Information Technology and Bank Competition

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Very preliminary and incomplete. Please do not circulate.

Abstract

We construct a spatial bank competition model to study how the development and diffusion of information technology and BigTech entry affect the competition in the lending market, the stability of the banking sector and social welfare. We show that, before the entry of a BigTech, the development and diffusion of information technology increases bank competition, and potentially makes the banking sector less stable. After the BigTech entry, banks face more competition and become less stable. The BigTech entry can either increase or decrease social welfare depending on the levels of banks' and the BigTech's information technology.

JEL:
Keywords: Bank Competition, Bank Stability, Information Technology, BigTech Entry

1 Introduction

In recently years, the banking industry is undergoing a digital revolution. One the one hand, banks feel increasing pressure from the threat of FinTech companies and BigTechs who adopt innovative information and automation technology in traditional banking businesses. Prominent examples can be seen in China where Alibaba and Tecent, the two largest BigTechs, are active in a wide range of financial services such as payments[1], wealth management[2] and lending[3]. On the other hand, the banking sector itself is transforming from being based in physical branches to adopting information technology and big data (Vives, 2019), in response to increasing technology supply and changes in consumer expectation of service, which are the two drivers of digital disruption (Carstens, 2018 and FSB, 2019). The COVID-19 pandemic makes more customers concerned about going to a physical bank[4], and therefore may further stimulate the development and diffusion of information technology in the banking sector.

Based on the background above, we construct a spatial bank competition model based on Salop (1979) to study how the development and diffusion of information technology and BigTech entry affect the competition of the lending market, the stability of the banking sector and social welfare. We show that, before a BigTech enters the lending market, the development and diffusion of information technology increases bank competition, and therefore can make the banking sector less stable. The entry of a Bigtech changes the form of competition in the lending market. Banks no longer compete directly with each other after the BigTech entry; instead, each bank directly competes with the BigTech. The change of competition form further increases the competition facing banks and therefore makes the banking sector less stable. BigTech entry can either increase or decrease social welfare depending on the levels of banks' and the BigTech's information technology.

Model Preview. We model the lending market with a circular city where two banks, which are located symmetrically at the two end points of a diameter of the city, compete for entrepreneurs who are uniformly distributed along the circumference of the city. Entrepreneurs have risky investment projects, but no initial capital, so they demand funding from banks. Banks have no access to real investment, so they make profits by offering loans to entrepreneurs

[1]According to Vives (2019), mobile payments for consumer goods now constitute 16% of China's GDP, while Alipay and Wechat, owned by Alibaba and Tencent respectively, account for 94% of the mobile payment sector.

[2]The assets under the management of Yu'ebao, which is the Ant Financial (controlled by Alibaba) online money market fund, has reached US$200 billion by September 2018.

[3]Ant Financial and Tencent's (part) subsidiary WeBank provide lending to consumers and firms(Frost et al., 2019).

[4]82% of consumers are concerned about going to a their bank during the pandemic, according to Lightico (March 15 survey of 1000 consumers). Seeing `https://www.americanbanker.com/news/coronavirus-throws-digital-banking-into-the-crucible` for the full report.

and charge a loan rate. Like in Salop (1979), we assume transportation costs are incurred when an entrepreneur approaches a bank. Transportation costs can be interpreted in several ways. We can interpret them as due diligence costs that are positively correlated with bank-entrepreneur distance. Considering that banks' services may not perfectly match all entrepreneurs' preferences, we can also follow Thisse and Vives (1988) and interpret transportation costs as an entrepreneur's utility discount caused by the imperfect match. Banks compete in a Bertrand fashion by simultaneously offering their loan rates. Risky projects of entrepreneurs may either succeed or fail. In addition to financing entrepreneurs' investment, the key role of banks is to monitor entrepreneurs in order to increase the probability of success for entrepreneurs' projects (Martinez-Miera and Repullo, 2019). Monitoring is more costly for a bank if the distance between the bank and the monitored entrepreneur is larger[5]. The influence of distance on monitoring costs inversely reflects the state of information technology of the banking sector. If the banking sector's information technology is advanced, then a bank's monitoring costs will not increase a lot as the distance goes up.

