea}(r_B^{ea})$ is a continuous function of r_B^{ea} and other parameters. Therefore, fintech entry can be allowed if $\frac{c_B}{1-\frac{1}{2N}q} < c_F$ and $\iota_B < \iota_F$ both hold.

Proof of Propositions 9 and 10. In the allowed entry case, according to the proof of Lemma 8, a bank's loan rate r_B^{ea} is determined by

$$\left(\begin{array}{c}\underbrace{\frac{1}{2c_B}\left(1-\frac{c_B\overline{r}_F\left(R-\overline{r}_F\right)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}\right)\left(1+\frac{c_B\overline{r}_F\left(R-\overline{r}_F\right)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}\right)}_{\text{term 1}}\\ +\underbrace{\left(\frac{\overline{r}_F\left(R-\overline{r}_F\right)}{2c_F\left(R-r_B^{ea}\right)}-\frac{\iota_B}{r_B^{ea}}\right)\frac{c_B\overline{r}_F\left(R-\overline{r}_F\right)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}\frac{\left(R-2r_B^{ea}\right)}{r_B^{ea}\left(R-r_B^{ea}\right)}}_{\text{term 2}}\end{array}\right)=0 \text{ s.t. } r_B^{ea}\in\left(\frac{R}{2},R\right). \tag{35}$$

Under Condition (6), it is easy to show that the first term (called "term 1") of the LHS of Equation (35) is positive, so term 2 is negative. Term 2 is simplified from $\left(\frac{\left(r_B^{ea}\right)^2\left(1-qx^{ea}\right)}{2c_B}-\iota_B\right)\frac{\partial x^{ea}}{\partial r_B^{ea}}$, where $\frac{\partial x^{ea}}{\partial r_B^{ea}}$ is negative while $\frac{\left(r_B^{ea}\right)^2\left(1-qx^{ea}\right)}{2c_B}-\iota_B$, which is a bank's profit at location $z_i=x^{ea}$, is positive.

Obviously, both terms 1 and 2 are independent of N and q, so L, N^0 - both affect N - and q have no effect on r_B^{ea}. x^{ea} is also independent of N, so L or N^0 does not affect x^{ea} either. According to Equation (23), x^{ea} is decreasing in q since r_B^{ea} is independent of q.

As c_F increases, terms 1 and 2 will increase (i.e., term 1 becomes more positive while term 2 becomes less negative) if r_B^{ea} does not adjust. As a result, r_B^{ea} must increase, which decreases both terms 1 and 2, to ensure that Equation (35) holds.

As c_B increases, terms 1 and 2 will decrease (i.e., term 1 becomes less positive while term 2 becomes more negative) if r_B^{ea} does not adjust. As a result, r_B^{ea} must decrease, which increases both terms 1 and 2, to ensure that Equation (35) holds.

As ι_B increases, term 1 will not change while 2 will increase (i.e., term 2 becomes less negative) if r_B^{ea} does not adjust. As a result, r_B^{ea} must increase, which decreases term 2, to ensure that Equation (35) holds.

Next we look at how c_F, c_B and ι_B affect x^{ea}. According to Equation (23), $x^{ea}=\frac{1}{q}\left(1-\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}\right)$. Denoting $\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}$ by β, obviously x^{ea} is decreasing in β. Since r_B^{ea} is increasing in ι_B, β is also increasing in ι_B. As a result, x^{ea} is decreasing in ι_B.

Equation (35) can be rewritten as follows:

$$\left(\underbrace{\frac{1}{2}\left(1-\beta\right)\left(1+\beta\right)}_{\text{term 1}}+\underbrace{\beta\left(\frac{1}{2}\beta-\frac{c_B\iota_B}{\left(r_B^{ea}\right)^2}\right)\frac{\left(R-2r_B^{ea}\right)}{\left(R-r_B^{ea}\right)}}_{\text{term 2}}\right)=0 \text{ s.t. } r_B^{ea}\in\left(\frac{R}{2},R\right). \tag{36}$$

We look at how β varies with c_F and c_B. If c_F increases but β does not adjust, then term 1 of LHS of (36) will not change while term 2 will become more negative because r_B^{ea} is increasing in c_F. As a result, β must decrease, which means x^{ea} must increase, to ensure that Equation (36) holds.

