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# Information Technology and Lender Competition

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**Abstract**

We study how information technology (IT) affects lender competition, entrepreneurs' investment, and welfare in a spatial model. The effects of an IT improvement depend on whether it weakens the influence of lender–borrower distance on monitoring costs. If it does, it has a hump-shaped effect on entrepreneurs' investment and social welfare. If not, competition intensity does not vary, improving lender profits, entrepreneurs' investment, and social welfare. When entrepreneurs' moral hazard problem is severe, IT-induced competition is more likely to reduce investment and welfare. We also find that price discrimination is not welfare-optimal and that lenders will invest excessively in IT if it is cheap enough. Our results are consistent with received empirical work on lending to SMEs.

*JEL Classification:* G21, G23, I31

*Keywords:* credit, monitoring, FinTech, price discrimination, moral hazard, regulation

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# 1 Introduction

The banking industry is undergoing a digital revolution. A growing number of financial technology (FinTech) companies and BigTech platforms are engaging in traditional banking businesses using their innovative information and automation technologies.[1] Traditional banks are also moving from reliance on physical branches to adopting information technology (IT) and Big Data in response to the availability of technology and to changes in consumer expectations of service, which are two main drivers of digital disruption (FSB, 2019). Such a transformation spurs the banking sector's increasing investment in IT, allowing financial intermediaries to offer personalized services and to price discriminate. The COVID-19 pandemic has accelerated this digitalization process and fostered remote loan operations and the development and diffusion of IT in the credit market (Carletti et al., 2020).

How do the development and diffusion of information technology affect lending competition? How do lenders determine their IT investment? What are the welfare implications of IT progress? To answer those questions, we build a model of spatial competition in which lenders compete to provide entrepreneurs with loans. Lenders in our model refer to institutions that can provide loans in the credit market, including commercial banks, shadow banks, fintechs, or BigTech platforms. Our model will help to illuminate the following empirical results:

- Small business lending by banks with better IT adoption is less affected by the distance between banks and their borrowers (Ahnert et al., 2023).
- Borrowers with better access to bank financing request loans at lower interest rates on a fintech's platform (Butler et al., 2017). A bank will charge its borrowers higher loan rates if the borrowers get geographically closer to the bank or/and farther away from competing banks (Herpfer et al., 2022).
- Increased bank/branch industry specialization (e.g., in export/SME) lending curtails bank competition (Paravisini et al., 2023; Duquerroy et al., 2022).

[1]Prominent examples can be seen in China, where Alibaba and Tencent – the two largest BigTech companies – are active in a wide range of financial services that include payments, wealth management, and lending. In the United States, almost one-third of small and medium firms that sought financing applied with a FinTech firm or online lender, up from 19% in 2016 (US Federal Reserve's Small Business Credit Survey 2019). The annual growth rate of the volume of FinTech business lending in the United States was greater than 40% from 2016 to 2020 (Berg et al., 2022). See also Vives (2019).

- Banks with superior IT adoption have higher loan growth (Dadoukis et al., 2021 and Branzoli et al., 2023). Entrepreneurship (proxied by job creation by young enterprises) is stronger in US counties that are more exposed to IT-intensive banks (Ahnert et al., 2023).

- The relationship between bank competition and bank credit supply is hump-shaped (Di Patti and Dell'Ariccia, 2004).

The lending market is modeled as a linear city à la Hotelling (1929) where two lenders, located at the two extremes of the city, compete for entrepreneurs who are distributed along the segment. Entrepreneurs can undertake scalable risky investment projects, which may either succeed or fail, but have no initial capital. Hence, they require funding from lenders. Lenders have no direct access to investment projects and compete in a Bertrand fashion by posting their discriminatory loan rate schedules simultaneously. We take it as given that IT is advanced enough so that lenders can price flexibly. An entrepreneur can shirk and derive private benefits after obtaining loans from her lender; if she shirks, her investment project will fail for sure. In addition to financing entrepreneurs, another critical lender function is monitoring entrepreneurs to reduce their private benefits of shirking (see, e.g., Holmstrom and Tirole, 1997). Monitoring is more costly for a lender if there is a larger distance between the lender and the monitored entrepreneur. This distance can be physical[2] or in the characteristics space from the lender's expertise in certain sectors or industries.[3]

In the model, we distinguish two types of information technology: (a) information collection/processing technology (IT-basic for short) and (b) distance friction-reducing technology (IT-distance for short). Improvements in the two types of IT generate different outcomes. Specifically, an improvement in IT-basic lowers *evenly* the costs of monitoring entrepreneurs in different locations. Such an improvement in the lending sector does not affect lenders' relative cost advantage in different locations – for example, by improving the ability to collect more valuable data and process them with better computer hardware or information management software (e.g., desktop applications). In contrast, improving IT-distance reduces the negative effect of lender-borrower distance on monitoring costs.

[2]There is evidence that firm–lender *physical* distance matters for lending. See Degryse and Ongena (2005), Petersen and Rajan (2002) and Brevoort and Wolken (2009).

[3]Blickle et al. (2023) find that a bank "specializes" by concentrating its lending disproportionately on one industry where it has better knowledge. Paravisini et al. (2023) document that exporters to a given country are more likely to be financed by a bank with 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.

Such an improvement lowers more significantly the costs of monitoring entrepreneurs located farther away. For example, better internet connectivity and communication technology (e.g., video conferencing) reduce the physical distance friction. The improvement in remote learning devices, search engines, and artificial intelligence (AI) makes it easier to extend expertise, thereby reducing the expertise distance friction. Big Data and machine learning techniques may improve both IT-basic and IT-distance.[4]

We assume that lenders (say banks or fintechs) have no own capital to finance loans, so they must attract funds (say deposits or short-term debt) from risk-neutral investors. For simplicity, we do not model how lenders compete to develop relationships with investors or depositors, which we admit is a limitation.[5]

Under the set-up described, we study how information technology affects lender competition and obtain results consistent with the available empirical evidence. The equilibrium consequences of improvements in the two types of technology (IT-basic v.s. IT-distance) are compared. We find that by adopting more advanced IT, whatever its type, a lender can charge higher loan rates and provide more loans. This is so because a lender's IT progress increases its competitive advantage over its rival.

When both lenders make technological progress, that progress will not increase the overall competitive advantage of either lender. In this case, different types of IT progress can yield different results. If IT progress reduces the costs of monitoring an entrepreneur without altering lenders' relative cost advantage (i.e., IT-basic improves), lenders' competition intensity will not be affected. In this case, the loan rates that lenders offer to entrepreneurs do not vary; lenders become more profitable and provide more loans because monitoring is now cheaper (i.e., monitoring efficiency is higher). However, if IT progress involves a weakening in the influence of lender-borrower distance on monitoring costs (i.e., IT-distance improves), lenders' competition intensity will increase because their differentiation becomes smaller. Then, the loan rates offered to entrepreneurs decline for both lenders. Such a differentiation-reducing effect, when strong enough, will decrease lenders' profits despite the fact that IT progress makes monitoring cheaper.

The two types of IT have different effects on lenders' loan supply. IT-basic progress

[4]There are many companies (e.g., Zestfinance, Scienaptic systems, Datarobot, Underwrite.ai) that help the financial industry improve information processing via Big Data and machine learning techniques, thus transforming soft data into hard data. See also Boot et al. (2021).

[5]Drechsler et al. (2021) emphasize the importance of the deposit franchise for banks to increase their market power over retail deposits, allowing them to borrow at rates that are low and insensitive to market interest rates. Matutes and Vives (1996) and Cordella and Yeyati (2002) study bank competition for deposits within a similar spatial competition framework, but in their models, banks can directly invest in risky assets.

increases lenders' loan supply because it improves lenders' monitoring efficiency without reducing their differentiation and monitoring incentives. Higher monitoring efficiency allows lenders to monitor more loans at lower costs, translating into a higher loan supply.

In contrast, the effect of IT-distance progress on lenders' loan supply is "hump-shaped". IT-distance progress generates three effects on loan supply: First, it improves lenders' monitoring efficiency, tending to increase their loan supply. Second, lenders' differentiation and loan rates decrease, increasing entrepreneurs' skin in the game and alleviating moral hazard; this effect also tends to increase loan supply. Finally, lenders' skin in the game decreases, reducing their monitoring incentives and willingness to provide loans. The first two effects dominate and increase lenders' loan supply when IT-distance is not sufficiently advanced (i.e., when lender differentiation is high), while the last effect – the decrease in lenders' monitoring incentives – dominates and reduces lenders' loan supply when IT-distance is sufficiently advanced. Moreover, as entrepreneurs' moral hazard problem becomes more severe, the last effect will be more likely to dominate the first two. The reason is that a more severe moral hazard problem increases the need for monitoring, hence making the provision of monitoring incentives (determined by lenders' skin in the game) more important to credit supply.

Our model can shed light on the competition between a traditional bank – which has better access to firm data and hence an advantage in IT-basic – and a fintech lender with better IT-distance and lack of firm data. With its better IT-basic, the bank can ensure a positive market share because it has higher monitoring efficiency than the fintech when serving firms sufficiently close to the bank. The implication is that although fintechs, with their advantage in IT-distance, can bring competitive pressure to banks, the latter will not be completely replaced. Moreover, if the bank has a cheaper funding source (e.g., deposits) than the fintech, then the bank will offer a lower loan rate and a smaller loan size than the fintech lender when serving entrepreneurs of similar characteristics.

When lenders endogenously determine their levels of IT, both lenders will acquire the best possible IT (i.e., improve both IT-basic and IT-distance to the highest level) if their lending profits can cover the IT investment costs. In this case, lender differentiation disappears, inducing extremely intense lender competition. Such an IT investment equilibrium traps lenders in a prisoner's dilemma: Both lenders would make higher profits if they invested less in IT-distance, but neither lender is willing to deviate. The reason is that when lender differentiation is low, a lender's IT investment has a strong business-stealing effect, giving rise to lenders' excessively high IT investment incentives.

A lender's welfare-maximizing loan rate does not depend on its IT. This rate represents the socially optimal way to share the project value between an entrepreneur and her lender. Although a lender's IT determines the value of a project it finances (i.e., the size of the pie), the welfare-maximizing way to share the pie must balance the severity of the entrepreneur's moral hazard and the lender's monitoring incentive, which is a trade-off independent of the lender's IT. The implication is that lenders' price discrimination will generate inefficient equilibrium outcomes: A lender will price aggressively at far-away locations – where the lender's IT advantage is low – to gain as much business as possible while at locations close to the lender's area of specialization it will price very high to exploit its high IT advantage. Such a strategy does not balance well the severity of moral hazard and the lender's monitoring incentive at each location. Regulators can improve welfare by setting a proper reference loan rate for lenders and limiting their ability to price discriminate.

Finally, we analyze the equilibrium welfare effects of information technology progress. We find that more intense competition is not always welcome from the perspective of social welfare. When competition in the lending market is not intense, increasing competition intensity improves welfare because it substantially increases entrepreneurs' skin in the game and alleviates their moral hazard problem. Yet "too much" competition can reduce social welfare because high competition intensity will decrease lenders' skin in the game and their monitoring incentives, thereby reducing lenders' willingness to provide more loans. Hence, an improvement in IT-distance may or may not benefit social welfare owing to the consequent increased lender competition (caused by the decrease in lender differentiation). IT-distance progress will be more likely to reduce social welfare when entrepreneurs' moral hazard problem is more severe because the need for monitoring will increase in this case, making lenders' monitoring incentives more crucial. In fact, if information technology is cheap to acquire, lenders are trapped in a prisoner's dilemma and choose a very low level of differentiation, excessive from the social point of view. In contrast, improving lenders' IT-basic brings no differentiation effect and hence improves welfare unambiguously.

**Related literature.** Our work builds on the spatial competition models of Hotelling (1929) and Thisse and Vives (1988) but focuses on lenders' competition to finance entrepreneurs' projects. Villas-Boas and Schmidt-Mohr (1999) build a spatial lending competition model in which banks offer menus of contracts with different collateral levels to sort borrowers of different qualities. Their focus is on how competition affects the collateral requirements of contracts, while ours is on how IT affects lender competition.

Several papers have emphasized the importance of monitoring in lending.[6] Almazan (2002) studies how lender capitalization, interest rates, and regulatory shocks can affect lender competition and monitoring efficiency in a spatial competition model where a lender's monitoring expertise decreases with the lender-borrower distance. In Almazan's model, the only difference between lenders is the levels of their capital; lenders cannot strategically choose loan rates because loan contracts are offered by entrepreneurs, who have all bargaining power vis-a-vis lenders. In our work, lenders differ in their IT, and the strategic pricing of lenders is based on their competitive advantage – which is affected by information technology. Martinez-Miera and Repullo (2019) examine the effectiveness of monetary and macroprudential policies in addressing a financial system's risks within a framework where lender monitoring can increase the probability that investing in an entrepreneur yields a positive return; this set-up is different from our model where monitoring reduces entrepreneurs' private benefits of shirking. Bouvard et al. (2022) study lending and monitoring in a market where a bigtech and competitive banks can provide loans and monitor entrepreneurs. In addition to providing loans, the bigtech itself is a monopolistic platform where entrepreneurs (i.e., merchants) can serve buyers, giving rise to a cross-side network externality. Their paper studies how the network externality affects the bigtech's lending strategy and how the credit market is segmented. Unlike the aforementioned papers, our model focuses on (a) how different types of IT progress (IT-basic v.s. IT-distance) generate different equilibrium outcomes on lenders' monitoring, market power, loan supply, and welfare, and (b) whether lenders' IT investment is efficient from the social point of view.

Our study also belongs to the literature that studies information technology and lending competition. Hauswald and Marquez (2003) in an adverse selection model find that improving an informed lender's ability to process information strengthens the "winner's curse" faced by an uninformed lender, decreases the intensity of lender competition, and increases the loan rate that borrowers are expected to pay. Hauswald and Marquez (2006) extend that model by allowing (a) endogenous investment by lenders in information processing technology and (b) lender-borrower distance to harm the precision of lenders' information. Similarly to our work, these authors find that the equilibrium loan rates received by borrowers are decreasing in the lender-borrower distance and in the intensity of lender competition (measured by the number of lenders). However, the mechanism behind our results differs since there is no scope for a winners' curse in our model. Furthermore, our results differ from their models, in which an improvement in the entire

[6] See, e.g., Diamond (1984) and Holmstrom and Tirole (1997) for pioneering work.

lending sector's IT will soften lender competition; lenders' IT investment is decreasing in the intensity of lender competition; social welfare is increasing in the intensity of lender competition if competition is already very intense. In contrast, we find that lender competition is either intensified or unaffected by the lending sector's IT improvements, depending on the type of the improved IT; lenders may have extremely strong incentives to invest in IT even if lender competition is highly intense, in which case lenders are trapped in a prisoner's dilemma; and social welfare is decreasing in the intensity of lender competition if competition is very intense. In addition, our work analyzes the relationship between entrepreneurs' moral hazard and the welfare effects of IT progress.

In a model where a traditional bank and a fintech lender compete to extend loans, He et al. (2023) analyze the effects of "open banking" – an information sharing mechanism that enables borrowers to share their customer data stored in a bank with a fintech that has advanced information processing technology but less access to customer data. They find that open banking increases the fintech's screening ability and competitiveness but that it can soften lending competition and hurt borrowers if the fintech is "over-empowered" by the data sharing mechanism. Our work has a different focus: we distinguish two types of information technology and compare their different equilibrium consequences. Moreover, in He et al. (2023), the improvement of the fintech's screening efficiency – which potentially brings adverse welfare effects – is driven by the presence of an exogenous open banking policy, while in our model, socially undesirable IT improvements can arise from lenders' endogenous technology investment.

Finally, we propose a theoretical framework relevant to the empirical literature on information technology adoption in the lending market, which has thrived owing to the rise of FinTech in recent years.[7] To start with, there is considerable evidence showing that IT makes non-traditional data – 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., 2023; Netzer et al., 2019), contract terms (Kawai et al., 2022; Hertzberg et al., 2018), mobile phone call records (Björkegren and Grissen, 2020), digital footprints (Agarwal et al., 2021; Berg et al., 2020), and cashless payment information (Ghosh et al., 2022; Ouyang, 2023) – useful for assessing the quality of borrowers. Moreover, a wide stream of research documents the lending efficiency increase brought about by information technology. Frost et al. (2019) report that, in Argentina, credit assessment based on

[7]Philippon (2016) claims that the existing financial system's inefficiency can explain the emergence of new entrants that bring novel technology to the sector. Gopal and Schnabl (2022) show that most of the increase in fintech lending to SMEs after the 2008 financial crisis substituted for a bank lending reduction.

Big Data (e.g., platform transactions and the reputation of sellers) and processed with machine learning techniques has outperformed credit bureau ratings in terms of predicting the loss rates of small businesses. Liu et al. (2022) find that a BigTech lender has superior information about entrepreneurs in its ecosystem, so it can extend loans to borrowers underserved by banks without incurring greater risks.[8]

Several papers provide evidence consistent with our results. Branzoli et al. (2023) and Dadoukis et al. (2021) find that banks with higher IT adoption have larger loan growth; this is consistent with our finding that an improvement of a lender's IT increases the loan volume the lender can extend. Ahnert et al. (2023) document that small business lending by banks with higher IT adoption is less affected by the distance between the bank headquarters and their borrowers. Our model aligns with the findings since we show that a lender's geographic reach will be extended if the lender adopts better information technology. Ahnert et al. (2023) also find that job creation by young enterprises, a proxy for entrepreneurship, is stronger in US counties that are more exposed to IT-intensive banks; consistent with this finding, our model shows that IT-basic progress in the lending sector will encourage lenders to provide more loans to entrepreneurs. However, IT-distance progress will intensify lender competition, so its effect on lenders' loan supply is hump-shaped, which is consistent with Di Patti and Dell'Ariccia (2004).

The Paycheck Protection Program (PPP) launched by the US Small Business Administration (SBA) also highlights the importance of technology.[9] However, we will refrain from explaining those results within our framework because PPP loans - when properly used by borrowers - are forgivable and carry a uniform loan rate of 1%, which drastically diminishes the space for lenders' monitoring and strategic pricing.[10]

The rest of our paper proceeds as follows. Section 2 presents the model setup. Section 3 examines the lending market equilibrium with given information technology. Sec-

[8]Furthermore, Fuster et al. (2019) estimate that technology-based lenders process mortgage applications 20% faster than traditional banks without incurring greater default risk. Buchak et al. (2018) find that lenders with advanced technology can offer more convenient services to borrowers and hence charge higher loan rates in the US mortgage market than traditional banks.