Under the setups above, we first study bank competition assuming that a bank must offer a uniform loan rate to all its entrepreneurs. We find that the development and diffusion of information technology decreases banks' equilibrium loan rates. Two factors contribute to this result. First, more advanced information technology makes it less costly for banks to monitor far-away entrepreneurs, which effectively reduces entrepreneurs' costs of moving along the city, weakens banks' market power and therefore increases bank competition. Second, by reducing monitoring costs, more advanced information technology increases banks' marginal benefit from financing each entrepreneur, which gives banks more incentive to extend market shares by lowering their loan rates. Both effects of technology progress work in the same direction and decrease the equilibrium loan rate. A lower loan rate, due to the progress of information technology, implies not only a lower profit buffer, but also a lower monitoring intensity for a bank. Therefore, we find that the development and diffusion of information technology potentially makes banks less stable, although it makes monitoring less costly.

One consequence of information technology progress is that banks' services are becoming increasingly personalised in recent years. Therefore, we also study bank competition assuming that a bank can offer discriminatory loan rates to different entrepreneurs. Degryse and Ongena (2005) provide evidence that distance does matter in loan pricing, justifying our assumption. When spatial discrimination is allowed in loan pricing, the development and diffusion of in-

[5]There are evidences that firm-bank distance does matter for bank lending. E.g., Degryse and Ongena (2005) document spatial discrimination in loan pricing. Petersen and Rajan (2002) and Brevoort and Wolken (2009) also acknowledge the importance of distance.

formation technology again decreases banks' equilibrium loan rates, because more advanced information technology makes banks more capable of offering attractive loan rates to far-away entrepreneurs, which reduces banks ability to set high loan rates to nearby entrepreneurs. Lower loan rates decrease banks' profit buffer and incentive to monitor entrepreneurs, so we find again that the development and diffusion of information technology potentially makes banks less stable, although it makes monitoring less costly. Overall, in both cases (with and without spatial discrimination), our main results are consistent.

Then we analyse the effects of BigTech entry on the lending market equilibrium. We model the BigTech as a lender located at the heart of the circular city. Therefore, the distances between the BigTech and different entrepreneurs are the same, which captures the idea that the BigTech connects entrepreneurs with the Internet and is able to use non-traditional information to perform due diligence and monitoring, so physical distance is not important for the BigTech[6]. The BigTech can also monitor entrepreneurs, and the corresponding monitoring cost is inversely affected by the BigTech's information technology. Intuitively, we find that the BigTech can enter the lending market if and only if its information technology is advanced enough. After the BigTech enters, the form of competition in the lending market changes. Before the BigTech enters, the two banks compete directly with each other, while after the BigTech entry, each bank only compete directly with the BigTech. This is becuase the BigTech is equally far away from all entrepreneurs, and therefore has cost advantage in monitoring entrepreneurs who are far away from both banks. As a result, the BigTech attracts entrepreneurs located in the middle of the city, and effectively cuts off direct bank competition. We find that the change of competition form due to the BigTech entry puts banks into a more fierce competition, therefore decreases banks' loan rates and makes banks less stable. The reason is that the BigTech's monitoring efficiency does not vary with entrepreneurial location, which reduces banks market power to set high loan rates to their nearby entrepreneurs[7].

The effect of banks' information technology progress is also changed by the BigTech entry. Before the BigTech entry, the development and diffusion of banks' information technology increases bank competition and therefore decreases banks' loan rates. After the BigTech entry, banks no longer compete with each other, so developing banks' information technology can increase banks' market power in their competition with the BigTech, and therefore increase

[6]There are evidences that non-traditional data such as soft information (Iyer et al., 2016), friendships and social networks (Lin et al., 2013), description text of applicants (Gao et al., 2018;Dorfleitner et al., 2016;Netzer et al., 2019), contract terms (Kawai et al., 2014;Hertzberg et al., 2016) and digital footprints (Berg et al., 2020) are useful for FinTech and BigTech companies.