If c_B increases but β does not adjust, then term 1 of LHS of (36) will not change while term 2 will become less negative because r_B^{ea} is decreasing in c_B. As a result, β must increase, which means x^{ea} must decrease, to ensure that Equation (36) holds.

Proof of Corollary 7. We can show that

$$\frac{\partial\left(\left(\int_0^{x^{ea}} r_B^{ea}(1-qz_i)/c_B dz_i\right)/x^{ea}\right)}{\partial\iota_B}$$
$$= \frac{x^{ea}\int_0^{x^{ea}} \frac{\partial r_B^{ea}}{\partial\iota_B}\frac{(1-qz_i)}{c_B}dz_i + \frac{\partial x^{ea}}{\partial\iota_B}\left(x^{ea}\frac{r_B^{ea}(1-qx^{ea})}{c_B} - \int_0^{x^{ea}}\frac{r_B^{ea}(1-qz_i)}{c_B}dz_i\right)}{\left(x^{ea}\right)^2},$$

which must be positive because $\frac{\partial r_B^{ea}}{\partial\iota_B} > 0$, $\frac{\partial x^{ea}}{\partial\iota_B} < 0$ and $x^{ea}\frac{r_B^{ea}(1-qx^{ea})}{c_B} < \int_0^{x^{ea}}\frac{r_B^{ea}(1-qz_i)}{c_B}dz_i$. As a result, the average loan quality of bank i is increasing in ι_B in the allowed entry case.

Proof of Proposition 11 and Corollary 8. First we show how $r_F(z_i)$ is marginally affected by c_B, q and ι_B at $z_i \in (x^{ea}, 1/N - x^{ea})$. We can focus on location $z_i \in (x^{ea}, 1/(2N)]$ where the fintech competes with bank i. In the proof of Corollary 4, we have shown that $r_F(z_i)$ is determined by Equation (33) for $z_i \in (x^{ea}, 1/(2N)]$. Denoting $\frac{c_B\overline{r}_F(R-\overline{r}_F)}{c_F r_B^{ea}\left(R-r_B^{ea}\right)}$ by β, Equation (33) can be rewritten as follows:

$$\frac{1}{\beta} = \frac{r_F(z_i)(R-r_F(z_i))}{(1-qz_i)\overline{r}_F(R-\overline{r}_F)} \text{ s.t. } r_F(z_i) \geq \overline{r}_F. \tag{37}$$

As c_B increases, β will increase (see Proof of Propositions 9 and 10), so $r_F(z_i)$ will increase to ensure Equation (37) holds. As q increases, β will not change because r_B^{ea} is independent of q; as a result, $r_F(z_i)$ is independent of q for a given $z_i \in (x^{ea}, 1/(2N)]$. As ι_B increases, β will increase because r_B^{ea} is increasing in ι_B; as a result, $r_F(z_i)$ is increasing in ι_B. As L increases (or N^0 decreases), N will weakly decrease; but r_B^{ea} and hence β are independent of N. As a result, $r_F(z_i)$ is independent of L and N^0.

Next look at the average fintech loan rate. As L increases (or N^0 decreases), N will weakly decrease. For convenience, we ignore the restriction that N is an integer, and try to show that the derivative of average fintech loan rate with respect to N is negative. For symmetry reason, average fintech loan rate can be written as $\int_{x^{ea}}^{1/(2N)} r_F(z_i)/(1/(2N)-x^{ea})\,dz_i$.