[9]Erel and Liebersohn (2021) find that fintech lenders extend PPP loans to small businesses that are poorly served by the banking system (e.g., ZIP codes with fewer bank branches and lower incomes or industries with little ex-ante small business lending). Kwan et al. (2022) show that banks with better IT originate more PPP loans – especially in areas with more severe COVID-19 outbreaks, higher levels of Internet use, and more intense bank competition.

[10]PPP loans aim to help small businesses pay their employees and additional fixed expenses during the COVID-19 pandemic. Under SBA's interpretation of the initial bill, PPP loans can be forgiven if two conditions are satisfied: (a) loans are used to cover payroll costs, mortgage interest, rent, and utility costs; (b) employee counts and compensation levels are maintained. See Granja et al. (2022) for a detailed introduction and an evaluation of the program.

tion 4 studies how lenders endogenously determine their IT investment. Section 5 provides a welfare analysis of information technology progress. We conclude in Section 6 with a summary of our findings. Appendix A presents all the proofs. Appendix B deals with the extension where lenders have heterogeneous funding costs.

## 2 The model

**The economy and players.** The economy is represented by a linear "city", of length 1, that is inhabited by entrepreneurs and lenders. At each location, there is one penniless entrepreneur. A point on the city represents the characteristics of the entrepreneur (type of project, technology, geographical position, industry, . . .) at this location, and two close points mean that the entrepreneurs in those locations are similar.

There are two lenders, labeled by $i = \{1, 2\}$, located at the two extremes of the city. Hence, a lender is closer to some entrepreneurs than to others. This means, for example, that lenders are specialized in different sectors of the economy (see Paravisini et al., 2023 for export-related lending, Duquerroy et al., 2022 for SME lending and Giometti and Pietrosanti, 2023 for syndicated corporate loans). If the distance between an entrepreneur and lender 1 is $z$, we say that the entrepreneur is located at (location) $z$. As a result, the distance between the entrepreneur at $z$ and lender 2 is $1-z$. Figure 1 gives an illustration of the economy.

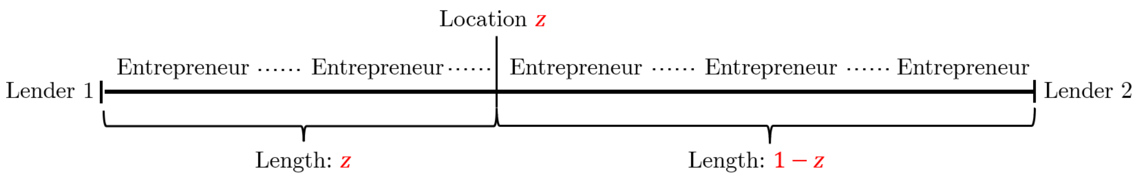


**Figure 1:** The Economy.

**Entrepreneurs and investment projects.** Each entrepreneur has no initial capital but is endowed with a scalable risky investment project; hence, entrepreneurs require funding from lenders to undertake projects. An entrepreneur's project return depends on (a) whether the entrepreneur shirks and (b) the entrepreneur's investment size. If the entrepreneur at $z$ invests $I(z)$ and does not shirk, her project yields the following risky return (where $R > 0$):

$$\tilde{R}(I(z)) = \begin{cases} I(z)R & \text{with probability } p, \\ 0 & \text{with probability } 1-p. \end{cases}$$

In the case of success (resp. failure) – which happens with probability $p$ (resp. $1-p$) – the entrepreneur's project yields $I(z)R$ (resp. 0). The success probability $p \in (0, 1)$ is a constant.[11] For entrepreneurs who do not shirk, their projects are perfectly correlated (i.e., succeed or fail together).

**Lending, shirking, and monitoring.** Lenders post loan rates and provide funds to entrepreneurs. If the entrepreneur at $z$ borrows $I_i(z)$ units of funds from lender $i$ ($i = \{1, 2\}$) at loan rate $r_i(z)$, the entrepreneur must promise to repay $I_i(z)r_i(z)$.

Entrepreneurs can shirk and derive private benefits after borrowing from lenders. Following Holmstrom and Tirole (1997), we assume that shirking brings the entrepreneur (at $z$) a total private benefit of $I_i(z)B$ if the entrepreneur is not monitored, where $B > 0$ is the marginal private benefit derived from a unit of funding. If the entrepreneur shirks, her investment project fails (i.e., returns 0) for sure.

Lenders, however, can monitor their borrowers to reduce the private benefits entrepreneurs can derive. Specifically, by monitoring the entrepreneur at $z$, lender $i$ decreases her private benefit of shirking from $I_i(z)B$ to $I_i(z)B - m_i(z)$, where $m_i(z) > 0$ is the lender's *monitoring intensity* at $z$. As a result, the entrepreneur will not shirk if and only if the following incentive compatibility (IC) condition holds:

$$pI_i(z)(R - r_i(z)) \geq I_i(z)B - m_i(z) \quad \text{[IC]}. \tag{1}$$

If the entrepreneur does not shirk, her expected utility (i.e., profit) equals the left-hand side of (1): she will receive $I_i(z)(R - r_i(z))$ in the event of success, which happens with probability $p$. If she shirks, her utility becomes $I_i(z)B - m_i(z)$ since the project returns 0.

**Monitoring and information technology.** If the entrepreneur at $z$ borrows from lender $i$ and is monitored with intensity $m_i(z)$, then the lender incurs the non-pecuniary monitoring cost

$$C_i(m_i(z), z) = \frac{c_i}{2(1 - q_i s_i)}(m_i(z))^2. \tag{2}$$

[11] We could also allow the entrepreneur to influence the success probability by exerting effort. Then, an additional effect is introduced, but our results are robust to this extension. The analysis is available upon request.

Here $c_i \geq \underline{c} > 0$, $q_i \in [0, 1)$, and $s_i$ is the distance between lender $i$ and location $z$; hence, we have $s_i = z$ (resp. $s_i = 1 - z$) if $i = 1$ (resp. $i = 2$). The parameters $c_i$ and $q_i$ are inverse measures of the efficiency of lender $i$'s information technology. Parameter $c_i$ is the slope of marginal monitoring costs when lender-borrower distance is zero, and hence represents lender $i$'s basic monitoring efficiency (*IT-basic*). Parameter $q_i$ (*IT-distance* of lender $i$) measures the negative effect of lender-borrower "distance friction" on the lender's information collection and data analysis.[12] The cost function (2) captures the idea that a lender has a greater capacity to discipline nearby borrowers and must expend more effort to monitor entrepreneurs who are more distant from the lender's expertise or geographic location.[13] The lower bound $\underline{c}$ of $c_i$ is assumed to be positive to ensure that monitoring will allways be costly.

***Remark:*** The cost function (2) has two crucial properties when $q_1 = q_2 = q$ and $c_1 = c_2 = c$. First, the ratio of the two lenders' monitoring costs at location $z$ (i.e., $C_1(m_1, z)/C_2(m_2, z)$) is independent of $c$ for any given $m_1$ and $m_2$:

$$\frac{C_1(m_1, z)}{C_2(m_2, z)} = \frac{1 - q(1 - z)}{1 - qz} \left(\frac{m_1}{m_2}\right)^2.$$

This property implies that increasing $c$ does not affect a lender's relative cost advantage, although it makes monitoring more costly for both lenders. The second property is

$$\frac{\partial^2 \left(\frac{C_1(m_1,z)}{C_2(m_2,z)}\right)}{\partial z \partial q} = \frac{2(1 - q(1 - z))}{(1 - qz)^3} \left(\frac{m_1}{m_2}\right)^2 > 0, \tag{3}$$

which means that the sensitivity of the relative cost advantage to $z$ is increasing in $q$. Note that $C_1(m_1, z)/C_2(m_2, z)$ is increasing in $z$. Therefore, a higher $q$ not only makes monitoring more costly but also magnifies the importance of lender specialization by increasing the importance of distance in determining the relative cost advantage of a lender's monitoring.

***Interpretation of monitoring***. Lenders typically monitor their borrowers through information collection and covenant restrictions (Wang and Xia, 2014; Minnis and Sutherland, 2017; Gustafson et al., 2021; Branzoli and Fringuellotti, 2022). Specifically, lenders can collect entrepreneurs' data (e.g., by onsite visits or frequently requesting information)

[12] A similar classification of technology can be found in Boot et al. (2021).

[13] This is consistent with Giometti and Pietrosanti (2023) who document that lenders specialize in lending to specific industries because of their information advantages in monitoring those industries.

and assess how the business is doing and whether there is a diversion of funds towards private benefits. If borrowers are not acting appropriately, lenders can provide warnings and threats, which discipline borrowers and potentially improve their behavior. If the collected information shows a breach of covenants, lenders can obtain control rights and directly intervene to fix borrowers' behavior. Such intervention is easier for BigTech lenders since they have advantages in information collection and contract enforcement in their ecosystems (Liu et al., 2022); in addition, they can threaten to exclude misbehaving borrowers from future use of their platforms (Frost et al., 2019 and Li and Pegoraro, 2023). With advanced information technology (such as the abundance of comprehensive transactional and locational data on borrowers' online activities and machine learning techniques), this kind of monitoring process can be conducted almost on a real-time basis (Chen et al., 2022).

To give a more specific interpretation to parameters $q_i$ and $c_i$ of the monitoring cost function (2), we assume that lender $i$'s monitoring intensity $m_i(z)$ at $z$ is determined by two factors: data analysis and distance friction:

$$m_i(z) \equiv \underbrace{\alpha_i \tau_i(z)}_{\text{data analysis}} \overbrace{\sqrt{1 - q_i s_i}}^{\text{distance friction}},$$

where $\alpha_i$ measures lender $i$'s efficiency of information processing and $\tau_i(z)$ is the amount of information (data) the lender acquires about the entrepreneur at $z$. The data analysis factor, $\alpha_i \tau_i(z)$, reflects the idea that monitoring relies on collecting and processing information about the firm. Monitoring is more effective if the lender has more information about the firm (i.e., if $\tau_i(z)$ is higher) or if the lender has a better model for processing the data (i.e., if $\alpha_i$ is larger). However, the effectiveness of a lender's data analysis must be discounted by a distance friction factor $\sqrt{1 - q_i s_i}$ because a lender may not have a uniform capability to collect and analyze the information of entrepreneurs of different characteristics.

The distance friction can be interpreted in two ways. First, we can view $s_i$ as the "physical distance" between location $z$ and lender $i$. Physical distance matters because first-hand borrower information often contains soft information that is hard to perfectly convey to distant loan officers (see Liberti and Petersen, 2019); in this case, the distance friction factor reflects the informativeness loss in the process of remote information transmission. In contrast, if an entrepreneur is physically close to the lender, loan officers can closely communicate with the borrower, avoiding the loss of soft information. The second way is to view $s_i$ as the "expertise distance" between an entrepreneur's characteristics and lender $i$'s s specialization. The expertise distance matters because the effectiveness of an information processing model will be lower when it is used to deal with firms beyond the model's intended scope of application. For example, the framework for analyzing a food company's information cannot be highly effective if applied to a real estate company.

We further assume that acquiring information amount $\tau_i(z)$ will incur a cost of $\gamma_i(\tau_i(z))^2/2$ for lender $i$, where $\gamma_i$ measures the lender's cost of information acquisition. If the lender chooses monitoring intensity $m_i\,(z)$ for the entrepreneur at $z$, the amount of information (i.e., $\tau_i(z)$) needed is equal to $m_i\,(z)/(\alpha_i\sqrt{1-q_i s_i})$, which will cost the lender

$$\frac{\gamma_i}{2\alpha_i^2\,(1-q_i s_i)}\,(m_i\,(z))^2\,. \tag{4}$$

Letting $c_i \equiv \gamma_i/\alpha_i^2$, the cost of monitoring the entrepreneur at location $z$ with intensity $m_i\,(z)$ is exactly given by the cost function (2). Therefore, $c_i$ can be interpreted as the *cost of acquiring an efficiency unit of information* at zero distance, which inversely measures a lender's basic efficiency of information acquisition and processing (i.e., IT-basic).

Technologies that decrease $c_i$ are related to improvements in information acquisition (i.e., a lower $\gamma_i$) and processing (i.e., a higher $\alpha_i$), as shown in the following examples. Advances in chip technology and cloud computing/storage increase $\alpha_i$. Adopting better software (e.g., desktop applications) improves the efficiency of document assembly and information classification and processing, which facilitates both information acquisition and data analyzing (i.e., decreases $\gamma_i$ and increases $\alpha_i$, see He et al., 2022). Exploiting new sources of information (like transaction data and digital footprints) with machine learning (ML) techniques also decreases $c_i$ because it extends the pool of valuable information (i.e., decreases $\gamma_i$) and upgrades information processing methods (i.e., increases $\alpha_i$).[14]

One consequence of technological progress is the increased availability of cheap but imprecise data (see Dugast and Foucault, 2018). In our model, the abundance of such data can be represented by a decrease in both $\gamma_i$ and $\alpha_i$. As information availability increases, $\gamma_i$ will decrease because information acquisition becomes easier. However, the decrease in data quality increases the difficulty of information processing, thereby reducing $\alpha_i$. A

[14] ML can process real-time borrower data quickly at large volumes and low operating costs (Huang et al., 2020). Mester et al. (2007) find that transaction information in borrowers' accounts - which provides ongoing data on borrowers' activities - is useful for lenders' monitoring. Dai et al. (2023) show that monitoring borrowers' digital footprints can increase the repayment likelihood on delinquent loans by 26.5% because digital footprints (e.g., cell phone, email or/and apps footprints) reveal borrowers' social networks and physical locations, thereby increasing lenders' ability to intervene and enforce the repayment of borrowers.

lender's basic monitoring efficiency will decrease (i.e., $c_i$ increases) if the lower $\alpha_i$ (caused by low-quality data) dominates.

Technologies that decrease $q_i$ can diminish the physical distance friction (e.g., improvements in communication) or the expertise friction (such as extending the competence of human capital or hardening soft information). The diffusion of the internet and the development of communication technology (like smartphones, mobile apps, social media, or video conferencing) facilitate remote information collection and exchange, reducing the friction caused by the lender-borrower physical distance. The friction of the expertise distance can be weakened if an IT improvement facilitates lenders' expansion of specialized areas. For example, improvements in human capital, facilitated by remote learning, better search engines, and AI (like GPT-4), make it easier for loan officers to process the information of firms they do not specialize in, thereby decreasing $q_i$. The emergence of code-sharing platforms (like Github) is another example that can facilitate lenders' expertise extension.

**Table 1: Technology Improvements and Monitoring Efficiency**

| Improvement of efficiency | Related technology |
|---|---|
| Decreasing $c_i$<br>(improvement in collecting or/and processing information) | ML with big/unconventional data<br>advances in cloud storage and computing, information management software |
| Decreasing $q_i$ (physical distance friction)<br>(improvement in communication) | Diffusion of internet, video conferencing, smartphone, mobile apps, social media |
| Decreasing $q_i$ (expertise distance friction)<br>(extending competence of human capital/ hardening soft information) | ML with big/unconventional data, remote learning and AI |

Some technologies decrease both $c_i$ and $q_i$: ML with Big Data decreases $c_i$ by improving lender $i$'s ability to acquire and process information. It also helps to harden soft information (e.g., digital footprints) and hence reduces the reliance on lenders' expertise in certain areas, which lowers $q_i$. Table 1 summarizes the technology improvements and the corresponding effects on monitoring efficiency.

The difference between a traditional bank and a fintech lender can be reflected in parameters $q_i$ and $c_i$. Compared with banks, fintechs tend to have better IT-distance (i.e., lower $q_i$) since they connect digitally with entrepreneurs and process information with automatic algorithms. In contrast, banks may have higher basic monitoring efficiency (i.e., lower $c_i$) because they usually have better access to firm information.[15] Banks and

[15]Banks' advantage in the access to customer data is the rationale of the Open Banking initiative

fintechs have different abilities to acquire information (measured by $\gamma_i$) and to process it (measured by $\alpha_i$). Better access to firm information by banks shows in a lower $\gamma_i$ than fintech lenders. Fintechs' more capable IT infrastructure shows in a higher $\alpha_i$. Therefore, a bank will have better basic monitoring efficiency than a fintech if the bank's advantage in information acquisition dominates the disadvantage in the capability of information processing.

**Funding source.** We assume lenders have no capital to finance their loans, so they must attract deposits or short-term debt from competitive risk-neutral investors. Investors' funding supply to lender $i$ is perfectly elastic when the lender's expected return to investors is no less than their break-even return $f$, which can be viewed as their marginal funding cost.[16] The promised nominal return of lender $i$ to its investors is denoted by $d_i$, which must be set to make investors break even. We assume $pR - f > 0$, meaning that entrepreneurs' projects can generate positive expected returns net of investors' funding cost $f$.

**Non-trivial moral hazard.** Throughout the paper, we assume that the marginal private benefit $B$ is sufficiently large such that the following inequality holds:

$$pR - B < f, \tag{5}$$

which implies that, without monitoring, an entrepreneur's expected pledgeable income for each unit of borrowed funding is smaller than investors' break-even return $f$. The left-hand side of (5) is an entrepreneur's expected marginal pledgeable income when she is not monitored. To see this, consider that the entrepreneur at $z$ borrows from lender $i$ with the loan rate $r_i(z)$. Without monitoring, she will not shirk if and only if $p(R-r_i(z)) \geq B$, implying $pr_i(z) \leq pR - B$; that is, the expected marginal return the entrepreneur can pledge to lender $i$ is at most $pR - B$.

Inequality (5) implies that, without monitoring, lenders are unwilling to finance entrepreneurs since their expected pledgeable income cannot cover investors' funding costs. Hence, entrepreneurs' moral hazard problem is non-trivial, and lenders must monitor their entrepreneurs when lending.[17] In addition, we assume $B < f$, implying that shirk-

launched by several governments, including the European Union and the United Kingdom. See Babina et al. (2023) and He et al. (2023).

[16] In Appendix B, we let the two lenders have different marginal funding costs.

[17] If Inequality (5) does not hold, entrepreneurs' moral hazard becomes trivial. In this case, competition will force lender $i$ to set $r_i(z) = f/p$, provide unlimited loans, and choose $m_i(z) = 0$. Entrepreneurs earn infinite profits.

ing is always socially undesirable since it cannot generate a non-negative return net of investors' marginal funding cost.