[7]In contrast, banks can set quite high loan rates for their nearby entrepreneurs when banks compete directly with each other, because the monitoring efficiency of a bank will be discounted due to physical distance when it monitors an entrepreneur near the rival bank.

banks' loan rates. On the contrary, the progress of the BigTech's information technology decreases banks' market power and their loan rates.

Finally, we analyse the welfare effects of the BigTech entry. The entry of a BigTech increases the overall competition of the lending market, which decreases banks' loan rates and their incentive to monitor entrepreneurs. Therefore, from this perspective, the BigTech has negative welfare effect. However, the BigTech can enter the lending market only if its information technology is advanced enough, so the BigTech entry may introduce more advanced information technology into the lending market. More advanced information technology can save monitoring costs for the lending market, which has positive welfare effect. If we consider the possibility that the BigTech can save transportation costs associated with traditional bank lending, then there are more social benefits from the BigTech entry. Overall, the BigTech entry may either increase or decrease social welfare, depending on which effect dominates.

Related Literature. (To be written).

The remainder of the paper is organized as follows: Section 2 presents the model setups. Section 3 studies the bank competition equilibrium assuming that banks can only offer uniform loan rates. In Section 4, we allow banks to discriminate entrepreneurs based on entrepreneurial location. Section 5 studies the effects of the BigTech entry on the lending market equilibrium. Section 6 analyses the welfare effect of the BigTech entry. Proofs are gathered in the Appendix (to be included).

2 The Model

The Economy and Players. The economy is represented by a circular city whose circumference is 2. The city is inhabited by entrepreneurs and banks. Entrepreneurs of mass 1 are distributed uniformly along the circumference. There are two banks, labeled by $i = \{1, 2\}$, located symmetrically at the two end points of a diameter of the city. If the distance between an entrepreneur and bank 1 is z, we say that the entrepreneur is located at location z and call her "entrepreneur z". As a result, the distance between entrepreneur z and bank 2 is $1 - z$. Figure 1 gives a graphic illustration for the economy.

Entrepreneurs and Monitoring Intensity. Each entrepreneur has no initial capital, but is endowed with a risky investment project that requires a unit of fund to be implemented. If an entrepreneur wants to implement her investment project, she must get financed by a bank

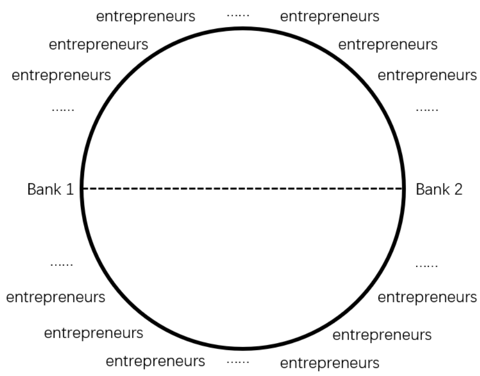

Figure 1: The Economy

through bank loans. Entrepreneur z's investment project yields the following risky return:

$$\tilde{R}(z) = \begin{cases} R & \text{w.p.} \quad m(z) \\ 0 & \text{w.p.} \quad 1 - m(z). \end{cases}$$

In case of success (failure), the investment project yields R (0), and the probability of success is $m(z)$ for entrepreneur z. $m(z) \in [0, 1]$ is assumed to equal the monitoring intensity with which entrepreneur z is monitored by a bank. We assume that the choice of $m(z)$ is not observable. When approaching a bank to ask for a loan, entrepreneur z faces transportation costs, $ts > 0$, where t is the marginal transportation cost and s is the distance between entrepreneur z and the bank she approaches. Specifically, $s = z$ ($s = 1 - z$) if entrepreneur z borrows from bank 1 (bank 2). Transportation costs can be interpreted in several ways. We can interpret them as due diligence costs borne by entrepreneurs. Due diligence costs are increasing in bank-entrepreneur distance because it will take an entrepreneur more time and efforts to prepare application materials as the distance increases. Considering that banks' services may not perfectly match all entrepreneurs' preferences, we can also follow Thisse and Vives (1988) and interpret transportation costs as an entrepreneur's utility discount caused by the imperfect match. Since transportation costs will be incurred no matter whether an entrepreneur's project succeeds or not, such costs are assumed to be non-pecuniary. Finally, we assume that implementing the risky investment project can generate an intrinsic value V for entrepreneur z, in addition to the potential profit from the risky project.