It is easy to show that

$$\frac{\partial\left(\int_{x^{ea}}^{1/(2N)}\frac{r_F(z_i)}{1/(2N)-x^{ea}}dz_i\right)}{\partial N}=\frac{\int_{x^{ea}}^{1/(2N)}\frac{\partial r_F(z_i)}{\partial N}dz_i+\frac{\partial(1/(2N))}{\partial N}\left(r_F\left(\frac{1}{2N}\right)-\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i\right)}{(1/(2N)-x^{ea})^2}<0,$$

because x^{ea} is independent of N in the allowed entry case. Therefore, the average fintech loan rate is decreasing in N and hence weakly increasing in L (weakly decreasing in N^0), so is the average fintech loan quality.

The effect of c_B. For a given integer N, we can show that

$$\frac{\partial\left(\int_{x^{ea}}^{1/(2N)}\frac{r_F(z_i)}{1/(2N)-x^{ea}}dz_i\right)}{\partial c_B}=\frac{\left(\int_{x^{ea}}^{1/(2N)}\frac{\partial r_F(z_i)}{\partial c_B}dz_i-\frac{\partial x^{ea}}{\partial c_B}\left(r_F(x^{ea})-\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i\right)\right)}{(1/(2N)-x^{ea})^2}>0$$

because $\frac{\partial r_F(z_i)}{\partial c_B}>0$, $\frac{\partial x^{ea}}{\partial c_B}<0$ and $r_F(x^{ea})>\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i$; where the last inequality holds because $r_F(x^{ea})\geq\frac{R}{2}$ and $r_F(z_i)<R$ hold. Meanwhile, the average fintech loan rate is decreasing in N, which is weakly decreasing in c_B. Therefore, the average fintech loan rate is increasing in c_B.

The effect of q. For a given integer N, we can show that

$$\frac{\partial\left(\int_{x^{ea}}^{1/(2N)}\frac{r_F(z_i)}{1/(2N)-x^{ea}}dz_i\right)}{\partial q}=\frac{\left(-\frac{\partial x^{ea}}{\partial q}\left(r_F(x^{ea})-\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i\right)\right)}{(1/(2N)-x^{ea})^2}>0$$

because $\frac{\partial r_F(z_i)}{\partial q}=0$, $\frac{\partial x^{ea}}{\partial q}<0$ and $r_F(x^{ea})>\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i$. Therefore, the average fintech loan rate is increasing in q.

The effect of ι_B. For a given integer N, we can show that

$$\frac{\partial\left(\int_{x^{ea}}^{1/(2N)}\frac{r_F(z_i)}{1/(2N)-x^{ea}}dz_i\right)}{\partial \iota_B}=\frac{\left(\int_{x^{ea}}^{1/(2N)}\frac{\partial r_F(z_i)}{\partial \iota_B}dz_i-\frac{\partial x^{ea}}{\partial \iota_B}\left(r_F(x^{ea})-\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i\right)\right)}{(1/(2N)-x^{ea})^2}>0$$

because $\frac{\partial r_F(z_i)}{\partial \iota_B}>0$, $\frac{\partial x^{ea}}{\partial \iota_B}<0$ and $r_F(x^{ea})>\int_{x^{ea}}^{1/(2N)}r_F(z_i)\,dz_i$. Therefore, the average fintech loan rate is increasing in ι_B.