**An entrepreneur's investment size.** After an entrepreneur chooses a lender to approach, she must also determine the size of the loans to borrow (which equals her investment size). However, lenders can set loan size upper bounds (e.g., credit lines) for their entrepreneurs to limit moral hazard. Specifically, if the entrepreneur at $z$ approaches lender $i$ for funding, the lender can set a loan size upper bound $\overline{I_i(z)}$ to cap the entrepreneur's investment $I_i(z)$ (i.e., $I_i(z) \in [0, \overline{I_i(z)}]$).

**Competition with discriminatory loan pricing.** Lenders compete in a localized Bertrand fashion to attract entrepreneurs. Lender $i$ follows a discriminatory pricing policy in which the loan rate $r_i(z)$ varies as a function of the entrepreneurial location $z$.[18]

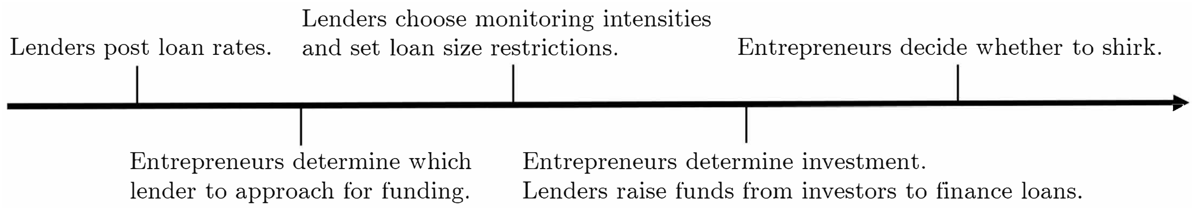


**Figure 2:** Timeline.

The timing of the duopoly lending game is shown in Figure 2. First, lenders post loan rate schedules simultaneously. Once the loan rate schedules are chosen and posted, entrepreneurs decide which lender to approach for funding. Given entrepreneurs' decisions and the loan rates of each lender, lender $i$ chooses its optimal monitoring intensity $m_i(z)$ and loan size (i.e., investment size) restriction $\overline{I_i(z)}$ depending on its entrepreneurs' locations. Entrepreneurs choose their investment sizes, under the restriction $I_i(z) \in [0, \overline{I_i(z)}]$. To finance the loans, lender $i$ raises funds from investors and promises them a nominal return $d_i$. Finally, entrepreneurs determine whether to shirk.

Note that loan size restriction $\overline{I_i(z)}$ and monitoring intensity $m_i(z)$ are determined after entrepreneurs have decided which lender to borrow from. In practice, detailed loan characteristics (like maximum loan size, the frequency that borrowers report information, and how the lender disciplines borrowers) are hard to pre-commit credibly at the beginning.[19]

[18] Degryse and Ongena (2005) document spatial discrimination in loan pricing. See also Agarwal and Hauswald (2010) and Herpfer et al. (2022).

[19] For example, according to the Fair Credit Reporting Act, credit card issuers can lower borrowers'

In Section 4, we will consider how lenders simultaneously choose their information technologies (i.e., lender $i$ determines $q_i$ and $c_i$) at an IT investment stage before the Bertrand competition takes place.

***Remark (alternative timeline):*** In the timeline above, we let lender $i$ determine $\overline{I_i(z)}$ and $m_i(z)$ together for convenience. Our model can also work with an alternative timeline in which lender $i$ chooses its monitoring intensity $m_i(z)$ *after* raising funds from investors and promising a nominal return $d_i$.[20] This adjustment in the timeline will not affect the model results because investors cannot observe $\overline{I_i(z)}$ or $m_i(z)$, which means $d_i$ is not a function of $\overline{I_i(z)}$ or $m_i(z)$. As a result, lender $i$ must take $d_i$ (or the anticipated value of $d_i$) as given no matter when it determines $m_i(z)$.

# 3 Equilibrium

This section characterizes the equilibrium of lenders' loan rate schedule competition and analyzes its implications. We first derive some optimal decisions of lenders and entrepreneurs, solve for equilibrium loan rates, analyze how improvements in information technology affect the equilibrium outcomes, and finally, characterize the competition between a bank and a fintech lender.

Since lenders' loan rates can vary with entrepreneurial locations, there is localized Bertrand competition between lenders at each location. Without loss of generality, we concentrate on location $z$ and analyze how lenders set loan rates to compete for the entrepreneur at $z$.

credit limits at will. Furthermore, banks can refuse to waive borrowers' covenant violations, triggering renegotiations and reducing committed loans (Chodorow-Reich and Falato, 2022), and can adjust their monitoring frequency as policies or borrowers' financial conditions change (Cerqueiro et al., 2016 and Gustafson et al., 2021).

[20]The alternative timeline in detail: First, lenders post loan rate schedules simultaneously. Second, entrepreneurs decide which lender to approach for funding. Given entrepreneurs' decisions and the loan rates of each lender, lender $i$ chooses its loan size restriction $\overline{I_i(z)}$. Then, entrepreneurs choose their investment sizes, under the restriction $I_i(z) \in [0, \overline{I_i(z)}]$; lender $i$ raises funds from investors and promises them a nominal return $d_i$. Next, lender $i$ determines the monitoring intensity $m_i(z)$. Finally, entrepreneurs determine whether to shirk.

## 3.1 Optimal monitoring intensity, loan size restriction, and entrepreneurs' decisions

It is easy to see that the entrepreneur at $z$ always chooses the highest possible loan size (i.e., $I_i(z) = \overline{I_i(z)}$ holds when she is served by lender $i$). The entrepreneur's expected utility is as follows:

$$\max \left\{ I_i(z)p\left(R - r_i(z)\right), I_i(z)B - m_i(z) \right\}. \tag{6}$$

According to the timeline, $r_i(z)$, $m_i(z)$, and $\overline{I_i(z)}$ have already been determined and hence taken as given when the entrepreneur chooses $I_i(z)$, so $I_i(z) = \overline{I_i(z)}$ is obviously the optimal choice that maximizes the utility (6).

**Optimal monitoring intensity.** Lender $i$ can anticipate $I_i(z) = \overline{I_i(z)}$ when determining its monitoring intensity $m_i(z)$ at $z$. Since an entrepreneur's shirking implies the failure of her project and a zero return to her lender, lenders always have incentives to prevent their entrepreneurs from shirking, yielding the following lemma.

**Lemma 1.** *If the entrepreneur at $z$ borrows from lender $i$ at the loan rate $r_i(z)$, lender $i$'s optimal monitoring intensity for the entrepreneur is given by:*

$$m_i(z) = \overline{I_i(z)}(B - p(R - r_i(z))), \tag{7}$$

*where $\overline{I_i(z)}$ is the lender's loan size upper bound at $z$.*

With $I_i(z) = \overline{I_i(z)}$, Lemma 1 means Condition (1) holds with equality. For lenders, the only benefit of costly monitoring is to prevent entrepreneurs' shirking. Hence, lender $i$ will choose $m_i(z)$ as low as possible, subject to Condition (1), which ensures that the entrepreneur will not shirk.

According to Equation (7), a higher monitoring intensity is needed as the entrepreneur's investment size (i.e., loan size) increases. The reason is that a larger loan size implies more private benefits must be reduced (by monitoring) to ensure Condition (1). Consistent with the result, Heitz et al. (2023) document that a bank will monitor a borrower more frequently if the loan size is larger.

In addition, note that $m_i(z)$ is increasing in $B - p(R - r_i(z))$, which reflects the severity of the entrepreneur's moral hazard. To see this, recall that $p(R - r_i(z))$ is the marginal expected return to the entrepreneur at $z$ if she does not shirk. Thus $B - p(R - r_i(z))$ measures the additional utility she can derive by shirking. As $B - p(R - r_i(z))$ increases, shirking becomes more attractive, so a higher monitoring intensity is needed to prevent shirking. Obviously, increasing $r_i(z)$ will worsen the entrepreneur's moral hazard problem (i.e., increasing $B-p(R-r_i(z)))$ because it reduces $R-r_i(z)$, which is the entrepreneur's skin in the game.

**Optimal loan size restriction.** According to the timeline, an entrepreneur has decided which lender to borrow from *before* lenders determine their loan size restrictions. If the entrepreneur at $z$ approaches lender $i$, then the lender's expected profit from financing the entrepreneur can be written as

$$\pi_i(z) = \underbrace{\overline{I_i(z)}(pr_i(z) - f)}_{=pI_i(z)(r_i(z)-d_i) \text{ with } d_i=f/p} - \frac{c_i}{2(1-q_is_i)}(m_i(z))^2. \tag{8}$$

The first term of $\pi_i(z)$ is the entrepreneur's expected loan repayment minus the lender's expected payment to investors. When monitoring prevents shirking, lender $i$ will receive entrepreneurs' full loan repayment when their projects succeed. Specifically, the entrepreneur at $z$ repays $\overline{I_i(z)}r_i(z)$ to lender $i$ in the event of success; the lender then returns $\overline{I_i(z)}d_1$ to investors (here $I_i(z) = \overline{I_i(z)}$ is used), earning the monetary profit $\overline{I_i(z)}(r_i(z) - d_i)$.

Investors can anticipate: (a) lender $i$ will prevent its entrepreneurs' shirking, and (b) it will fully repay investors (resp. repays 0) when entrepreneurs' projects succeed (resp. fail). Since projects (with no shirking) succeed with probability $p$, the promised nominal return $d_i$ to investors should equal $f/p$. Therefore, at location $z$, the expected value of the entrepreneur's loan repayment minus the lender's payment to investors is $p\overline{I_i(z)}(r_i(z) - f/p)$, which is the first term of $\pi_i(z)$. The second term of $\pi_i(z)$ represents lender $i$'s non-pecuniary monitoring costs.

With Lemma 1, lender $i$ chooses its optimal loan size restriction $\overline{I_i(z)}$ to maximize its expected profit $\pi_i(z)$, taking $r_i(z)$ as given; the result is presented in Lemma 2.

**Lemma 2.** *If lender $i$ serves location $z$ with loan rate $r_i(z)$, the lender's loan size restriction for the entrepreneur at $z$ is given by:*

$$\overline{I_i(z)} = \frac{1-q_is_i}{c_i}\frac{pr_i(z) - f}{(B - p(R - r_i(z)))^2}$$

*The entrepreneur's investment size $I_i(z)$ equals $\overline{I_i(z)}$.*

Recall that a larger loan size or more severe moral hazard needs a higher monitoring intensity (Lemma 1). Hence, $\overline{I_i(z)}$ is determined by how much moral hazard lender $i$'s monitoring can alleviate. Lemma 2 states that there are three factors affecting $\overline{I_i(z)}$: (a) lender $i$'s information technology at $z$, which is represented by $(1 - q_i s_i)/c_i$, (b) the lender's skin in the game $r_i(z) - f/p$, and (c) the entrepreneur's skin in the game $R - r_i(z)$. First, $\overline{I_i(z)}$ is increasing in $(1 - q_i s_i)/c_i$ because better IT implies a higher monitoring efficiency (i.e., monitoring becomes cheaper). Second, $\overline{I_i(z)}$ is increasing in $r_i(z) - f/p$ because a higher lender $i$'s skin in the game increases its willingness to provide loans and monitoring. Finally, $\overline{I_i(z)}$ is increasing in $R - r_i(z)$ because a higher entrepreneur's skin in the game makes the moral hazard problem less severe (i.e., $B - p(R - r_i(z))$ becomes smaller), reducing the need for monitoring. Note that increasing $r_i(z)$ increases lender $i$'s skin in the game but decreases the entrepreneur's, so the net effect of changing $r_i(z)$ on $\overline{I_i(z)}$ is ambiguous (to be analyzed later in detail).

**Entrepreneurs' decisions**. After observing the loan rates posted by lenders, an entrepreneur will approach the lender that can provide higher expected entrepreneurial utility. If lender $i$ offers loan rate $r_i(z)$ at $z$, then the entrepreneur at $z$ can expect that the lender's maximum loan size $\overline{I_i(z)}$ is as given in Lemma 2. Hence, she will consider lender 1 for loans if and only if she derives higher expected utility by approaching it instead of lender 2: $\overline{I_1(z)}p(R - r_1(z)) \geq \overline{I_2(z)}p(R - r_2(z))$. This inequality has taken into consideration that monitoring will prevent shirking. When the inequality holds, the entrepreneur at $z$ will approach lender 1.

Note that the entrepreneur's expected utility depends not only on her skin in the game $R - r_i(z)$, but also on the loan size $\overline{I_i(z)}$. The latter is affected by lender $i$'s IT and skin in the game. Therefore, the entrepreneur does not simply choose the lender with a lower loan rate.

## 3.2 Equilibrium loan rates

In this section, we study how lenders determine their loan rates.

**Best loan rate and monopoly loan rate**. Before proceeding, we define two special loan rates of lender $i$ as follows.

**Definition 1.** *Lender $i$'s best loan rate at $z$ is the loan rate that maximizes the expected utility of the entrepreneur at $z$. Lender $i$'s monopoly loan rate at $z$ is the loan rate lender $i$ would choose if it faced no competition at $z$.*

The best loan rate determines how much utility a lender can provide in the Bertrand competition, while the monopoly loan rate determines the maximum profit a lender can earn. The following lemma characterizes the two loan rates.

**Lemma 3.** *At any location, a lender's best loan rate is*

$$\underline{r} \equiv R - \frac{B(pR-f)}{p(2B+f-pR)},$$

*while the monopoly loan rate is $R$. The relation $f/p < \underline{r} < R$ holds. Neither lender will offer a loan rate that is lower than $\underline{r}$.*

If lender $i$ faces no competition at $z$, its profit-maximizing strategy is to offer the highest possible loan rate $R$ and monitor the entrepreneur at $z$ to prevent shirking. Under this strategy, the lender extracts the entire project value, leaving zero surplus to the entrepreneur.

According to Lemma 3, the best loan rate $\underline{r}$ is higher than $f/p$, implying that lowering the loan rate may not increase a lender's attractiveness to entrepreneurs. The reason is that entrepreneurs care about not only the loan rate but also the loan size. Consider location $z$; if $r_i(z)$ is lower than $\underline{r}$, lender $i$'s skin in the game and the monitoring incentive will be very small. In this case, further reducing $r_i(z)$ will decrease $\overline{I_i(z)}$ rapidly, thereby hurting the entrepreneur at $z$. As $r_i(z)$ approaches $f/p$, the lender's skin in the game $r_i(z) - f/p$ will decrease to 0, implying $\overline{I_i(z)} \to 0$ (see Lemma 2). Hence, $\underline{r} > f/p$ must hold.

Note that $\underline{r}$ is unaffected by lender $i$'s monitoring efficiency (i.e., is independent of $q_i$, $c_i$, or $s_i$). The reason is that $\underline{r}$ represents the entrepreneurial utility-maximizing way to allocate the project total value between an entrepreneur and her lender. Although parameters $q_i$, $c_i$, and $s_i$ affect the project total value (net of funding and monitoring costs), the utility-maximizing allocation rule is independent of them.

To better explain the sharing of the pie underlying $\underline{r}$, we can rewrite its formula as follows:

$$\frac{\underline{r} - f/p}{R - f/p} = 1 - \frac{B/(pR-f)}{2B/(pR-f)-1}, \tag{9}$$

which is positive and lower than 1 because of Inequality (5). The left-hand side of Equation (9) is lender $i$'s *relative skin in the game* at the best loan rate $\underline{r}$.[21] According to Equation (9), this relative skin in the game is increasing in $B/(pR-f)$ (the ratio of the private benefit to the expected project return net of funding costs), which we refer to

[21] The numerator is lender $i$'s skin in the game at the loan rate $\underline{r}$; the denominator is the sum of the lender's and the entrepreneur's skin in the game. Hence, their ratio is the relative skin in the game at the loan rate $\underline{r}$.

as the *relative private benefit*. When the relative private benefit is high, entrepreneurs' moral hazard problem is severe, implying a high need for monitoring. As a result, the lender's credit supply will be very low if its skin in the game – which determines the lender's monitoring incentive – is small. In this case, allocating a higher share of the pie to lenders (i.e., raising their monitoring incentives) is aligned with entrepreneurs' interests, leading to a higher lender $i$'s relative skin in the game at the best loan rate $\underline{r}$.

In a competition of the Bertrand type, lender $i$'s loan rate is always within the interval $[\underline{r}, R]$. If $r_i(z) < \underline{r}$, decreasing $r_i(z)$ hurts the lender without increasing its attractiveness, so neither lender will offer a loan rate below $\underline{r}$. In the interval $[\underline{r}, R]$, increasing $r_i(z)$ implies a higher lender $i$'s profit at $z$, but it implies lower entrepreneurial utility, thereby reducing the lender's attractiveness in the competition.

**Equilibrium loan rates**. We can solve for lenders' equilibrium loan rates by using Lemmas 1 to 3. If lender 1 wants to attract the entrepreneur at $z$, it must offer a loan rate more attractive than the best loan rate $\underline{r}$ of lender 2 (that is, providing expected utility no less than the maximum utility lender 2 can provide). If lender 1 cannot do so, then the entrepreneur will be served by lender 2 instead. Reasoning in this way yields the equilibrium loan rates in Proposition 1.

**Proposition 1.** *Let*

$$\tilde{x} \equiv \frac{1 - \frac{c_1}{c_2} + \frac{c_1}{c_2} q_2}{\frac{c_1}{c_2} q_2 + q_1}.$$

*When $0 < \tilde{x} < 1$, there exists a unique equilibrium in which entrepreneurs located in $[0, \tilde{x}]$ (resp. $(\tilde{x}, 1]$) are served by lender 1 (resp. lender 2). At $z \in [0, \tilde{x}]$, the equilibrium loan rate schedule for $i = 1$, $r_1^*(z)$, is the unique solution (in interval $[\underline{r}, R]$) of*

$$\underbrace{\frac{1 - q_1 z}{c_1} \frac{(p r_1^*(z) - f)\, p\,(R - r_1^*(z))}{(B - p\,(R - r_1^*(z)))^2}}_{\text{entrepreneurial utility provided by } r_1^*(z)} = \underbrace{\frac{1 - q_2\,(1 - z)}{c_2} \frac{(p \underline{r} - f)\, p\,(R - \underline{r})}{(B - p\,(R - \underline{r}))^2}}_{\text{maximum utility lender 2 provides}} \tag{10}$$

*At $z \in (\tilde{x}, 1]$, $r_2^*(z)$ is determined in a symmetric way.*

Proposition 1 shows the existence and uniqueness of the equilibrium. The restriction $0 < \tilde{x} < 1$ guarantees that both lenders can attract a positive mass of entrepreneurs in equilibrium. If this restriction does not hold (which occurs when the difference between the two lenders' IT is sufficiently large), then one lender will drive the other lender out; in this case, lenders' pricing policy displayed in Proposition 1 is still robust for the dominant lender.[22] For convenience, we focus on the case $0 < \tilde{x} < 1$ for the rest of the paper.