Correlation among Entrepreneurs' Projects. The outcomes of projects are driven by a single aggregate risk factor θ that is uniformly distributed in $[0, 1]$. The project of entrepreneur z with monitoring intensity $m(z)$ fails if and only if

$$\theta < 1 - m(z).$$

Banking Sector and Information Technology. The two banks have access to the same information technology that allows them to increase entrepreneurs' probability of success through monitoring. Specifically, by incurring a non-pecuniary monitoring cost $C_i(m_i, z)$, bank i can monitor entrepreneur z with intensity m_i. $C_i(m_i, z)$ is given by the following quadratic function:

$$C_i(m_i, z) = \frac{c}{2(1-qs)} m_i^2,$$

with $c > 0$ and $q \in (0, 1)$. $s = z$ ($s = 1-z$) if $i = 1$ ($i = 2$). The parameter c captures how costly bank monitoring is. $C_i(m_i, z)$ is increasing in the distance s between bank i and entrepreneur z when $q > 0$, which captures the idea that the efficiency of monitoring is decreasing in the distance s. Intuitively, banks have greater capacity to discipline nearby borrowers, while must pay more efforts to monitor entrepreneurs far away. Evidence [8] shows that closer distances can help improve banking relationships. The parameter q inversely measures banks' state of information technology. A decrease in q implies an improvement in banks' information technology, which ameliorates the impact that distance has on monitoring costs.

Uninsured Bank Deposits. For simplicity, we assume that banks have no initial capital and have to raise deposits from risk neutral depositors to finance the bank loans. Bank deposits are not insured, and the funding supply of depositors are perfectly elastic when the expected payoff of deposits is no less than the risk-free rate f. The deposit rate of bank i is denoted as d_i, which must be set to make depositors break even.

Competition with Uniform Loan Pricing. Banks compete in a Bertrand fashion to extend loans. Consider that bank i follows a uniform pricing policy in which the loan rate, r_i, is set irrespective of the entrepreneurial location. The timing of the lending game is as follows (seeing Figure 2). First, banks set loan rates simultaneously. Once the loan rates are chosen and hence observable, entrepreneurs decide which banks to approach and the potential market share for each bank is determined. Given the potential market shares and loan rates of both banks, bank i chooses its optimal monitoring intensity in terms of location, $m_i(z)$, to entrepreneur z. Finally, depositors put their money into banks and ask for a nominal deposit rate d_i based on r_i and their anticipation of $m_i(z)$.

3 Equilibrium with Uniform Loan Rates

In this section we analyse the equilibrium and try to find out how the development and diffusion of information technology can affect bank competition and bank stability. we consider two

[8] See Petersen and Rajan (2002) and Brevoort and Wolken (2009).

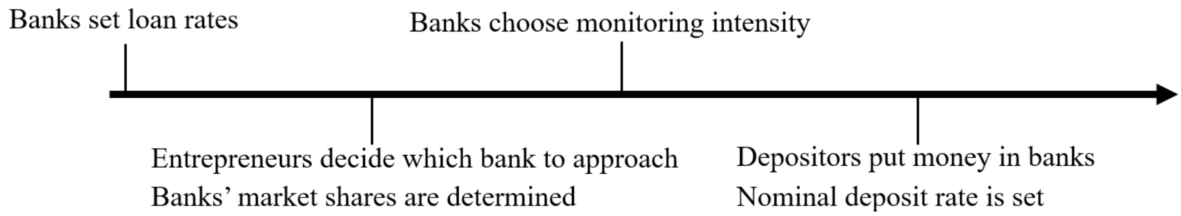

Figure 2: Timeline

typical types of equilibria in the spatial competition model. The first type is the equilibrium with direct competition. In this type of equilibrium, all entrepreneurs are served by the two banks. The other type is the local monopoly equilibrium where the two banks do not compete with each other and some entrepreneurs are not served by either bank. We consider first the equilibrium with direct competition, and then go to the local monopoly equilibrium.