Proof of Lemma 3. For the existence of $\widetilde{c}_F$ and $\underset{\sim}{c}_F$, we provide a sketch of the proof. The way to show the existence of $\widetilde{c}_F$ and $\underset{\sim}{c}_F$ is the same as showing the existence of $\overline{c}_F$ and $\underline{c}_F$. In the first step, we can show that for given N, there exist $\underset{\approx}{c}_F(N)$ and $\widetilde{\widetilde{c}}_F(N)$ $(>\underset{\approx}{c}_F(N))$ such that fintech is blockaded if and only if $c_F\geq\widetilde{\widetilde{c}}_F(N)$, that fintech entry is prevented if and only if $\underset{\sim}{c}_F(N) \leq c_F < \widetilde{\widetilde{c}}_F(N)$, and that fintech entry is allowed if and only if $c_F < \underset{\sim}{c}_F(N)$. In the second step, we need to show that as c_F decreases, the profit of a bank staying at the market will weakly decrease, hence N will also weakly decrease. Finally, we need to show that if fintech entry is not blockaded (resp. is allowed) for a given N, then fintech entry is still not blockaded (resp. is still allowed) if N decreases. With all the statements above holding, $\widetilde{c}_F$ and $\underset{\sim}{c}_F$ will exist. We can show that Lemmas 8 to 11 indeed holds when banks can also discriminate. With Lemmas 8 to 11, $\widetilde{c}_F$ and $\underset{\sim}{c}_F$ will exist according to the proof of Proposition 1.

In the allowed entry case, fintech entry can serve location z_i if and only if

$$\overline{U}_F \geq \max\{\frac{(1-qz_i)\,\overline{r}_B(z_i)\,(R-\overline{r}_B(z_i))}{c_B}, \frac{\left(1-q\left(\frac{1}{N}-z_i\right)\right)\overline{r}_B\left(\frac{1}{N}-z_i\right)\left(R-\overline{r}_B\left(\frac{1}{N}-z_i\right)\right)}{c_B}\}. \tag{38}$$

The RHS of Inequality (38) is maximized when $z_i = 1/(2N)$. At locations $z_i \in [0, 1/(2N))$ (resp. $z_i \in (1/(2N, 1/N])$, the RHS of Inequality (38) is decreasing (resp. increasing) in z_i. Therefore, Inequality (38) holds in the middle region of the arc between banks i and $i+1$ when $c_F < \underset{\sim}{c}_F$ holds. Meanwhile, since $\overline{U}_F < \overline{U}_B(0)$ holds, $\hat{x}^{ea} \in (0, 1/(2N))$ must exist.

Proof of Proposition 12. We look at the arc between banks i and $i+1$. At location $z_i = \hat{x}^{ea}$, entrepreneurs are indifferent between bank i and the fintech. Since bank i can also price discriminate, both bank i and the fintech will offer their best loan rates, which implies the following equation:

$$\frac{\overline{r}_B(\hat{x}^{ea})\,(R-\overline{r}_B(\hat{x}^{ea}))}{\frac{c_B}{1-q\hat{x}^{ea}}} = \overline{U}_F = \frac{\overline{r}_F\,(R-\overline{r}_F)}{c_F}. \tag{39}$$

Since $\iota_B = \iota_F$, Equation (39) holds if and only if $\frac{c_B}{1-q\hat{x}^{ea}} = c_F$ holds.

Proof of Corollary 9. At location $z_i = \frac{1}{2N}$ bank i can provide utility

$$\overline{r}_B(\frac{1}{2N})\left(R-\overline{r}_B(\frac{1}{2N})\right)/\left(\frac{c_B}{1-\frac{1}{2N}q}\right),$$

which is higher than $\overline{U}_F$ if $\frac{c_B}{1-\frac{1}{2N}q} < c_F$ and $\iota_B < \iota_F$ both hold. Therefore, fintech entry cannot be allowed at locations $z_i \in [0, 1/(2N)]$. Reasoning symmetrically, fintech entry cannot be allowed at locations $z_i \in (1/(2N, 1/N]$ because of bank $i+1$'s competition. Overall, fintech entry is not allowed if $\frac{c_B}{1-\frac{1}{2N}q} < c_F$ and $\iota_B < \iota_F$ both hold.

Proof of Proposition 13. For a given N, a bank's profit must be weakly higher when banks can discriminate than when they cannot, because a bank has a larger choice set about its loan rate when it can price discriminate. Specifically, a bank can still offer a uniform loan rate r_B^{ea} even if it can price discriminate. Therefore, allowing banks to price discriminate will weakly increase a bank's lending profit when they compete with the fintech in the allowed entry case. As a result, N is weakly larger when banks can price discriminate than when they cannot.