Proposition 1 implies that lender-borrower distance matters for lending if $q_i > 0$ holds for some $i$ (i.e., if distance friction exists in the market). Attracting an entrepreneur will be harder for a lender if the entrepreneur is located farther away because then the lender's relative cost advantage in monitoring is smaller. As a result, lender 1 (resp. lender 2) can originate loans only in the region $[0, \tilde{x}]$ (resp. $(\tilde{x}, 0]$), and so must give up entrepreneurs who are sufficiently distant. The location $z = \tilde{x}$ is the *indifference location* where neither lender has a cost advantage in monitoring, that is: $(1 - q_1\tilde{x})/c_1 = (1 - q_2(1 - \tilde{x}))/c_2$. Note that $\tilde{x}$ is decreasing in $q_1$ and $c_1/c_2$; this means lender 1 can reach farther locations if its information technology develops. This result is consistent with Ahnert et al. (2023) who document that small business lending by banks with higher IT adoption is less affected by bank-borrower distance.

Next, we characterize lenders' pricing strategies.

**Corollary 1.** *Let $q_i > 0$ for some $i \in \{1, 2\}$ and $z \in [0, \tilde{x}]$. Lender 1's equilibrium loan rate $r_1^*(z)$ is decreasing in $z$. At the indifference location $z = \tilde{x}$, $r_1^*(z) = \underline{r}$ holds. A symmetric result holds for $r_2^*(z)$ at $z \in (\tilde{x}, 1]$.*

With distance friction (i.e., $q_i > 0$ for some $i \in \{1, 2\}$), the schedule $r_1^*(z)$ displays a "perverse" pattern (see Panel 1 of Figure 3): As lender 1's monitoring efficiency goes down (i.e., as an entrepreneur is farther away), the loan rate offered to that entrepreneur decreases. Such a pattern results from the optimal pricing strategy of lender 1 at $z \in [0, \tilde{x}]$: maximizing the lender's profit while ensuring that entrepreneurial utility is no less than the maximum utility the rival can provide. Based on this strategy, at $z \in [0, \tilde{x}]$ the entrepreneurial utility implied by lender 1's equilibrium loan rate $r_1^*(z)$ should exactly match the maximum utility lender 2 can provide (i.e., the utility implied by lender 2's best loan rate $\underline{r}$).

As $z$ increases in the region $[0, \tilde{x}]$, lender 1's monitoring efficiency decreases relative to lender 2's. Hence, lender 1 must offer a lower $r_1^*(z)$ to match the maximum utility provided by lender 2, implying the perverse loan rate pattern. The implication of the result is that entrepreneurs in the region $[0, \tilde{x}]$ cannot benefit from lender 1's advantageous monitoring efficiency; instead, lender 1 itself extracts the entire benefit of its IT advantage over lender 2. Corollary 1 is consistent with the findings of Herpfer et al. (2022): a bank

[22]For example, if $c_2$ is much larger than $c_1$, then $\tilde{x} \geq 1$ will hold; in this case, lender 1 is the dominant lender. The monitoring efficiency and the corresponding loan size of lender 2 are so low that it cannot attract any entrepreneur even if its best loan rate $\underline{r}$ is offered. The equilibrium loan rate of lender 1 at $z$ still equals $r_1^*(z)$ because lender 2's competitive pressure still exists even though it serves no locations.

will charge its borrowers higher loan rates if the borrowers geographically get closer to the bank or/and farther away from competing banks.

At the indifference location $z = \tilde{x}$, neither lender has a cost advantage in monitoring, so the intensity of lender competition is maximal there; lender 1 must offer its best loan rate $\underline{r}$ to attract the entrepreneur there. Panel 1 of Figure 3 graphically illustrates lenders' equilibrium rates when $q_i > 0$.

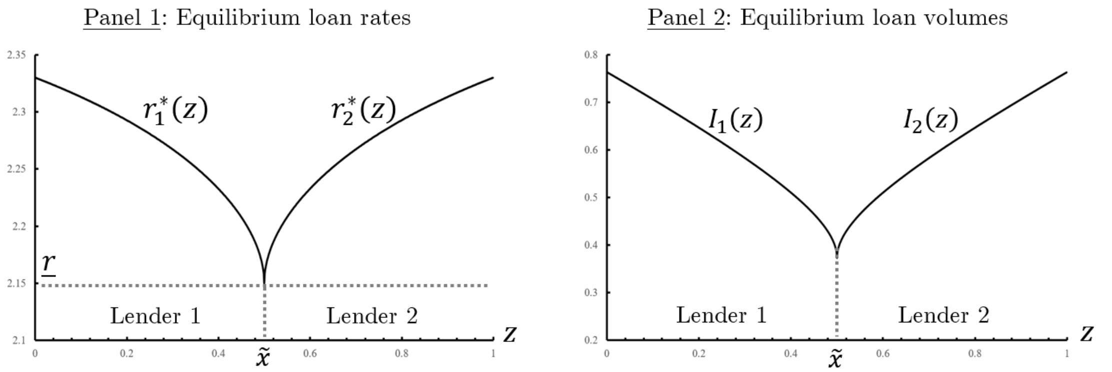


**Figure 3: Equilibrium Loan Rates and Volumes for Different Locations.** This figure plots the equilibrium loan rate and volume against the entrepreneurial location. The parameter values are $R = 2.4$, $B = 0.5$, $p = 0.5$, $f = 1$, $c_1 = 1$, $c_2 = 1$, $q_1 = 0.6$, and $q_2 = 0.6$.

**The case with no distance friction ($q_1 = q_2 = 0$).** If $c_1 = c_2$ holds, the two lenders have the same monitoring efficiency at all locations, meaning that competition intensity is unboundedly high everywhere. In this case, every location is an indifference location with both lenders offering the best loan rate $\underline{r}$; we let $\tilde{x} = 1/2$ still hold (since this is the natural limit by letting $q_1 = q_2$ tend to 0). Then the pricing strategies displayed in Proposition 1 hold: Lender 1's (resp. lender 2's) equilibrium loan rate is $r_1^*(z) = \underline{r}$ at $z \in [0, 1/2]$ (resp. $r_2^*(z) = \underline{r}$ at $z \in (1/2, 1]$).[23]

**Investment.** The following corollary characterizes how entrepreneurial investment varies with location.

**Corollary 2.** *Let $q_i > 0$ for some $i \in \{1, 2\}$ and $z \in [0, \tilde{x}]$. The entrepreneur's investment size $I_1(z)$ – which equals $\overline{I_1(z)}$ – is decreasing in $z$ when $z$ is sufficiently close to $\tilde{x}$. A symmetric result holds for $I_2(z)$ at $z \in (\tilde{x}, 1]$.*

[23]If $q_1 = q_2 = 0$ and $c_1 \neq c_2$ hold, then the lender with better IT-basic (i.e., higher monitoring efficiency) will drive out the other lender. In this case, the equilibrium loan rate of the dominant lender still follows the pricing policy in Proposition 1 and is invariant to $z$ because locations do not affect a lender's competitive advantage when distance friction is absent.

As $z$ increases in the region $[0, \tilde{x}]$, several competing effects work on lender 1's loan size. First, if $q_1 > 0$, the direct effect of increasing $z$ is to decrease lender 1's monitoring efficiency (because of the longer lending distance), which tends to reduce $I_1(z)$. Second, the indirect effect is that $r_1^*(z)$ decreases (see Corollary 1), which in general has an ambiguous effect on $I_1(z)$. On the one hand, a lower $r_1^*(z)$ increases the entrepreneur's skin in the game, making the moral hazard problem less severe and hence tending to increase $I_1(z)$; on the other hand, it reduces lender 1's skin in the game and monitoring incentive, tending to decrease $I_1(z)$. When $z$ is close to $\tilde{x}$, lender competition is very intense (i.e., $r_1^*(z)$ is very close to $\underline{r}$), so the dominant effect of decreasing $r_1^*(z)$ is to reduce lender 1's monitoring incentive, which, together with the direct effect, leads to a lower $I_1(z)$. Panel 2 of Figure 3 illustrates the result.[24]

## 3.3 Information technology and lender competition

In this subsection, we derive comparative statics of monitoring parameters on loan rates, lending volumes, and profits.

**Information technology and loan rates.** The following corollary shows how lenders' IT affects lender 1's loan rate schedule.

**Corollary 3.** *Let $z \in [0, \tilde{x})$. Lender 1's equilibrium loan rate $r_1^*(z)$ is increasing in the lender's competitive advantage, be it due to better basic monitoring technology (i.e., lower $c_1/c_2$) or to higher local expertise (i.e., lower $(1-q_2(1-z))/(1-q_1 z)$). A symmetric result holds for lender 2 at $z \in (\tilde{x}, 1]$.*

Lender 1's equilibrium loan rate is decreasing in $c_1$ and $q_1$ (except for location $z = 0$ where $q_1$ has no effect) and is increasing in $c_2$ and $q_2$. As $c_1$ or $q_1$ increases, monitoring becomes more costly for lender 1. This outcome reduces lender 1's competitive advantage and induces it to decrease its loan rate in an attempt to match the maximum utility provided by lender 2. Yet as $c_2$ or $q_2$ increases, lender 2's competitive advantage will decrease, which allows lender 1 to increase its loan rate. Corollary 3 is reminiscent of the loan rate pattern displayed in Corollary 1: At $z \in [0, \tilde{x})$, an increase in lender 1's

[24]When $z$ is not close to $\tilde{x}$, $I_1(z)$ may be increasing in $z$ (i.e., the indirect effect on $I_1(z)$ may be positive and dominant because the moral hazard problem becomes less severe). However, based on our numerical analysis, $I_1(z)$ is increasing in $z$ (for $z$ not close to $\tilde{x}$) only when the two lenders are quite asymmetric. In the symmetric case with $q_1 = q_2$ and $c_1 = c_1$, a numerical study finds that $I_1(z)$ is decreasing in $z$ even when $z$ is not close to $\tilde{x}$. This is in line with the evidence that a bank tends to lend more to firms about which the bank has better expertise (Blickle et al., 2023; Duquerroy et al., 2022; Paravisini et al., 2023).

monitoring efficiency does not translate into a lower loan rate because lender 1 itself extracts the entire benefit of its IT improvement.

We have witnessed the development and diffusion of information technology throughout the entire lending sector. We now check the implications for lender competition. Let $c_1 = c_2 = c$ and $q_1 = q_2 = q$ hold. The following corollary analyzes how equilibrium loan rates vary with $c$ and $q$, which represent the lending sector's information technology.

**Corollary 4.** *Let $c_1 = c_2 = c$ and $q_1 = q_2 = q$. Lender $i$'s equilibrium loan rate $r_i^*(z)$ is increasing in $q$ (except for $z = 1/2$ where $r_i^*(z) = \underline{r}$) but is not affected by $c$. If $q = 0$, $r_i^*(z) = \underline{r}$ holds for all locations.*

Corollary 4 highlights a crucial difference between $c$ (IT-basic) and $q$ (IT-distance). As $q$ increases, monitoring costs become more sensitive to distance, which increases lender differentiation. The higher differentiation increases lender 1's market power at $z \in [0, 1/2)$ because lender 2's monitoring efficiency is more severely hurt by a higher $q$ than lender 1's at a location closer to lender 1. Reasoning symmetrically, at $z \in (1/2, 1]$, lender 2 gains a larger market power because of the higher differentiation. Hence, both lenders can post higher loan rates for their respective entrepreneurs as $q$ increases. Note that lender differentiation will disappear when $q = 0$, implying unbounded competition intensity and $r_i^*(z) = \underline{r}$ at all locations. In contrast, although an increase in $c$ makes monitoring more costly, lenders' differentiation is unaffected; hence, equilibrium loan rates are unaffected.

In sum: unlike increasing $c$, increasing $q$ not only makes monitoring more costly but also increases lenders' differentiation, and the latter effect renders lender competition less intense. This result is consistent with Duquerroy et al. (2022) who find that increased branch specialization in SME lending – which can be viewed as an increase in $q$ – substantially curtails the intensity of lending competition.[25] Paravisini et al. (2023) find a similar result in the credit market for export-related loans.

Corollary 4 tells us that, when studying how changes in information technology affect lender competition, we should first specify the *type* of IT change. Finally, note that this corollary holds for a more general cost function $C_i(m_i, z) = g(c_i, q_i, s_i)m_i^2$ that satisfies

$$\frac{\partial\left(\frac{C_1(m_1,z)}{C_2(m_2,z)}\right)}{\partial c} = 0 \quad \text{and} \quad \frac{\partial^2\left(\frac{C_1(m_1,z)}{C_2(m_2,z)}\right)}{\partial z \partial q} > 0,$$

where $c_1 = c_2 = c$, $q_1 = q_2 = q$, and $g(c_i, q_i, s_i)$ is an increasing function of $c_i$, $q_i$ and $s_i$.

[25] As $q$ increases, a lender's knowledge specializes more in nearby locations and is discounted faster with distance, implying a higher lender specialization. The loan rate and volume disparity at different locations will increase as a consequence.

**Information technology and lending volume.** Lender 1's (resp. lender 2's) aggregate loan volume equals $L_1 \equiv \int_0^{\tilde{x}} I_1(z)dz$ (resp. $L_2 \equiv \int_{\tilde{x}}^1 I_2(z)dz$). The following proposition shows how the IT progress of a lender affects its total lending volume.

**Proposition 2.** *Lender i's aggregate loan volume $L_i$ is decreasing in $q_i$ and $c_i$.*

Proposition 2 states that the progress of a lender's IT, whatever its type, will induce the lender to provide more loans. We explain the result by looking at the IT progress of lender 1 (i.e., a decrease in $q_1$ or $c_1$). First, lender 1 will extend its market area (i.e., $\tilde{x}$ will increase) since the IT progress increases its competitiveness. Second, at a location served by lender 1, $I_1(z)$ will increase. To see this, recall that lender 1 will increase its loan rate $r_1^*(z)$ as $q_1$ or $c_1$ decreases (Corollary 3). An increase in $r_1^*(z)$ reduces the entrepreneur's skin in the game at $z$, so lender 1 must compensate the entrepreneur with a higher $\overline{I_1(z)}$ to match the maximum utility provided by lender 2. Both effects (i.e., larger $\tilde{x}$ and $I_1(z)$) lead to a higher lender 1's aggregate lending volume. This result is consistent with Dadoukis et al. (2021) and Branzoli et al. (2023), who find that banks with higher IT adoption have larger loan growth.

Next, we analyze how the lending sector's IT affects entrepreneurs' total investment (i.e., lenders' total lending volume $L_1 + L_2$).

**Proposition 3.** *Let $c_1 = c_2 = c$ and $q_1 = q_2 = q$. Entrepreneurs' total investment (i.e., $L_1 + L_2$) is decreasing in $c$ while it is increasing in $q$ if $q$ is sufficiently small.*

Proposition 3 states that the two types of IT have different effects on the market's credit supply. IT-basic progress (i.e., decreasing $c$) increases lenders' lending volume and, hence, total investment because it improves lenders' monitoring efficiency without intensifying their competition. See Panel 3 of Figure 4 for an illustration. This is consistent with Ahnert et al. (2023) who find that job creation by young enterprises, which is an indirect measure of entrepreneurial investment, is higher in US counties that are more exposed to IT-intensive banks.

A decrease in $q$ (IT-distance progress) has more complex effects. First, it improves lenders' monitoring efficiency (as IT-basic does), which tends to increase total investment. Second, it reduces lenders' differentiation and intensifies their competition, decreasing lenders' loan rates and generating an ambiguous effect on lenders' loan size. When $q$ is sufficiently small, lenders' loan rates will approach $\underline{r}$; in this case, the dominant effect of lowering lenders' loan rates is to decrease their monitoring incentives and loan size. In addition, the speed of loan rate reduction will be unboundedly high when $q$ is close to 0 because then the intensity of lender competition will tend to infinity (i.e., lender differentiation will disappear). As a result, when $q$ is very small, lenders' total lending volume will decrease as IT-distance improves, although monitoring becomes cheaper.

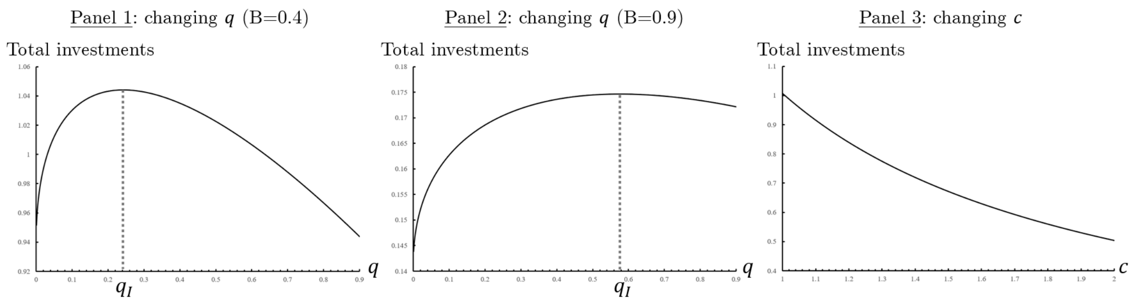


**Figure 4: Information Technology and Total Investment.** This figure plots entrepreneurs' total investment (i.e., lenders' total loan volume) against $c$ and $q$. In Panels 1 and 2, $q_I$ denotes the level of $q$ that maximizes total investment. The parameter values are: $R = 2.4$, $p = 0.5$, and $f = 1$ in all panels; $c = 1$ in Panels 1 and 2; $q = 0.6$ in Panel 3; $B = 0.4$ in Panels 1 and 3; $B = 0.9$ in Panel 2.