3.1 Equilibrium with Direct Competition

In this subsection we consider the case where the two banks compete with each other directly and all entrepreneurs are served. Since the two banks are ex ante identical, we look at the symmetric equilibrium where the two banks offer the same loan rate and adopt the same monitoring strategy. To study the equilibrium, we first characterize banks' monitoring strategies, which needs us to derive banks' objective function (profit function) first.

Banks' Profits. Denote the mass of entrepreneurs that approach bank 1 (bank 2) as $\widetilde{x}$ $(1-\widetilde{x})$. According to the timeline, $\widetilde{x}$ is determined after the loan rate r_i is chosen. Therefore, we can write $\widetilde{x}$ as a function of r_i, i.e., $\widetilde{x}(r_1, r_2)$. With the notation, the following lemma gives bank i's expected profit.

Lemma 1. *Bank 1's expected profit is given by*

$$\pi_1 = r_1 \int_0^{\widetilde{x}(r_1,r_2)} m_1(z)\, dz - \widetilde{x}(r_1, r_2) f - \int_0^{\widetilde{x}(r_1,r_2)} C_1(m_1(z), z) dz.$$

Symmetrically, bank 2's expected profit is given by

$$\pi_2 = r_2 \int_{\widetilde{x}(r_1,r_2)}^1 m_2(z)\, dz - (1-\widetilde{x}(r_1, r_2)) f - \int_{\widetilde{x}(r_1,r_2)}^1 C_2(m_2(z), z) dz.$$

Intuitively, Lemma 1 implies that the expected profit of a bank equals the aggregate expected value of the bank's loans less the funding cost evaluated with the risk-free rate ($\widetilde{x}(r_1, r_2) f$ for bank 1) and the aggregate non-pecuniary monitoring costs. Lemma 1 gives banks' objective function with which we can analyse banks' optimal monitoring policies and the equilibrium loan rates through backward induction.

Optimal Choice of Monitoring Intensity. By backward induction, we first look at banks' choices about their monitoring intensity. Bank i chooses its optimal monitoring intensity $m_i(z)$ to maximize its profit π_i given in Lemma 1. According to the timeline, bank i takes as given r_i and $\widetilde{x}(r_1, r_2)$ when determining its monitoring intensity. The following lemma gives the two banks' optimal choices of monitoring intensity.

Lemma 2. *Bank 1's optimal monitoring intensity for entrepreneur z is given by*

$$m_1(z, r_1) = \frac{r_1(1 - qz)}{c}.$$

Symmetrically, bank 2's optimal monitoring intensity for entrepreneur z is given by

$$m_2(z, r_2) = \frac{r_2(1 - q(1 - z))}{c}.$$

Since the two banks are symmetric, we look at only the monitoring intensity chosen by bank 1. First, we note that $m_1(z, r_1)$ is decreasing in c, which is intuitive since banks have less incentive to monitor as monitoring becomes more costly. Second, $m_1(z, r_1)$ is also decreasing in qz. This is because monitoring is more costly when banks' information technology is less advanced (q is higher), or the monitored entrepreneur is located farther away. Finally, $m_1(z, r_1)$ is increasing in r_1. This results from the fact that r_1 is bank 1's marginal benefit of monitoring an entrepreneur. The higher r_1 is, the more bank 1 receives in case of an entrepreneur's success, and therefore the more incentive bank 1 has to increase monitoring intensity.

Equilibrium Loan Rates. Next we need to determine bank 1's market share $\widetilde{x}(r_1, r_2)$ in order to find out the equilibrium loan rates of banks. As in other spatial competition models[9], $\widetilde{x}(r_1, r_2)$ is determined by the location of the "marginal entrepreneur" who is indifferent about which bank to approach. Letting $\pi_i^E(z)$ denote the expected payoff of entrepreneur z when she borrows from bank i, we have that

$$\pi_i^E(z) = V + (R - r_i)\, m_i(z) - t\left(z 1_{\{i=1\}} + (1 - z)\, 1_{\{i=2\}}\right),$$

where $1_{\{\}}$ is the indicator function. Therefore, the marginal entrepreneur's location is determined by

$$\pi_1^E(\widetilde{x}(r_1, r_2)) = \pi_2^E(\widetilde{x}(r_1, r_2)). \tag{1}$$

[9] See Salop (1979) for an example

Solving equation (1) yields the following lemma that gives the marginal entrepreneur's location, which is also bank 1's market share.