Proof of Proposition 14. According to Lemma 5, bank i default with probability θ^*, where θ^* is determined by

$$\int_0^{\tilde{x}} r_B 1_{\{1-m_B(z_i)\leq\theta^*\}} dz_i = \tilde{x}\iota_B. \tag{40}$$

In the prevented entry case, $r_B = r_B^{ep}$, $\tilde{x} = \frac{1}{2N}$and $m_B(z_i) = \frac{r_B^{ep}(1-qz_i)}{c_B}$. The inequality $1 - m_B(z_i) \leq \theta^*$ is equivalent to $z_i \leq \frac{c_B(\theta^*-1)+r_B^{ep}}{r_B^{ep}q}$. Obviously $\frac{c_B(\theta^*-1)+r_B^{ep}}{r_B^{ep}q}$ must be smaller than $\tilde{x}$; otherwise the LHS of Equation (40) would be $\tilde{x}r_B$, which means Equation (40) cannot hold. The reason is that $r_B > \iota_B$ must hold to ensure non-negative profits for banks. Since $\frac{c_B(\theta^*-1)+r_B^{ep}}{r_B^{ep}q}$ is smaller than $\tilde{x}$, Equation (40) can be reduced to:

$$\theta^* = 1 + \frac{q\iota_B/(2N) - r_B^{ep}}{c_B}.$$

Therefore, θ^* is decreasing in N and r_B^{ep}. As c_F increases, both r_B^{ep} and N will increase, so θ^* will decrease, which means bank i's probability of default is decreasing in c_F. Consequently, fintech entry increases bank i's probability of default when it is prevented.

Proof of Lemma 7. Let r_B be the loan rate of a bank that serves location z_i. Then the bank's monitoring intensity is $m_B(z_i) = \frac{r_B(1-qd)}{c_B}$ according to Lemma 1. It is easy to show that $r_B = R$ is the unique solution to the following FOC:

$$\frac{\partial V_B(z_i)}{\partial r_B} = 0.$$

Therefore $V_B(z_i)$ is maximized when the bank's loan rate is R. In the same way we can show that $V_F(z_i)$ is maximized when the fintech's loan rate is R.

Proof of Proposition 15. In the prevented entry case, U_E is given by the following equation:

$$U_E = 2N\left(\int_0^{\frac{1}{2N}} \frac{(1-qz_i)\, r_B^{ep}\,(R - r_B^{ep})}{c_B} dz_i\right).$$

According to Equation (26), the equation $\frac{r_B^{ep}\left(R-r_B^{ep}\right)}{c_B} = \frac{\overline{U}_F}{\left(1-q\frac{1}{2N}\right)}$ holds, which means

$$U_E = 2N\left(\int_0^{\frac{1}{2N}} \frac{\overline{U}_F\left(1-qz_i\right)}{\left(1-q\frac{1}{2N}\right)}dz_i\right) = \frac{4N-q}{4N-2q}\overline{U}_F.$$

Note that U_E is decreasing in N. As a result, U_E is decreasing in c_F because $\overline{U}_F$ is decreasing in c_F and N is weakly increasing in c_F.

Proof of Proposition 16. In the prevented entry case, we have $\Pi_F = 0$. Since $K = 0$ and N does not vary with c_F, it is easy to show that

$$\frac{\partial W}{\partial c_F} = \frac{\partial\left(U_E + N\Pi_B\right)}{\partial c_F} = \frac{\partial\left(2N\int_0^{\frac{1}{2N}} V_B\left(z_i\right)dz_i\right)}{\partial c_F}$$

where $V_B\left(z_i\right)$ is the net value of the entrepreneurs' projects at z_i. $\frac{\partial W}{\partial c_F} > 0$ must hold because $V_B\left(z_i\right)$ is increasing in r_B^{ep}, which is increasing in c_F in the prevented entry case.