Figure 4 illustrates Proposition 3. Decreasing $c$ has no differentiation effect and hence increases total investment unambiguously. Decreasing $q$, however, has a "hump-shaped" net effect on investment. When $q$ is large (i.e., when $q > q_I$ in Panels 1 and 2 of Figure 4), the investment-spurring effects of decreasing $q$ are dominant: (a) monitoring becomes cheaper, and (b) lower loan rates increase entrepreneurs' skin in the game, reducing the severity of the moral hazard. Hence, entrepreneurs' total investment is decreasing in $q$. However, when $q$ is small (i.e., when $q < q_I$ in Panels 1 and 2), the dominant effect of decreasing $q$ is reducing lenders' monitoring incentives, thereby decreasing total investment. This result is consistent with Di Patti and Dell'Ariccia (2004), who document that the relationship between bank competition – which is affected by $q$ in our model – and banks' credit supply is hump-shaped.

Furthermore, a numerical study finds that increasing $B/(pR - f)$ (i.e., the relative private benefit) will increase the investment-maximizing level of $q$. This can be seen from Panels 1 and 2 of Figure 4: $q_I$ is larger in Panel 2, where $B$ is higher. The intuition is that a higher relative private benefit implies a more severe moral hazard problem, increasing the need for monitoring (given loan rates and volumes). Therefore, the provision of monitoring incentives (determined by lenders' skin in the game) becomes more important to credit supply.[26] Hence, the differentiation effect of decreasing $q$ is more likely to reduce total investment when $B/(pR - f)$ is higher.

[26]Note that entrepreneurs' skin in the game can alleviate the moral hazard problem and reduce the need for monitoring, but alone can solve the moral hazard problem only when it is trivial. Otherwise,

**Information technology and aggregate lending profits.** Finally, we look at the relationship between the lending sector's IT and a lender's aggregate lending profit. Lender 1's aggregate lending profit from all locations is equal to $\int_0^{\tilde{x}} \pi_1(z)dz$; here $\pi_1(z)$ is lender 1's profit from financing the entrepreneur at $z$ (see Equation 8). Symmetrically, we can define lender 2's aggregate lending profit. The following proposition shows how the lending sector's information technology affects a lender's aggregate lending profit.

**Proposition 4.** *Let $c_1 = c_2 = c$ and $q_1 = q_2 = q$. Lender $i$'s aggregate lending profit from all locations is decreasing in $c$ while it is increasing in $q$ if $q$ is sufficiently small.*

Decreasing $c$ makes monitoring cheaper without reducing lender differentiation. In contrast, the net effect of $q$ is more complex. Decreasing $q$ has two competing effects on lender $i$'s aggregate lending profit. First, there is a cost-saving effect: a smaller $q$ makes monitoring less costly for lender $i$, which tends to increase the lenders' profits. Second, there is a differentiation effect: a smaller $q$ decreases lender differentiation (i.e., intensifies lender competition), which tends to reduce lenders' profits. The differentiation effect will dominate the cost-saving effect when $q$ is small enough. The reason is that the intensity of lender competition will tend to infinity as $q$ approaches 0 (i.e., as lender differentiation disappears); that is, both $r_i^*(z)$ and $\overline{I_i(z)}$ will decrease at a very high speed as $q$ approaches 0, which must dominate the cost-saving effect.[27]

## 3.4 Competition between a bank and a fintech

Suppose that lender 1 is a bank with relatively low $c_1$ (smaller than $c_2$) and positive $q_1$, while lender 2 is a fintech with relatively high $c_2$ (because of lack of data) and $q_2 = 0$ (uniform capability to monitor different entrepreneurs). Then, according to Corollary 1, the fintech's loan rate is decreasing in its lending distance (i.e., increase in $z$ when $z \in (\tilde{x}, 1]$, see Panel 1 of Figure 5). The reason is that the maximum utility provided by the bank (i.e., lender 1) is decreasing in $z$; to match this utility, the fintech will increase its loan rate as $z$ increases in the region $(\tilde{x}, 1]$. This result is consistent 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.[28] Moreover, note that $c_1 < c_2$ must

credit supply has to rely on lenders' monitoring, and a higher relative private benefit will strengthen the reliance.

[27]In a numerical study with $c_1 = c_2 = c$ and $q_1 = q_2 = q$, we find that reducing $q$ always decreases lenders' profits, implying that the differentiation effect numerically dominates the cost-saving effect even if $q$ is not small.

[28]Open banking policy can be viewed as a decrease in $c_2$ because it improves customer data availability for the fintech. Based on our model, the decrease in $c_2$ (due to open banking) will expand the market

imply $\tilde{x} > 0$, no matter how large the bank's $q_1$ is; the reason is that the bank, with its better access to firm information (which leads to $c_1 < c_2$), can ensure that it has higher monitoring efficiency than the fintech when $z$ is sufficiently close to 0. The implication is that although fintechs, with their advantage in IT-distance, can bring competitive pressure to banks, the latter will not be completely replaced because of their superior capability of serving certain types of firms.

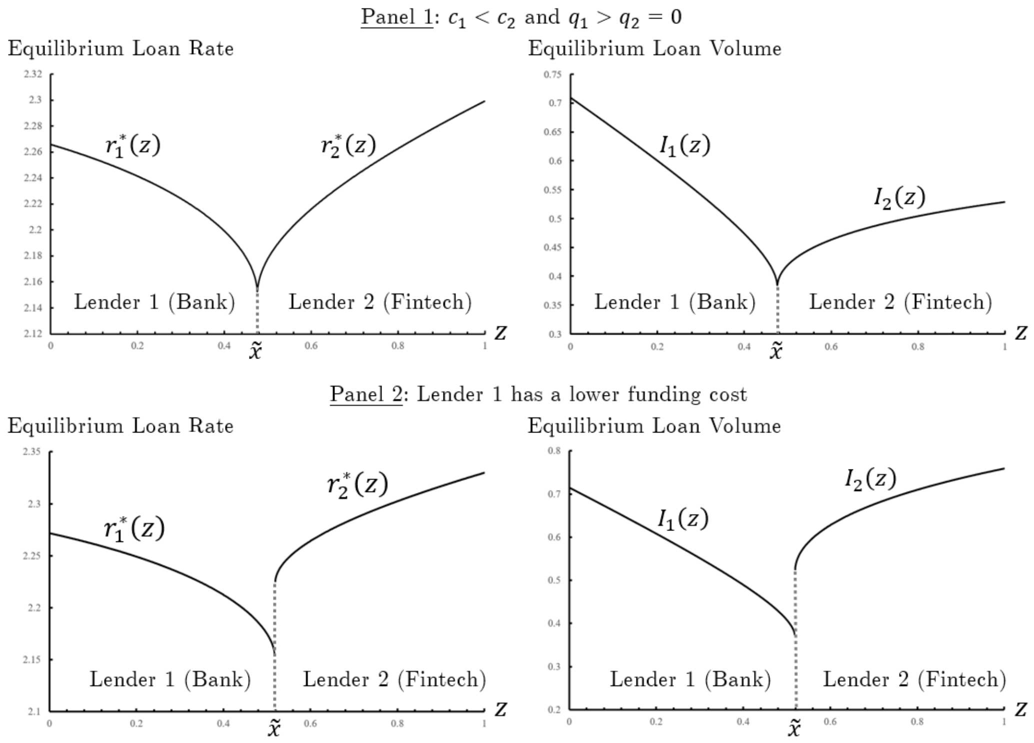


**Figure 5: Equilibrium Loan Rates and Volumes under Bank-Fintech Competition.** This figure plots the equilibrium loan rate and volume against the entrepreneurial location. In Panel 1, the parameter values are $R = 2.4$, $B = 0.5$, $p = 0.5$, $f = 1$, $c_1 = 1$, $c_2 = 1.4$, $q_1 = 0.6$, and $q_2 = 0$. In Panel 2, investors require a break-even expected return of $f_1$ (resp. $f_2$) when providing funds to lender 1 (resp., 2); the parameter values are $R = 2.4$, $B = 0.5$, $p = 0.5$, $f_1 = 1$, $f_2 = 1.05$, $c_1 = 1$, $c_2 = 0.7$, $q_1 = 0.6$, and $q_2 = 0$.

**Heterogeneous funding costs.** Banks and fintechs have different funding sources and, hence, may face heterogeneous funding costs. For simplicity, the paper assumes that the two lenders face the same marginal funding cost $f$. In Appendix B, we relax this assumption by letting the two lenders face different marginal funding costs (which reflects

area served by lender 2 (fintech). This result is consistent with Babina et al. (2023), who document that open banking policy significantly enlarges venture capital investment in fintechs, which can be viewed as a proxy for fintechs' expansion.

the potential heterogeneity in lender-investor relationships or funding sources). We find that decreasing a lender's funding cost will increase the lender's skin in the game and willingness to provide more loans, improving its competitive advantage. As a result, the lender gains a larger market area (Corollary B.2) and increases loan rates and volumes (Corollary B.3). However, if both lenders' funding costs decrease, their loan rates will decrease (Corollary B.4). It follows that if a policymaker aims to decrease loan rates by reducing lenders' funding costs, it should reduce the funding costs for *all* lenders. Otherwise, some lenders can exploit larger funding cost advantages and charge higher loan rates.

With heterogeneous funding costs, lenders' best loan rates are no longer the same: The lender with a lower marginal funding cost has a lower best loan rate (Corollary B.1). Suppose that lender 1 is a bank with a lower marginal funding cost than lender 2 (fintech). At the indifference location $z = \tilde{x}$, the two lenders offer the same entrepreneurial utility, but they have different advantages: The bank has an advantage in funding costs, while the fintech has an advantage in IT. As a result, the equilibrium loan rates and volumes are discontinuous at the indifference location (Proposition B.2). The bank's funding cost advantage allows it to offer a lower (best) loan rate at $z = \tilde{x}$, while the fintech's IT advantage allows it to provide more loans to compete with the bank (see Panel 2 of Figure 5).

# 4 Technology investment choice

In this section, we analyze how lenders determine their information technology, represented by $q_i$ and $c_i$. To do this, we assume that before lenders post their loan rates, there is an IT investment stage in which lender $i$ chooses $q_i$ and $c_i$ by paying IT investment costs.

To develop an IT infrastructure that is characterized by $q_i$ and $c_i$, lender $i$ must incur a cost $T(q_i, c_i) \geq 0$. We assume that $T(q_i, c_i)$ is decreasing in $q_i$ and $c_i$, meaning that adopting better information technology needs more investment and hence is more costly. Lender 1's ex-ante profit at the IT investment stage is equal to

$$\Pi_1(q_1, q_2, c_1, c_2) \equiv \int_0^{\tilde{x}} \pi_1(z)dz - T(q_1, c_1),$$

where $\int_0^{\tilde{x}} \pi_1(z)dz$ is lender 1's aggregate lending profit in the Bertrand competition. $\pi_1(z)$

is lender 1's lending profit at $z$ (see Equation 8). $\Pi_1(q_1, q_2, c_1, c_2)$ is also written as $\Pi_1$ for short. Symmetrically, we can define lender 2's profit $\Pi_2$ at the IT investment stage.

We restrict our attention to subgame perfect equilibria (SPE) of the two-stage game: First, both lenders simultaneously choose their IT investment (i.e., lender $i$ chooses $q_i$ and $c_i$ by paying $T(q_i, c_i)$). Second, lenders compete by posting loan rate schedules, of which the equilibrium is characterized in Section 3. The following proposition shows that lenders can be trapped in a *prisoner's dilemma* in the SPE of the two-stage game.

**Proposition 5.** *If*

$$\Pi_i(0, 0, \underline{c}, \underline{c}) = \frac{(pR - f)^2}{16B^2\underline{c}} - T(0, \underline{c}) > 0, \tag{11}$$

*then at the unique SPE we have that $q_1 = q_2 = 0$ and $c_1 = c_2 = \underline{c}$.*

Condition (11) means that each lender can still make a positive ex-ante profit when both lenders acquire the best possible information technology. Under this condition, Proposition 5 states that both lenders will choose the best possible IT (i.e., decrease both $q_i$ and $c_i$ to their lower bounds). In this equilibrium, lenders' price competition is unboundedly intense at all locations because there is no lender differentiation when $q_1 = q_2 = 0$. Lender 1 (resp. lender 2) serves entrepreneurs in $[0, 1/2]$ (resp. $(1/2, 1]$) and offers the best loan rate $\underline{r}$. Each lender's aggregate lending profit in the Bertrand competition (i.e., $\int_0^{1/2} \pi_1(z)dz$) equals $(pR - f)^2/(16B^2\underline{c})$.

We prove here that $\{q_i = 0, c_i = \underline{c}\}$ is indeed an equilibrium under Condition (11). Given that $q_2 = 0$ and $c_2 = \underline{c}$, lender 1 can make a positive expected profit by setting $q_1 = 0$ and $c_1 = \underline{c}$ according to Condition (11). If lender 1 deviates (from $q_1 = 0$ and/or $c_1 = \underline{c}$), it will lose all its market share and so make a non-positive ex-ante profit. Hence, lender 1 has no incentive to deviate. The same reasoning applies to lender 2. The uniqueness of the equilibrium is relegated to Appendix A.

The intuition is that when $q_1 = q_2 = 0$ and $c_1 = c_2 = \underline{c}$, a lender's IT investment has an infinitely strong business-stealing effect: lender $i$ will lose all its market share if it marginally increases $c_i$ or $q_i$, inducing a discontinuous decrease in profits. Such a strong business-stealing effect translates into lenders' strong IT investment incentives, preventing their deviation.

Note that both lenders would be better-off if $q$ $(= q_1 = q_2)$ were moderately increased from 0 (see Proposition 4). However, lender $i$ is unwilling to increase $q_i$ because of the infinitely strong business-stealing effect, implying a prisoner's dilemma.

# 5 Welfare analysis

In this section, we analyze the social planner's problem. First, we examine the relationship between equilibrium loan rates and socially optimal ones. We then analyze how the development and diffusion of the lending sector's information technology affect social welfare. Throughout the section, we let $q_1 = q_2 = q$ and $c_1 = c_2 = c$, and hence use $q$ and $c$ to represent the lending sector's IT-distance and IT-basic.

## 5.1 Socially optimal loan rates

If the entrepreneur at location $z$ is financed by lender $i$ (with $i = 1$ or $2$), then social welfare is given by

$$W \equiv \underbrace{\int_0^1 I_i(z)\, p\,(R - r_i(z))\, dz}_{\text{Entrepreneurs' aggregate expected utility}} + \underbrace{\int_0^1 \left( I_i(z)\,(pr_i(z) - f) - \frac{c(m_i(z))^2}{2(1 - qs_i)} \right) dz}_{\text{Lenders' expected profits}}. \quad (12)$$

Here $r_i(z)$, $m_i(z)$, and $I_i(z)$ are lender $i$'s loan rate, monitoring intensity, and loan size for the entrepreneur at $z$ respectively. Expression (12) divides social welfare into entrepreneurs' utility and lenders' profits and has incorporated that lenders' monitoring prevents entrepreneurs' shirking. Since $B < f$, shirking is never desirable for a lender or the social planner.

**Social planner's problem.** We consider the case where the social planner can choose the socially optimal loan rate schedule of lender $i$, denoted by $\{r_i^o(z)\}$, to maximize social welfare $W$. The other choice variables of lenders and entrepreneurs are determined in equilibrium for given loan rates; that is, each entrepreneur approaches the lender that provides higher utility, and lenders' monitoring and loan sizes are determined as in Lemmas 1 and 2. The following proposition characterizes the socially optimal loan rates.

**Proposition 6.** *Price discrimination is not efficient. At any location, the socially optimal loan rate for both lenders is $r^o$ (i.e., $r_i^o(z) = r^o$ for any $z$ and $i$), with*

$$r^o \equiv R - \frac{(pR - f)^2}{pB} \in (\underline{r}, R).$$

*Given that both lenders offer $r^o$, the entrepreneur at $z \in [0, 1/2]$ (resp. $z \in (1/2, 1]$) approaches lender 1 (resp. lender 2).*

From the social point of view, lowering $r_i^o(z)$ decreases lender $i$'s skin in the game (i.e., reducing its monitoring incentive), potentially reducing $\overline{I_i(z)}$ and hurting welfare. Yet as $r_i^o(z)$ decreases, the entrepreneur's skin in the game will increase, making its moral hazard less severe and reducing the need for monitoring (Lemma 1), which tends to improve social welfare. The social planner must balance the social benefits (less severe moral hazard) and costs (lower monitoring incentive) of decreasing $r_i^o(z)$ – here $\underline{r}$ is one extreme loan rate, which maximizes entrepreneurs' utility but implies an excessively low lender $i$'s monitoring incentive (and also excessively low $\overline{I_i(z)}$). The monopoly loan rate $R$ is the other extreme, which maximizes both lender $i$'s profit and the severity of the entrepreneur's moral hazard – leading to the relation $\underline{r} < r_i^o(z) = r^o < R$.

Given that lenders offer $r^o$, the entrepreneur at $z \in [0, 1/2]$ (resp. $z \in (1/2, 1]$) approaches lender 1 (resp. lender 2), which is an efficient choice for welfare since each location is served by the lender with better monitoring efficiency (i.e., with a smaller lending distance).

**Corollary 5.** *A lender's relative skin in the game at the socially optimal loan rate $r^o$ is given by:*

$$\frac{r^o - f/p}{R - f/p} = 1 - \frac{pR - f}{B} \in (0, 1),$$

*which is increasing in the relative private benefit $B/(pR - f)$.*

As the relative private benefit increases, entrepreneurs' moral hazard problem becomes more severe, raising the need for monitoring and making lenders' skin in the game more important for credit supply. Hence, the socially optimal loan rate $r^o$ will allocate higher skin in the game to lenders to give them higher monitoring incentives.

Note that $r^o$ is unaffected by information technology (i.e., $q$ or $c$) or the lending distance. The reason is that $r^o$ controls the efficient relative size of lender profit with respect to entrepreneurial utility (i.e., the sharing of the pie), which is a trade-off between the severity of moral hazard and the lender's monitoring incentive. Although $q$, $c$, and $s_i$ determine the absolute project value (i.e., the size of the pie), the welfare-maximizing way to share the pie is independent of those parameters.