Lemma 3. *Given r_i, bank 1's market share $\widetilde{x}(r_1, r_2)$ is given by*

$$\widetilde{x}(r_1, r_2) = \frac{(r_1)^2 - (1-q)(r_2)^2 - R(r_1 - (1-q)r_2) - ct}{q\Big((r_1)^2 + (r_2)^2 - R(r_1 + r_2)\Big) - 2ct}.$$

With Lemmas 1 to 3, we can characterize the symmetric equilibrium with direct bank competition. The following proposition justifies the existence of a unique equilibrium for a large R.

Proposition 1. *When R is large, there exists a unique symmetric interior equilibrium where the two banks compete with each other directly and choose the same loan rate $r_1 = r_2 = r_C^U \in \left(\frac{R}{2}, R\right)$.*

r_C^U is the largest solution of

$$\left(\frac{(1-\frac{1}{2}q)\left(r_C^U\right)^2}{2c} - f\right)(1-\frac{1}{2}q)\left(R - 2r_C^U\right) + 2\left(q\left(R - r_C^U\right)r_C^U + ct\right)r_C^U \int_0^{\frac{1}{2}} \frac{(1-qz)}{c}dz = 0$$

Proposition 1 states that when entrepreneurs' projects have sufficiently high payoffs in case of success (i.e, R is large enough), the interior equilibrium with direct bank competition exists. In Appendix B (to be included), we show that when R is not large enough, the equilibrium with direct competition may yield a corner solution $r_1 = r_2 = R$, or even not exist. Since in this subsection we care about the inner solution of an equilibrium with direct competition, we focus on the case that R is large here.

Comparative Statics. Next we study how the equilibrium loan rate changes with parameters. In particular, we want to find out how the development and diffusion of information technology affects bank competition. Since the existence of the interior equilibrium relies on a large R, we keep the assumption that R is large in the comparative statics study. The following proposition gives the relevant results.

Proposition 2. *When R is large, we have*

i) the equilibrium loan rate r_C^U is increasing in t.

ii) the equilibrium loan rate r_C^U is increasing in c.

iii) the equilibrium loan rate r_C^U is increasing in q.

The intuition of the proposition is as follows. As t increases, it becomes more costly for entrepreneurs to move along the city due to the existence of transportation costs. Therefore, entrepreneurs prefer moving less and approaching a closer bank, which effectively increases banks' market power and reduces competition. As a result, the equilibrium loan rate r_C^U is increasing in t.

The intuition behind Item ii) is more complex. First, increasing c can cause the the same effect of increasing t. To understand this point, we divide entrepreneur z's expected profit $\pi_i^E(z)$ into three different parts, as the following equation shows: intrinsic value (V) for entrepreneur z, expected value/payoff of the project ($(R - r_i)m_i(z)$), and transportation costs (ts).

$$\pi_i^E(z) = \underbrace{V}_{\text{Intrinsic Value}} + \underbrace{(R - r_i)\, m_i(z)}_{\text{Project Value}} - \underbrace{t\left(z 1_{\{i=1\}} + (1-z)\, 1_{\{i=2\}}\right)}_{\text{Transportation Costs}}.$$

For a given r_i, an increase in c decreases monitoring intensity $m_i(z)$, which decreases the relative importance of "Project Value" part of $\pi_i^E(z)$, and increases that of the "Transportation Costs" part. From this perspective, increasing c is effectively the same as increasing t, which should cause the equilibrium loan rate to increase according to Item i). The second effect of increasing c is that banks make a lower profit from each single entrepreneur (for a given r_i), which reduces banks' marginal benefit of increasing market share. Therefore, banks are less afraid of losing market share and have more incentive to increase loan rates. Both effects of increasing c works in the same direction and unambiguously cause the equilibrium loan rate to increase.