**Equilibrium loan rates v.s. socially optimal rates.** Proposition 6 and Corollary 5 mean that the "perverse" pattern of lender $i$'s equilibrium loan rate $r_i^*(z)$ is not efficient. In equilibrium, the priority of a lender is to maximize its own profit instead of social welfare, so it will extract more project value when it has larger market power. Such a strategy does not balance well the severity of moral hazard and the lender's monitoring incentive at each location. In addition, if lenders offer $r^o$, it is easy to show that lender $i$'s loan size $\overline{I_i(z)}$ is linearly increasing in $(1-qs_i)/c$. This aligns with the welfare-maximizing consideration because a higher monitoring efficiency corresponds to a higher loan size. In contrast, the equilibrium credit supply can violate the welfare-maximizing consideration: decreasing $q$ – which improves both lenders' monitoring efficiency – may reduce their loan sizes (Proposition 3). A straightforward policy implication of Proposition 6 and Corollary 5 is that regulators can guide lenders' pricing to improve allocation efficiency by setting $r^o$ as the reference loan rate for lenders and limiting their ability to price discriminate based on borrowers' types.

***Remark (asymmetric IT):*** If the two lenders' IT is asymmetric (i.e., $q_1 \neq q_2$ or/and $c_1 \neq c_2$), the socially optimal loan rate (of both lenders) is still equal to $r^o$ since $r^o$ is independent of lenders' IT. Given that both lenders offer $r^o$, the entrepreneur at $z$ will approach the lender that has better IT at $z$, which is an efficient choice from the social point of view.

For the rest of the section, we still focus on the case $q_1 = q_2 = q$ and $c_1 = c_2 = c$. The following proposition shows how the lending sector's IT affects the relationship between the equilibrium loan rates and the socially optimal one.

**Proposition 7.** *At location $z \in [0, 1/2]$ (served by lender 1), $r_1^*(z) < r^o$ if and only if $q < k(z)$, with*

$$k(z) \equiv \frac{1 - 4B(pR - f)/(pR - f + B)^2}{1 - z - 4B(pR - f)z/(pR - f + B)^2}.$$

*$k(z)$ is increasing in $z$ when $z \in [0, 1/2]$. A symmetric result holds for locations served by lender 2 (i.e., $z \in (1/2, 1]$).*

Proposition 7 states that IT-distance progress will induce excessive lender competition at $z$ (i.e., $r_1^*(z) < r^o$) when $q$ is smaller than a threshold $k(z)$. As $q$ decreases, lender differentiation will be smaller. The corresponding increase in competition intensity will gradually drive $r_1^*(z)$ (at $z \in [0, 1/2]$) to the best loan rate $\underline{r}$, which is lower than the socially optimal level $r^o$. See Panel 1 of Figure 6 for an illustration.

As $z$ approaches the middle location $z = 1/2$, lender competition will be more intense, so excessive competition (i.e., $r_1^*(z) < r^o$ ) can be induced by a higher $q$. As a result, the threshold $k(z)$ is increasing in $z$ when $z \in [0, 1/2]$. Note that when $z$ is sufficiently close to 1/2, $k(z)$ is higher than 1, implying that $r_1^*(z) < r^o$ holds (i.e., competition is excessive) for all $q \in [0, 1)$. The reason is that lender competition will be infinitely intense at the indifference location $z = 1/2$, where $r_1^*(z) = \underline{r} < r^o$ always holds. Panel 2 of Figure 6

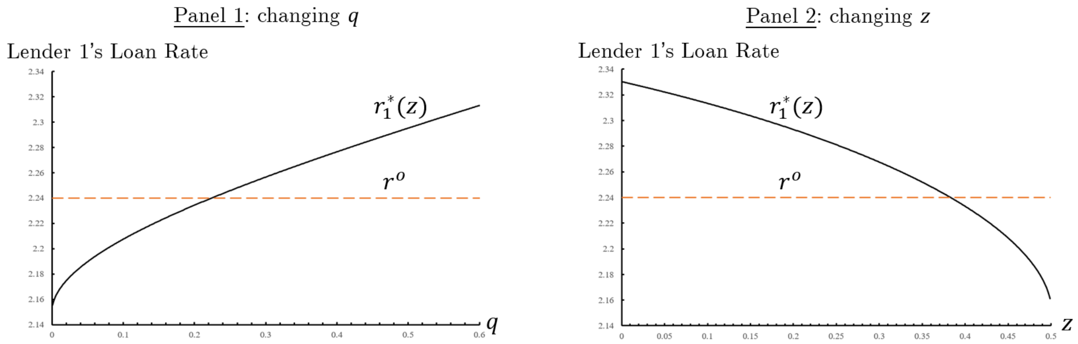


**Figure 6: Comparing $r_1^*(z)$ and $r^o$.** This figure plots $r_1^*(z)$ and $r^o$ against $q$ (Panel 1) and $z$ (Panel 2). The parameter values are: $R = 2.4$, $f = 1$, $B = 0.5$, $p = 0.5$ and $c = 1$ in both panels; $z = 0.1$ in Panel 1; $q = 0.6$ in Panel 2.

illustrates the result.

**Corollary 6.** *We have that $k(0) \in (0, 1)$. Hence, $r_i^*(z) < r^o$ holds for all locations when $q < k(0)$.*

When $q$ is sufficiently small (i.e., $q < k(0)$), lender 1's equilibrium loan rate will be lower than $r^o$ even at $z = 0$, where lender 1 has the highest market power. In this case, lenders' monitoring incentives are excessively low for all entrepreneurs.

Figure 7 illustrates Proposition 7 and Corollary 6 (i.e., the relationship between lender 1's equilibrium loan rate and $r^o$) in $z \times q$ space. In Region II (the colored area), lender competition is excessively intense (i.e., $q < k(z)$) such that $r_1^*(z) < r^o$ holds. The following corollary shows what determines the area of Region II.

**Corollary 7.** *At $z \in [0, 1/2)$, $k(z)$ is increasing in $B/(pR - f)$. That is, the region with too low market rates (Region $II$ of Figure 7) is larger as $B/(pR - f)$ increases.*

This corollary states that when the relative private benefit $B/(pR - f)$ is higher, IT-distance progress is more likely to induce excessive lender competition (i.e., $q < k(z)$ holds for a larger area in $z \times q$ space). The intuition is consistent with that underlying Corollary 5. An increase in $B/(pR - f)$ will raise the need for monitoring, so lenders' skin in the game (i.e., monitoring incentives) will be more important for welfare. Then, decreasing lender differentiation (through reducing $q$) can more easily induce $r_1^*(z) < r^o$.

## 5.2 Welfare properties of the symmetric equilibrium

In this subsection, we analyze the welfare effects of information technology progress. Figure 8 shows how entrepreneurs' utility, lenders' profits, and social welfare vary with

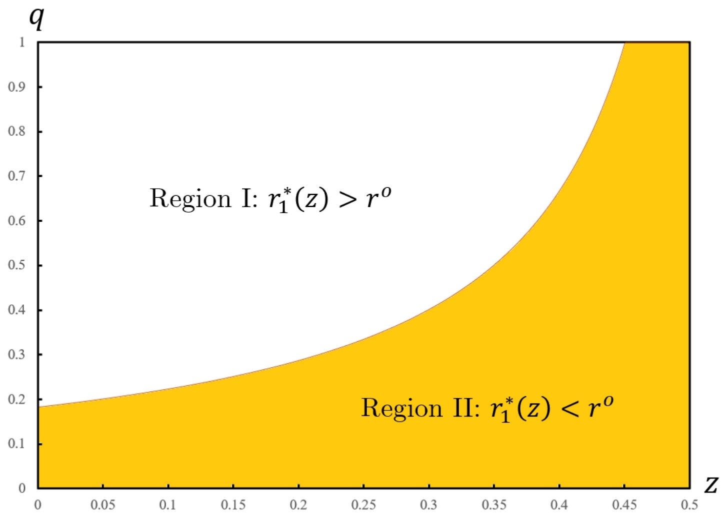


**Figure 7: Relations between $r_1^*(z)$ and $r^o$ in $z \times q$ space.** This figure compares $r_1^*(z)$ with $r^o$ in $z \times q$ space. The parameter values are $R = 2.4$, $f = 1$, $B = 0.5$ and $p = 0.5$.

$q$ and $c$. A decrease in $q$ will increase the intensity of lending competition because differentiation will be diminished (Corollary 4). Greater lender competition (together with higher monitoring efficiency) translates into lenders providing higher entrepreneurial utility. So, as can be seen in Panels 1 and 3 of Figure 8, entrepreneurial utility increases if $q$ decreases. From the lenders' perspective, reducing $q$ has two opposing effects: a cost-saving effect since monitoring is cheaper and a differentiation effect, which implies more intense competition. Our numerical study finds that the differentiation effect dominates, so lenders' profits decrease as $q$ decreases.[29] Perhaps more surprising is the following result: decreasing $q$ reduces social welfare for $q$ small enough.

**Proposition 8.** *Social welfare is increasing in $q$ if $q$ is sufficiently small while it is decreasing in $c$.*

In general, the effect of $q$ on welfare is ambiguous. Whether a reduction in $q$ (and the resultant increased competition intensity) is welfare-improving depends on whether we start with a low or high level of competition (Panels 1 and 3 of Figure 8). Lenders' loan rates will be excessively low when competition is very intense (i.e., when $q$ is small enough; Proposition 7 and Corollary 6). In this case, decreasing $q$ reduces social welfare because the reduction in lenders' skin in the game and monitoring incentives will be the dominant effect when lenders' loan rates are close to $\underline{r}$; the improvements in lenders' monitoring efficiency (i.e., cost-saving effect) and entrepreneurial utility are dominated.

[29]In Proposition 4 we show that the differentiation effect dominates when $q$ is sufficiently small.

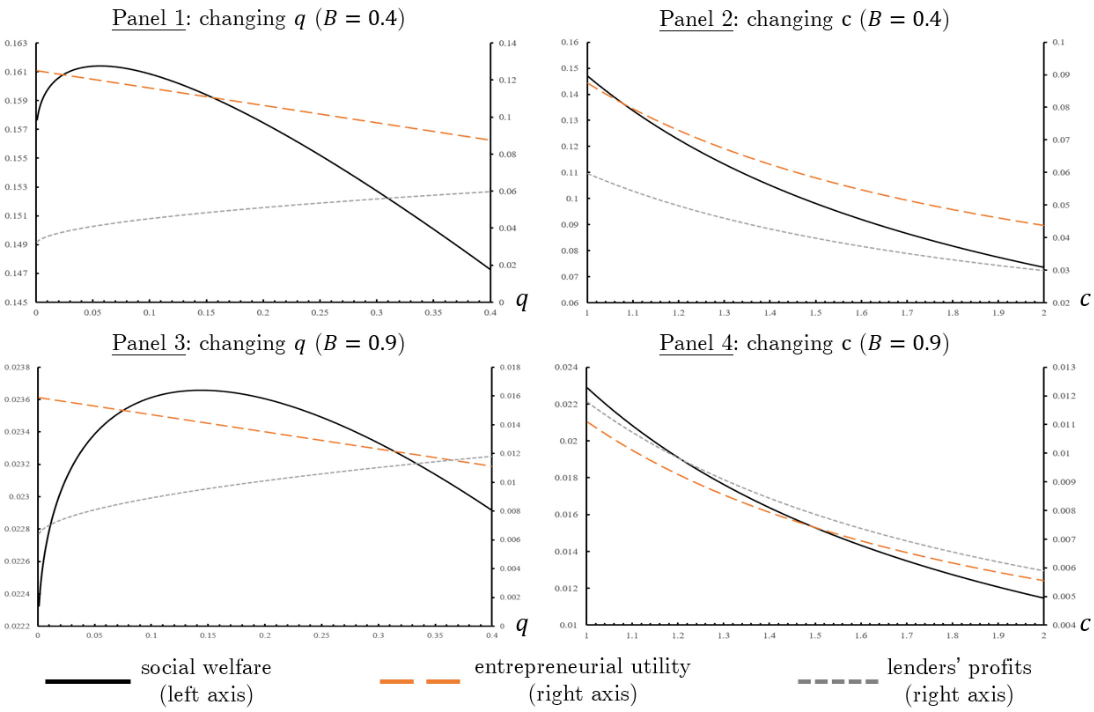


**Figure 8: Social Welfare and Lending Sector's Information Technology.** This figure plots social welfare, entrepreneurial utility, and lenders' profits against $c$ and $q$. The parameter values are: $R = 2.4$, $p = 0.5$ and $f = 1$ in all panels; $c = 1$ in Panels 1 and 3; $q = 0.4$ in Panels 2 and 4; $B = 0.4$ in Panels 1 and 2; and $B = 0.9$ in Panels 3 and 4.

In contrast, decreasing $c$ unambiguously improves social welfare since it does not affect lender differentiation (Corollary 4). See Panels 2 and 4 of Figure 8 for an illustration.

Furthermore, a numerical study finds that increasing the relative private benefit $B/(pR-f)$ will increase the welfare-maximizing level of $q$. This can be seen from Panels 1 and 3 of Figure 8: In Panel 3, where $B$ is higher, social welfare peaks at a higher $q$ than in Panel 1. This result is consistent with Corollary 7. A higher relative private benefit (i.e., more severe moral hazard) raises the need for monitoring, increasing the importance of lenders' monitoring incentives and their skin in the game. As a result, IT-distance progress is more likely to reduce social welfare when the relative private benefit is higher.

In short, although reducing $q$ (i.e., improving IT-distance) and reducing $c$ (i.e., improving IT-basic) can each be viewed as progress in information technology, their welfare effects are quite different. So when discussing IT progress, one must stipulate the type of IT involved.

**The effect of IT investment costs**. Finally, we consider the IT investment cost $T(q, c)$

when analyzing the welfare effect of changing $q$ and $c$. According to Proposition 8, IT-distance progress will reduce social welfare when $q$ is sufficiently small. Considering IT investment costs will obviously strengthen the negative effect of IT-distance progress on welfare (Panel 1 of Figure 9).

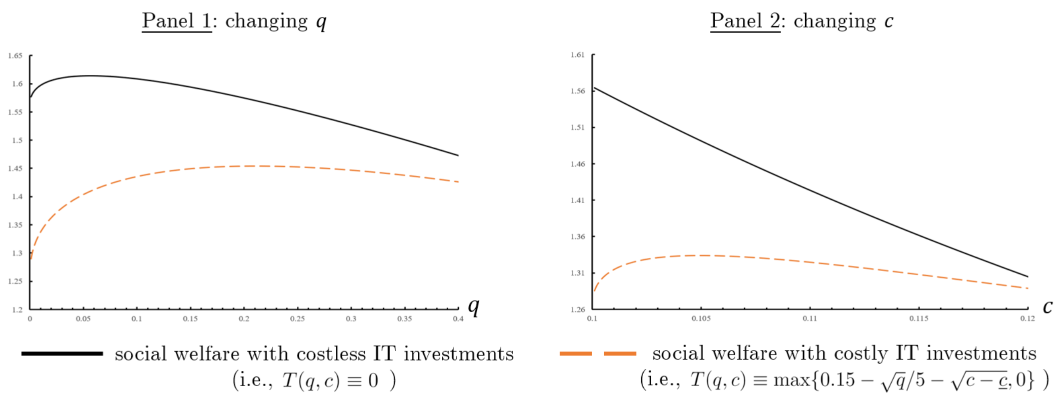


**Figure 9: Welfare Effect of IT Improvements and IT Investment Costs.** This figure plots social welfare (net of IT investment costs) against $c$ and $q$. The parameter values are: $R = 2.4$, $B = 0.4$, $p = 0.5$, $\underline{c} = 0.1$ and $f = 1$ in both panels; $c = \underline{c} = 0.1$ in Panel 1; $q = 0$ in Panel 2. For the solid curve, $T(q,c) \equiv 0$. For the dashed curve, $T(q,c) \equiv \max\{0.15 - \sqrt{q}/5 - \sqrt{c - \underline{c}}, 0\}$. For both the solid and the dashed curves, Condition (11) holds when $q = 0$ and $c = \underline{c}$.

Recall from Proposition 5 that $q = 0$ and $c = \underline{c}$ will arise endogenously when Condition (11) holds, meaning that excessive lender competition can arise from lenders' endogenously IT investment. This scenario can arise, for example, if information technology is highly advanced in non-financial sectors and then it spills over to the lending sector, leading to very low $T(q,c)$ and hence making Condition (11) hold.

As for IT-basic, note that Condition (11) does not restrict the marginal cost of decreasing $c$, so $c = \underline{c}$ (which is lenders' endogenous choice) will be lower than the socially optimal level if $\lim_{c \to \underline{c}} \partial T(q,c)/\partial c < 0$ is low enough. The reason is that the marginal social benefit (i.e., cost-saving effect) of decreasing $c$ is always finite, so the social planner will choose $c > \underline{c}$ if the marginal cost of decreasing $c$ to $\underline{c}$ is very high. In contrast, lenders will choose $c = \underline{c}$ under Condition (11) because of the infinitely strong business-stealing effect of IT investment. Panel 2 of Figure 9 (the dashed curve) gives an example. In this case, $\lim_{c \to \underline{c}} \partial T(q,c)/\partial c = -\infty$ holds, so social welfare does not peak at $c = \underline{c}$; however, lenders' choices would be $c = \underline{c}$ since Condition (11) is satisfied.

# 6 Conclusion

Our study shows that whether the development of information technology intensifies lender competition depends on its impact on differentiation. If IT progress in the lending sector is of type IT-basic – reducing the costs of monitoring an entrepreneur without altering lenders' relative cost advantage (i.e., lower $c$) – then neither differentiation nor competition among lenders is affected; hence, lenders will be more profitable and provide more loans. Yet, if the industry's IT progress is of type IT-distance – weakening the influence of lender-entrepreneur distance on monitoring costs (i.e., lower $q$) – then differentiation among lenders will decrease, competition will become more intense, and lenders may become less profitable (Proposition 4). The effect of IT-distance progress on lenders' total loan sizes is hump-shaped (Proposition 3 and Figure 4). IT-distance progress is more likely to reduce lenders' loan supply when entrepreneurs' moral hazard is more severe (i.e., the relative private benefit is higher). We should therefore be careful to identify the kind of information technology change being considered before gauging its impact.

In any case, and consistently with received empirical evidence, we have the testable implication that a technologically more advanced lender – regardless of how changes in IT affect lender differentiation – lends to more industries/locations, commands greater market power, and has larger loan sizes (Propositions 1 and 2). We also find that a lender's loan rate will increase after the lender's IT improves relative to other lenders' (Corollaries 1 and 3).

In our model, the equilibrium consequences of one lender's IT improvement are quite different from those of a general lending sector's IT improvement. For example, a lender adopting better IT increases its loan rates, while both lenders' loan rates will decrease if the lending sector's IT-distance improves. The reason for the difference is that a lender's IT improvement affects not only itself but also the other lender's behavior, giving rise to a competitive spillover effect. Our model highlights that caution is necessary when using diff-in-diff methods in empirical research on technological progress.[30]

When lenders endogenously determine their levels of IT, both lenders will acquire the best possible IT (i.e., $q_1 = q_2 = 0$ and $c_1 = c_2 = \underline{c}$) in an attempt to obtain all the market if their lending profits can cover the IT investment costs (Proposition 5). In this case, lender differentiation disappears, inducing extremely intense competition and trapping lenders in a prisoner's dilemma.

[30]Berg et al. (2021) analyze the spillover-induced bias and provide guidance on how to deal with it.

The welfare effect of information technology progress is ambiguous when it is of type IT-distance. On the one hand, higher competition intensity and better IT always favor entrepreneurs and alleviate their moral hazard; on the other hand, lower lender differentiation can reduce lenders' profits, monitoring incentives, and willingness to provide more loans. Whether or not an improvement in lenders' IT-distance benefits social welfare depends on whether the lending market has insufficient or too much competition at the outset. When $q$ is low, there is always excessive competition and insufficient monitoring incentives (Proposition 8). This is always the case when information technology is cheap because then lenders endogenously choose a very low $q$. IT-distance progress is more likely to induce excessive competition and harm welfare when entrepreneurs' moral hazard is more severe (Corollary 7 and Figure 8). The market may over- or under-shoot the welfare optimal rate. It will tend to under-shoot when the moral hazard problem of entrepreneurs is severe and the market under-provides monitoring. Finally, we find that price discrimination is inefficient and that a regulator could improve welfare by imposing a uniform reference loan rate.

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# Appendix A: Proofs

**Proof of Lemmas 1 and 2**. If lender $i$ chooses $m_i(z) < \overline{I_i(z)}(B - p(R - r_i(z)))$, the entrepreneur at $z$ will shirk; in this case, providing loans to the entrepreneur cannot bring a non-negative profit to the lender. Hence, $m_i(z) \geq \overline{I_i(z)}(B - p(R - r_i(z)))$ must hold. Obviously, choosing $m_i(z) > \overline{I_i(z)}(B - p(R - r_i(z)))$ is strictly dominated by choosing $m_i(z) = \overline{I_i(z)}(B - p(R - r_i(z)))$ because the latter is sufficient to prevent shirking. With $m_i(z) = \overline{I_i(z)}(B - p(R - r_i(z)))$, maximizing $\pi_i(z)$ (Equation 8) yields Lemma 2.

**Proof of Lemma 3**. In this proof, we take as given that lender $i$'s monitoring intensity and loan size restriction are as given in Lemmas 1 and 2. If the entrepreneur at $z$ borrows from lender $i$ at the loan rate $r_i(z) \in [0, R]$, her expected utility is

$$U_i(z) = \underbrace{\frac{1 - q_i s_i}{c_i} \frac{p r_i(z) - f}{(B - p(R - r_i(z)))^2}}_{= \overline{I_i(z)} = I_i(z)} p(R - r_i(z)), \tag{A.1}$$

which is maximized when $r_i(z) = \underline{r}$. It can be shown that $\underline{r} \in (f/p, R)$ holds because of Inequality (5).

Lender $i$'s expected profit from serving the entrepreneur is

$$\pi_i(z) = \overline{I_i(z)}(p r_i(z) - f) - \frac{c_i (m_i(z))^2}{2(1 - q_i s_i)} = \frac{1 - q_i s_i}{2c_i} \frac{(p r_i(z) - f)^2}{(B - p(R - r_i(z)))^2}.$$

It can be shown that

$$\frac{\partial \pi_i(z)}{\partial r_i(z)} = \frac{1 - q_i s_i}{c_i} \frac{p(p r_i(z) - f)(B + f - pR)}{(B - p(R - r_i(z)))^3},$$

which is positive for $r_i(z) \in (f/p, R]$ because of Inequality (5). The lender will never choose $r_i(z) \leq f/p$; otherwise, its profit from serving the entrepreneur at $z$ is negative. Hence the monopoly loan rate is $R$, which maximizes $\pi_i(z)$.

**Proof of Proposition 1 and Corollary 1**. First, we determine the cut-off (indifference) location. Because the two lenders compete in a localized Bertrand fashion, both lenders will offer their best loan rate $\underline{r}$ at the indifference location; meanwhile, the entrepreneur at the location feels indifferent. So we have the following equation for the indifference location $\tilde{x}$:

$$\frac{1 - q_1 \tilde{x}}{c_1} \frac{(p\underline{r} - f)\, p(R - \underline{r})}{(B - p(R - \underline{r}))^2} = \frac{1 - q_2(1 - \tilde{x})}{c_2} \frac{(p\underline{r} - f)\, p(R - \underline{r})}{(B - p(R - \underline{r}))^2},$$

and the result is the $\tilde{x}$ displayed in Proposition 1. At the point $\tilde{x}$, neither lender has a competitive advantage. On the left (resp. right) side of $\tilde{x}$, lender 1 (resp. lender 2) will have an advantage in the competition with its rival. So if $0 < \tilde{x} < 1$, entrepreneurs in $[0, \tilde{x}]$ are served by lender 1, while the other locations are served by lender 2.

At location $z \in [0, \tilde{x}]$, lender 1 must offer a loan rate $r_1(z)$ to maximize its own profit from this location, subject to the constraint that the entrepreneur at $z$'s utility is no less than what she would derive from the best loan rate $\underline{r}$ of lender 2. Recall that lender 1's monopoly loan rate is $R$, which leaves 0 profit to the entrepreneur. Lender 1's optimal choice is to set $r_1(z)$ as high as possible, implying Equation (10). Similarly, lender 2's equilibrium loan rate $r_2^*(z)$ at $z \in (\tilde{x}, 1]$ is determined by:

$$\frac{1 - q_2(1-z)}{c_2} \frac{(pr_2^*(z) - f)\, p(R - r_2^*(z))}{(B - p(R - r_2^*(z)))^2} = \frac{1 - q_1 z}{c_1} \frac{(p\underline{r} - f)\, p(R - \underline{r})}{(B - p(R - \underline{r}))^2}.$$

When $r_1^*(z) \in [\underline{r}, R]$, the left-hand side of Equation (10) is decreasing in $r_1^*(z)$. If $z$ increases in the region $[0, \tilde{x}]$, the left-hand side of Equation (10) will decrease for a given $r_1^*(z)$, while the right-hand side will increase; hence, $r_1^*(z)$ must decrease to keep Equation (10) holding.

**Proof of Corollary 2**. At $z \in [0, \tilde{x}]$, it can be shown that

$$\begin{cases} \frac{\partial \overline{I_1(z)}}{\partial z} = \frac{-q_1}{c_1} \frac{\left(pr_1^*(z) - f\right)}{\left(B - p\left(R - r_1^*(z)\right)\right)^2} + \frac{1 - q_1 z}{c_1} \underbrace{\frac{p\,(B + 2f - p\,(R + r_1^*(z)))}{(B - p\,(R - r_1^*(z)))^3}}_{+ \text{ if } r_1^*(z) \text{ is close to } \underline{r}} \frac{\partial r_1^*(z)}{\partial z} \\ \frac{\partial r_1^*(z)}{\partial z} = \frac{c_1}{c_2} \left(\frac{q_1 + q_2 - q_1 q_2}{(1 - q_1 z)^2}\right) \frac{(p\underline{r} - f)p(R - \underline{r})}{(B - p(R - \underline{r}))^2} \frac{\left(B - p\left(R - r_1^*(z)\right)\right)^3}{p\left(p\left(r_1^*(z) - R\right)(pR - f) + B\left(f + p\left(R - 2r_1^*(z)\right)\right)\right)} \end{cases}.$$

When $z$ is sufficiently close to $\tilde{x}$, $r_1^*(z)$ will be very close to $\underline{r}$. It can be shown that

$$\begin{cases} p\,(r_1^*(z) - R)\,(pR - f) + B\,(f + p\,(R - 2r_1^*(z))) < 0 \text{ for } r_1^*(z) > \underline{r} \\ \lim\limits_{r_1^*(z) \to \underline{r}} p\,(r_1^*(z) - R)\,(pR - f) + B\,(f + p\,(R - 2r_1^*(z))) = 0 \\ \lim\limits_{r_1^*(z) \to \underline{r}} p\,(B + 2f - p\,(R + r_1^*(z))) = \frac{2(B + f - pR)^2}{2B + f - pR} > 0 \end{cases}. \tag{A.2}$$

When $q_i > 0$ holds for some $i \in \{1, 2\}$, $\lim\limits_{z \to \tilde{x}} \partial r_1^*(z)/\partial z = -\infty$ and $\lim\limits_{z \to \tilde{x}} \partial \overline{I_1(z)}/\partial z = -\infty$ must hold since $\lim\limits_{z \to \tilde{x}} r_1^*(z) = \underline{r}$.

**Proof of Corollaries 3 and 4**. At $z \in [0, \tilde{x})$, Equation (10) can be written as:

$$\frac{\left(pr_1^*(z) - f\right) p\left(R - r_1^*(z)\right)}{\left(B - p\left(R - r_1^*(z)\right)\right)^2} = \frac{c_1}{c_2} \frac{1 - q_2(1-z)}{1 - q_1 z} \frac{\left(p\underline{r} - f\right) p\left(R - \underline{r}\right)}{\left(B - p\left(R - \underline{r}\right)\right)^2} \tag{A.3}$$

The left-hand side of Equation (A.3) is decreasing in $r_1^*(z)$. If $c_1/c_2$ or $(1 - q_2(1-z))/(1 - q_1 z)$ marginally decreases, the right-hand side of Equation (A.3) will decrease; hence, $r_1^*(z)$ must increase to keep Equation (A.3) holding.

If $q_1 = q_2 = q$ and $c_1 = c_2 = c$, obviously the right-hand side of Equation (A.3) is independent of $c$, so is $r_1^*(z)$. At $z \in [0, 1/2)$, $(1 - q(1-z)) / (1 - qz)$ is decreasing in $q$. Hence, $r_1^*(z)$ is increasing in $q$ at $z \in [0, 1/2)$. At $z = 1/2$, $r_1^*(z) = \underline{r}$ according to Corollary 1.

**Proof of Proposition 2**. We focus on lender 1's aggregate loan volume $L_1$ in the proof. It can be shown that

$$\frac{\partial L_1}{\partial c_1} = \int_0^{\tilde{x}} \frac{\partial I_1(z)}{\partial c_1} dz + I_1(\tilde{x}) \frac{\partial \tilde{x}}{\partial c_1}.$$

Obviously, $\partial \tilde{x} / \partial c_1 < 0$. At $z \in [0, \tilde{x})$, the following equation (which is another form of Equation 10) must hold:

$$\underbrace{\overline{I_1(z)} p\left(R - r_1^*(z)\right)}_{\text{entrepreneurial utility provided by } r_1^*(z)} = \underbrace{\frac{1 - q_2(1-z)}{c_2} \frac{\left(p\underline{r} - f\right) p\left(R - \underline{r}\right)}{\left(B - p\left(R - \underline{r}\right)\right)^2}}_{\text{maximum utility lender 2 provides}}. \tag{A.4}$$

As $c_1$ increases, $r_1^*(z)$ will decrease while the right-hand side of Equation (A.4) is unaffected. Hence, $\overline{I_1(z)}$ must decrease to keep Equation (A.4) holding. As a result, $\partial \overline{I_1(z)} / \partial c_1 < 0$ (i.e., $\partial I_1(z) / \partial c_1 < 0$) and $\partial L_1 / \partial c_1 < 0$ hold. In the same way, we can show $\partial L_1 / \partial q_1 < 0$.

**Proof of Proposition 3**. With $c_1 = c_2 = c$ and $q_1 = q_2 = q$, it holds that $\tilde{x} = 1/2$ and $L_1 = L_2$, so we focus on $L_1$ in the proof. It can be shown that $\partial L_1 / \partial c = \int_0^{1/2} \partial I_1(z) / \partial c dz$. Since $r_1^*(z)$ is independent of $c$, $I_1(z)$ must be decreasing in $c$ according to Lemma 2. Hence, $L_1$ is decreasing in $c$.

As for the effect of $q$, we also have $\partial L_1 / \partial q = \int_0^{1/2} \partial I_1(z) / \partial q dz$. It can be shown that

$$\begin{cases} \frac{\partial \overline{I_1(z)}}{\partial q} = \frac{-z}{c} \frac{pr_1^*(z) - f}{\left(B - p\left(R - r_1^*(z)\right)\right)^2} + \frac{1 - q_1 z}{c_1} \underbrace{\frac{p\left(B + 2f - p\left(R + r_1^*(z)\right)\right)}{\left(B - p\left(R - r_1^*(z)\right)\right)^3}}_{+ \text{ if } r_1^*(z) \text{ is close to } \underline{r}} \frac{\partial r_1^*(z)}{\partial q} \\ \frac{\partial r_1^*(z)}{\partial q} = \frac{-1 + 2z}{(1 - qz)^2} \frac{\left(p\underline{r} - f\right) p\left(R - \underline{r}\right)}{\left(B - p\left(R - \underline{r}\right)\right)^2} \frac{\left(B - p\left(R - r_1^*(z)\right)\right)^3}{p\left(p\left(r_1^*(z) - R\right)(pR - f) + B\left(f + p\left(R - 2r_1^*(z)\right)\right)\right)} \end{cases}.$$

When $q$ is sufficiently close to 0, $r_1^*(z)$ will be very close to $\underline{r}$. According to (In)equality (A.2), $\lim_{q\to 0}\partial r_1^*(z)/\partial q = +\infty$ and $\lim_{q\to 0}\partial \overline{I_1(z)}/\partial q = +\infty$ must hold when $z \in [0, 1/2)$. When $z = 1/2$, $\partial r_1^*(z)/\partial q = 0$ holds, so

$$\frac{\partial \overline{I_1(1/2)}}{\partial q} = -\frac{1/2}{c}\frac{p\underline{r} - f}{(B - p(R - \underline{r}))^2},$$

which is finite. Therefore, $\lim_{q\to 0}\int_0^{1/2} \partial I_1(z)/\partial q dz = +\infty$. That is, $L_1$ is increasing in $q$ if $q$ is sufficiently small.

**Proof of Proposition 4**. We need only look at lender 1's aggregate profit because the two lenders are symmetric. In equilibrium, lender 1's expected profit from serving the entrepreneur at $z$ is

$$\pi_1(z) = \overline{I_1(z)}(pr_1^*(z) - f) - \frac{c\,(m_1(z))^2}{2\,(1 - qz)} = \frac{1 - qz}{2c}\frac{(pr_1^*(z) - f)^2}{(B - p(R - r_1^*(z)))^2}.$$

Hence, we have

$$\frac{\partial\left(\int_0^{1/2}\pi_1(z)dz\right)}{\partial q} = \int_0^{1/2}\frac{\partial \pi_1(z)}{\partial q}dz = \int_0^{1/2}\left(\begin{array}{c}\frac{-z}{2c}\frac{\left(pr_1^*(z)-f\right)^2}{(B-p(R-r_1^*(z)))^2}\\ +\frac{1-qz}{2c}\frac{p\left(pr_1^*(z)-f\right)(B+f-pR)}{(B-p(R-r_1^*(z)))^3}\frac{\partial r_1^*(z)}{\partial q}\end{array}\right)dz.$$

According to the proof of Proposition 3, $\lim_{q\to 0}\partial r_1^*(z)/\partial q = +\infty$ when $z \in [0, 1/2)$; $\partial r_1^*(z)/\partial q = 0$ when $z = 1/2$. As a result, $\lim_{q\to 0}\int_0^{1/2}\partial \pi_1(z)/\partial q dz = +\infty$. That is, lender 1's aggregate lending profit from all locations is increasing in $q$ if $q$ is sufficiently small.

Since $c$ does not affect $r_1^*(z)$, it is easy to show that

$$\frac{\partial\left(\int_0^{1/2}\pi_1(z)dz\right)}{\partial c} = \int_0^{1/2}\left(-\frac{1 - qz}{2c^2}\frac{(pr_1^*(z) - f)^2}{(B - p(R - r_1^*(z)))^2}\right)dz < 0.$$

Hence, lender 1's aggregate lending profit from all locations is decreasing in $c$.

**Proof of Proposition 5**. In the main text we have already shown that $q_1 = q_2 = 0$ and $c_1 = c_2 = \underline{c}$ indeed constitute an equilibrium. Here we show that the equilibrium is unique.

First, we show that $\{q_2 = 0, c_2 = \underline{c}\}$ and $\{q_1 > 0$ or $c_1 > \underline{c}\}$ cannot be an equilibrium. If lender 2 chooses $\{q_2 = 0, c_2 = \underline{c}\}$, then lender 1's best response must be $\{q_1 = 0, c_1 = \underline{c}\}$, in which case lender 1's ex-ante profit is $\Pi_1(0, 0, \underline{c}, \underline{c}) > 0$. Otherwise, if lender 1's IT choice is not $\{q_1 = 0, c_1 = \underline{c}\}$, the lender's market share must be 0, which means

$$\Pi_1 (q_1, 0, c_1, \underline{c})\big|_{q_1>0 \text{ or } c_1>\underline{c}} = -T (q_1, c_1) \leq 0.$$

Therefore, $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ cannot be lender 1's best choice. Overall, $\{q_2 = 0, c_2 = \underline{c}\}$ and $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ cannot be an equilibrium. Reasoning symmetrically, $\{q_1 = 0, c_1 = \underline{c}\}$ and $\{q_2 > 0 \text{ or } c_2 > \underline{c}\}$ cannot be an equilibrium either.

Next, we show that $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ and $\{q_2 > 0 \text{ or } c_2 > \underline{c}\}$ cannot be an equilibrium. In this case, we can show that lender 1 (resp. lender 2) has an incentive to deviate if $\tilde{x} \leq 1/2$ (resp. $\tilde{x} \geq 1/2$). If $\tilde{x} \leq 1/2$, lender 1's market share will increase from $\tilde{x}$ to 1 if the lender deviates from $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ to $\{q_1 = 0, c_1 = \underline{c}\}$; the cost of this deviation is no higher than $T (0, \underline{c})$, while the lender's profit from the incremental market area $(\tilde{x}, 1]$ must satisfy

$$\int_{\tilde{x}}^{1} \pi_1(z)dz\bigg|_{q_1=0, c_1=\underline{c};\ q_2>0 \text{ or } c_2>\underline{c}} > \int_0^{1/2} \pi_1(z)dz\bigg|_{q_1=q_2=0, c_1=c_2=\underline{c}}.$$

because $\tilde{x} \leq 1/2$. Meanwhile, lender 1's profit from its initial market area $[0, \tilde{x}]$ will also (weakly) increase as the lender deviates to $\{q_1 = 0, c_1 = \underline{c}\}$. Overall, because of the deviation, lender 1's profit in the Bertrand competition will increase by more than $\int_0^{1/2} \pi_1(z)dz\Big|_{q_1=q_2=0, c_1=c_2=\underline{c}}$, while the IT investment costs will increase by no more than $T (0, \underline{c})$. Because of the condition

$$\Pi_1 (0, 0, \underline{c}, \underline{c}) = \int_0^{1/2} \pi_1(z)dz\bigg|_{q_1=q_2=0, c_1=c_2=\underline{c}} - T (0, \underline{c}) > 0,$$

lender 1 will become strictly better off if it deviates to $\{q_1 = 0, c_1 = \underline{c}\}$. Therefore, if $\tilde{x} \leq 1/2$, $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ and $\{q_2 > 0 \text{ or } c_2 > \underline{c}\}$ cannot be an equilibrium.

Reasoning symmetrically, $\{q_1 > 0 \text{ or } c_1 > \underline{c}\}$ and $\{q_2 > 0 \text{ or } c_2 > \underline{c}\}$ cannot be an equilibrium if $\tilde{x} \geq 1/2$ because then lender 2 can be strictly better off by deviating to $\{q_2 = 0, c_2 = \underline{c}\}$. Overall, the unique equilibrium is $\{q_1 = 0, c_1 = \underline{c}\}$ and $\{q_2 = 0, c_2 = \underline{c}\}$ if we have the condition $\Pi_1 (0, 0, \underline{c}, \underline{c}) > 0$.

**Proof of Proposition 6**. Note that controlling lenders' loan rates allows the social planner to determine which lender serves a certain location. For example, if the social planner does not want lender 1 to serve location $z$, it can simply let $r_1(z) = R$; then the entrepreneur at $z$ will approach lender 2 for any $r_2(z) \in [\underline{r}, R)$.

Assume that lender $i$ serves location $z$. Social welfare at this location equals:

$$
\begin{aligned}
& I_i(z)\,p\,(R-r_i(z)) + I_i(z)\,(pr_i(z)-f) - \frac{c(m_i(z))^2}{2(1-qs_i)} \\
= \; & \underbrace{\frac{1-qs_i}{c}\frac{(pr_i(z)-f)\,p\,(R-r_i(z))}{(B-p(R-r_i(z)))^2}}_{\text{entrepreneur utility at } z} + \underbrace{\frac{1-qs_i}{2c}\frac{(pr_i(z)-f)^2}{(B-p(R-r_i(z)))^2}}_{\text{lender } i\text{'s profit at } z}.
\end{aligned}
$$

To maximize the equation above, the first order condition is $r_i(z) = r^o$. Hence, the maximum welfare at $z$ is

$$
\frac{1-qs_i}{c}\underbrace{\frac{2\,(pr^o-f)\,p\,(R-r^o)+(r^o-f)^2}{2(B-p(R-r^o))^2}}_{\text{unaffected by } q_i,\, c_i, \text{ or } s_i}
$$

if location $z$ is served by lender $i$. To maximize welfare at $z$, the location should be served by the lender with a smaller lending distance. Given that both lenders offer $r^o$, each entrepreneur indeed will approach the lender with a smaller lending distance.

Finally, it can be shown that

$$
r^o - \underline{r} = \frac{(B+f-pR)^2\,(pR-f)}{Bp\,(2B+f-pR)} > 0,
$$

so $r^o > \underline{r}$.

**Proof of Proposition 7 and Corollaries 6 and 7**. Since $r_1^*(z)$ is increasing in $q$, $r_1^*(z) = r^o$ must hold when $q = k(z)$, implying

$$
\underbrace{\frac{1-k(z)z}{c}\frac{(pr^o-f)\,p\,(R-r^o)}{(B-p\,(R-r^o))^2}}_{\text{entrepreneurial utility provided by } r_1^*(z)=r^o} = \underbrace{\frac{1-k(z)\,(1-z)}{c}\frac{(p\underline{r}-f)\,p\,(R-\underline{r})}{(B-p\,(R-\underline{r}))^2}}_{\text{maximum utility lender 2 provides}},
$$

which yields

$$
k(z) = \frac{1-4B(pR-f)/(pR-f+B)^2}{1-z-4B(pR-f)z/(pR-f+B)^2}.
$$

If $k(z) > 1$, then $r_1^*(z) < r^o$ holds for any $q \in [0,1]$. It can be shown that

$$
k(0) = 1 - \frac{4B(pR-f)}{(pR-f+B)^2} = \left(\frac{pR-f-B}{pR-f+B}\right)^2 > 0.
$$

Let $\varphi = B/(pR - f) > 1$, we have

$$k(z) = \frac{1 - \frac{4}{(1+1/\varphi)(1+\varphi)}}{1 - z - \frac{4z}{(1+1/\varphi)(1+\varphi)}} \Rightarrow \frac{\partial k(z)}{\partial \varphi} = \frac{4\left(\varphi^2 - 1\right)(1 - 2z)}{\left(-\left(1+\varphi\right)^2 + z + \varphi\left(6+\varphi\right)z\right)^2} > 0.$$

Hence, at $z \in [0, 1/2)$, $k(z)$ is increasing in $B/(pR - f)$.

**Proof of Proposition 8**. Since the two lenders are symmetric, social welfare $W$ equals

$$2\int_0^{1/2} \frac{1 - qz}{c} \frac{\left(pr_1^*(z) - f\right) p\left(R - r_1^*(z)\right)}{(B - p(R - r_1^*(z)))^2} dz + 2\underbrace{\int_0^{1/2} \frac{1 - qz}{2c} \frac{\left(pr_1^*(z) - f\right)^2}{(B - p(R - r_1^*(z)))^2} dz}_{=\int_0^{1/2} \pi_1(z)dz}.$$

Since $c$ does not affect $r_1^*(z)$, obviously $W$ is decreasing in $c$.

As for effect of $q$, it can be shown that

$$\frac{\partial W}{\partial q} = 2\int_0^{1/2} \left( \begin{array}{c} -\frac{z}{c}\left(\frac{\left(pr_1^*(z)-f\right)p\left(R-r_1^*(z)\right)}{(B-p(R-r_1^*(z)))^2} + \frac{\left(pr_1^*(z)-f\right)^2}{2(B-p(R-r_1^*(z)))^2}\right) \\ +\frac{1-qz}{c}\frac{p\left(Bp(R-r_1^*(z))-(pR-f)^2\right)}{(B-p(R-r_1^*(z)))^3}\frac{\partial r_1^*(z)}{\partial q}. \end{array} \right) dz$$

As $q$ approaches 0, $r_1^*(z)$ will approach $\underline{r}$. It holds that

$$Bp(R - \underline{r}) - (pR - f)^2 = \frac{(pR - f)\left(B + f - pR\right)^2}{2B + f - pR} > 0.$$

Meanwhile, recall that $\lim\limits_{q\to 0} \partial r_1^*(z)/\partial q = +\infty$ for $z < 1/2$ (see the Proof of Proposition 3), so $\lim\limits_{q\to 0} \partial W/\partial q = +\infty$ must hold. Hence, social welfare is increasing in $q$ if $q$ is sufficiently small.

# Appendix B: Heterogeneous funding costs

**Summary.** In this appendix, we let the two lenders face different marginal funding costs. Then, lenders' best loan rates are no longer the same; the lender with a lower marginal funding cost has a lower best loan rate. Reducing a lender's marginal funding cost will increase its competitive advantage, extending its market share and raising its loan rates and volumes. In contrast, reducing both lenders' marginal funding costs will decrease their loan rates. At the indifference location, both lenders offer their best loan rates and provide the same entrepreneurial utility. However, the curve of equilibrium loan rates is discontinuous at the indifference location when lenders face heterogeneous funding costs (see Panel 2 of Figure 5): The lender with a lower marginal funding cost – which can be viewed as a bank with access to cheap funding (e.g., deposits) – offers a lower (best) loan rate because of its advantage in funding costs. In contrast, its rival (which can be viewed as a fintech lender with a more expensive funding source) has an advantage in IT and provides a larger loan volume at the indifference location.

**Model setup.** In the main text, investors require an expected return of $f$ when providing funds to lenders, which does not consider the possibility that investors may require different returns for different lenders because of the heterogeneity in lender-investor relationships. In this appendix, we consider this possibility by assuming that investors' required expected return is $f_i$ for lender $i$. Now the non-trivial moral hazard condition (i.e., Inequality 5 of the main text) is modified to

$$pR - B < f_i, \ i \in \{1, 2\}. \tag{B.1}$$

All the other assumptions of the main text still apply.

Now, lender $i$ faces a marginal funding cost of $f_i$ (instead of $f$), so Lemma 3 of the main text should be modified as follows.

**Lemma B.1.** *At any location, lender $i$'s best loan rate is*

$$\underline{r_i} \equiv R - \frac{B(pR - f_i)}{p(2B + f_i - pR)},$$

*while the monopoly loan rate is $R$. The relation $f_i/p < \underline{r_i} < R$ holds. Lender $i$ will not offer a loan rate that is lower than $\underline{r_i}$.*

Lemma B.1 is not qualitatively different from Lemma 3. The only difference is that now $f_i$ replaces $f$ in the formula of lender $i$'s best loan rate. Hence, lenders' best loan rates need not be the same. In this appendix, we denote lender $i$'s best loan rate by $\underline{r_i}$, which has a subscript "$i$".

**Corollary B.1.** *Lender $i$'s best loan rate $\underline{r_i}$ is increasing in $f_i$.*

An increase in $f_i$ will raise $\underline{r_i}$ for two reasons. First, everything else being equal, a higher $f_i$ will decrease lender $i$'s skin in the game, which is $r_i(z) - f_i/p$. Hence, the best loan rate must increase to alleviate the decrease in lender $i$'s skin in the game and monitoring incentive. Second, a higher $f_i$ will make the moral hazard problem of lender $i$'s entrepreneurs more severe. The reason is that the severity of an entrepreneur's moral hazard problem is determined by the relative private benefit $B/(pR - f_i)$, which is increasing in $f_i$. As $f_i$ increases (the moral hazard problem becomes more severe), lender $i$'s monitoring incentive becomes more important for the lender's loan sizes, so $\underline{r_i}$ must allocate a larger share of "pie" to lender $i$. Specifically, we can show

$$\frac{\underline{r_i} - f_i/p}{R - f_i/p} = 1 - \frac{B/(pR - f_i)}{2B/(pR - f_i) - 1},$$

which is increasing in $f_i$. The increase in lender $i$'s share of the pie also raises $\underline{r_i}$.

**Equilibrium loan rates.** If an entrepreneur at $z$ borrows from lender $i$ at the loan rate $r_i(z)$, her expected utility is equal to

$$U_i(r_i(z), z) \equiv \underbrace{\frac{1 - q_i s_i}{c_i} \frac{p r_i(z) - f_i}{(B - p(R - r_i(z)))^2}}_{I_i(z)} p\left(R - r_i(z)\right). \tag{B.2}$$

Obviously, the maximum utility lender $i$ can provide at $z$ is $U_i(\underline{r_i}, z)$. If lender 1 wants to attract the entrepreneur at $z$, it must offer a loan rate more attractive than the best loan rate $\underline{r_2}$ of lender 2 (that is, providing expected utility no less than $U_2(\underline{r_2}, z)$). If lender 1 cannot do so, then the entrepreneur will be served by lender 2 instead. Reasoning in this way yields the following result.

**Proposition B.1.** *Let*

$$U_1(\underline{r_1}, 0) > U_2(\underline{r_2}, 0) \text{ and } U_1(\underline{r_1}, 1) < U_2(\underline{r_2}, 1). \tag{B.3}$$

*There exists a unique $\tilde{x} \in (0, 1)$ such that entrepreneurs located in $[0, \tilde{x}]$ (resp. $(\tilde{x}, 1]$) are served by lender 1 (resp. lender 2). At $z \in [0, \tilde{x}]$, the equilibrium loan rate schedule for*

*$i = 1$, $r_1^*(z)$, is the unique solution (in interval $[\underline{r_1}, R]$) of*

$$U_1(r_1^*(z), z) = U_2(\underline{r_2}, z) \tag{B.4}$$

*At $z \in (\tilde{x}, 1]$, lender 2's equilibrium loan rate $r_2^*(z)$ is determined in a symmetric way.*

Condition B.3 means that lender 1 (resp. lender 2) can provide strictly higher utility than the rival at location $z = 0$ (resp. $z = 1$), so each lender will have a positive market share in equilibrium. If Condition B.3 does not hold, one lender will dominate the entire market and drive out the other lender. Throughout the appendix, we focus on the case with $\tilde{x} \in (0, 1)$.

Proposition B.1 is consistent with Proposition 1. At $z \in [0, \tilde{x}]$ (i.e., a location served by lender 1), the lender's pricing strategy is maximizing its own profit while ensuring that entrepreneurial utility is no less than the maximum utility lender 2 can provide. Based on this strategy, at $z \in [0, \tilde{x}]$ the entrepreneurial utility implied by lender 1's equilibrium loan rate $r_1^*(z)$ should exactly match $U_2(\underline{r_2}, z)$ (i.e., the utility implied by lender 2's best loan rate $\underline{r_2}$).

**The effects of heterogeneous funding costs**. The following proposition characterizes lenders' loan rates at different locations.

**Proposition B.2.** *Let $q_i > 0$ for some $i \in \{1, 2\}$ and $f_1 < f_2$. Lender $i$'s equilibrium loan rate $r_i^*(z)$ is decreasing in its lending distance $s_i$.*

*At the indifference location $z = \tilde{x}$, the following relations hold:*

$$\begin{cases} r_1^*(\tilde{x}) = \underline{r_1} < \underline{r_2} = \lim\limits_{z \to \tilde{x}} r_2^*(z) \\ \frac{\frac{1-q_1\tilde{x}}{c_1}}{I_1(\tilde{x})} < \frac{\frac{1-q_2(1-\tilde{x})}{c_2}}{\lim\limits_{z \to \tilde{x}} I_2(z)} \end{cases}.$$

The first part of the result is consistent with Corollary 1: as lender $i$'s lending distance increases, its competitive advantage will decrease, so the lender must offer a lower loan rate to match the maximum utility provided by the rival.

The second part of Proposition B.2 shows the effects of heterogeneous funding costs. With heterogeneous funding costs, the two lenders behave differently at the indifference location $z = \tilde{x}$. At $z = \tilde{x}$, both lenders must offer their best loan rates to attract the entrepreneur. With $f_1 < f_2$, lender 1 has a lower best loan rate (i.e., $\underline{r_1} < \underline{r_2}$; see Corollary B.1), so its loan rate is lower than lender 2's at the indifference location. Panel 2 of Figure 5 illustrates the result.

At $z = \tilde{x}$, the entrepreneur is indifferent between the two lenders' offers. Although a lower marginal funding cost allows lender 1 to offer a lower loan rate, lender 2 has better monitoring efficiency (i.e., $(1 - q_1\tilde{x})/c_1 < (1 - q_2(1 - \tilde{x}))/c_2$) and provides a larger loan volume (i.e., $\overline{I_1(\tilde{x})} < \lim_{z \to \tilde{x}} \overline{I_2(z)}$), making the entrepreneur at $z = \tilde{x}$ indifferent (Panel 2 of Figure 5).

We can view lender 1 as a bank with access to cheap funding (e.g., deposits), while lender 2 as a fintech with a more expensive funding source. Then, Proposition B.2 implies that, when serving entrepreneurs of similar characteristics (i.e., entrepreneurs around the indifference location), fintech lenders will offer higher loan rates and larger loan volumes than traditional banks.

The following corollary shows how $f_i$ affects lenders' market shares.

**Corollary B.2.** *Lender 1's market share (measured by $\tilde{x}$) is decreasing in $f_1$ and increasing in $f_2$.*

Given lender 1's loan rate $r_1(z)$, a decrease in $f_1$ will increase lender 1's skin in the game without reducing the entrepreneur's skin in the game (as a result, $\overline{I_1(z)}$ will increase; see Equation B.2). Hence, everything else being equal, a decrease in $f_1$ will increase the utility lender 1 provides, improving its competitive advantage. A higher competitive advantage enables lender 1 to obtain a larger market share, thereby reducing the rival's market share.

The following corollary shows how $f_i$ affects a lender's pricing and loan volume.

**Corollary B.3.** *Let $z \in [0, \tilde{x})$. Lender 1's equilibrium loan rate $r_1^*(z)$ and loan size upper-bound $\overline{I_1(z)}$ are decreasing in $f_1$.*

As $f_1$ decreases, lender 1's competitive advantage becomes higher, allowing the lender to increase $r_1^*(z)$. An increase in $r_1^*(z)$ reduces the entrepreneur's skin in the game, so lender 1 must provide more loans (i.e., increase $\overline{I_1(z)}$) to match the maximum utility lender 2 provides.

The implication of Corollary B.3 is that reducing a lender's funding costs does not translate into the lender's lower loan rates; instead, the lender will fully exploit its market power and extract the entire benefit of its funding cost advantage.

Finally, we look at the symmetric case with $q_i = q$, $c_i = c$, and $f_i = f$ and study the effect of $f$.

**Corollary B.4.** *Let $c_1 = c_2 = c$, $q_1 = q_2 = q$, and $f_1 = f_2 = f$. Lender $i$'s equilibrium loan rate $r_i^*(z)$ is increasing in $f$.*

As both lenders' marginal funding cost $f$ decreases, lender 1 must decrease its loan rates for $z \in [1, 1/2]$ to protect its market share. The reason is that a lower $f$ allows lender 2 to offer a lower best loan rate, increasing its threat to lender 1. As a result, both lenders charge lower loan rates from their entrepreneurs.

Comparing Corollaries B.3 and B.4 yields the following implication: If a policymaker aims to decrease loan rates by reducing lenders' funding costs, it should reduce the funding costs for all lenders. Otherwise, some lenders can enjoy a larger funding cost advantage and charge higher loan rates.