Item iii) implies that the development and diffusion of information technology (decreasing q) decreases the equilibrium loan rate. The intuition is also complex. First, a higher q (less advanced information technology) makes entrepreneurs more reluctant to move along the city, because monitoring intensity $m_i(z)$, which is also the probability of success for entrepreneur z, decreases more rapidly with distance when q is higher. Entrepreneurs' reluctancy to move increases banks' market power, which can cause a higher loan rate in equilibrium. Second, for a given r_i, increasing q decreases banks' expected profit from each single entrepreneur, which makes banks less afraid of losing market shares[10]. As a result, banks have more incentive to increase their loan rates as q increases. Both effects of increasing q work in the same direction and lead to the result that the equilibrium loan rate r_C^U is increasing in q.

Bank Stability. An important issue is how the development and diffusion of information technology affects bank stability. To study the issue with our model, we use the probability of bank default to inversely measure bank stability. Since the two banks are symmetric, we look only at bank 1's probability of default. We denote bank 1's probability of default as θ^*. The following lemma gives the formula of θ^*.

[10] This effect is similar to the second effect of increasing c

Lemma 4. *If entrepreneurs located in* $[0, \widetilde{x}]$ *are served by bank 1 and offered a uniform loan rate* r_1*, then bank 1 defaults with probability*

$$\theta^* = 1 - \sqrt{\left(\frac{r_1}{c}\right)^2 - 2\frac{\widetilde{x} f q}{c}}.$$

According to Lemma 4, first we note that θ^* is increasing in $\widetilde{x}$ when $q > 0$. This is because for a given r_1, a higher $\widetilde{x}$ implies that bank 1 finances more far-away entrepreneurs for whom the monitoring efficiency is low (and the risk of failure is high), which is bad for bank stability; in contrast, if $\widetilde{x}$ is small, bank 1 focuses more on nearby entrepreneurs for whom the monitoring is easier, which is good for bank stability. Note that when $q = 0$, θ^* is independent of $\widetilde{x}$. This is because all entrepreneurs fail or succeed together when $q = 0$, making $\widetilde{x}$ irrelevant to bank stability. Second, we note that θ^* is increasing in q. This is because for a given r_1, a higher q decreases bank 1's overall monitoring intensity, which makes entrepreneur more likely to fail. Next, θ^* is increasing in c, which is quite intuitive because a higher monitoring cost also decreases monitoring intensity for a given r_1, as a higher q does. Finally, θ^* is decreasing in r_1. This is because as r_1 increases, bank 1 can receive a higher payoff from each entrepreneur in case of success, which increases the profit buffer of the bank. Meanwhile, with a higher r_1, bank 1 monitors entrepreneurs with a higher intensity, which increases entrepreneurs' probability of success. Both effects of increasing r_1 are good for bank stability.

However, the overall effect of changing a parameter on banks' default probability is not so simple as Lemma 4 shows, because r_1 endogenously varies as a parameter changes. Fortunately, the effect of changing t on bank stability is relatively straightforward, which is presented in the following proposition.

Proposition 3. *When* R *is large, bank 1 defaults with a lower probability as* t *increases in the equilibrium with direct competition.*

Proposition 3 is quite intuitive. In the symmetric equilibrium with direct competition, $\widetilde{x}$ is always fixed at $\frac{1}{2}$ and unaffected by t. As t increases, banks set a higher equilibrium loan rate, which increases banks' profit buffer and monitoring intensity. Meanwhile, the information technology and monitoring cost (represented by q and c) remains the same. Therefore, banks' default probability must decrease as t increases according to Lemma 4.

We also care about how the development and diffusion of information technology affects bank stability, i.e., the effect of changing q. However, the effect of changing q is complex. As q increases (information technology becomes less advanced), the direct effect is that the monitoring efficiency of banks decreases, which should increase the default probability of banks according to Lemma 4. However, increasing q also has an indirect effect. An increase in q causes the equilibrium loan rate r_i to increase (Proposition 2), which should decrease the default probability of banks according to Lemma 4. Whether banks becomes more stable or not depends on the net effect of changing q. Numerical study shows that the indirect effect dominates, which means an increase in q decreases the default probability of banks (seeing Figure 3). In other words, the development and diffusion of information technology potentially makes banks less stable.

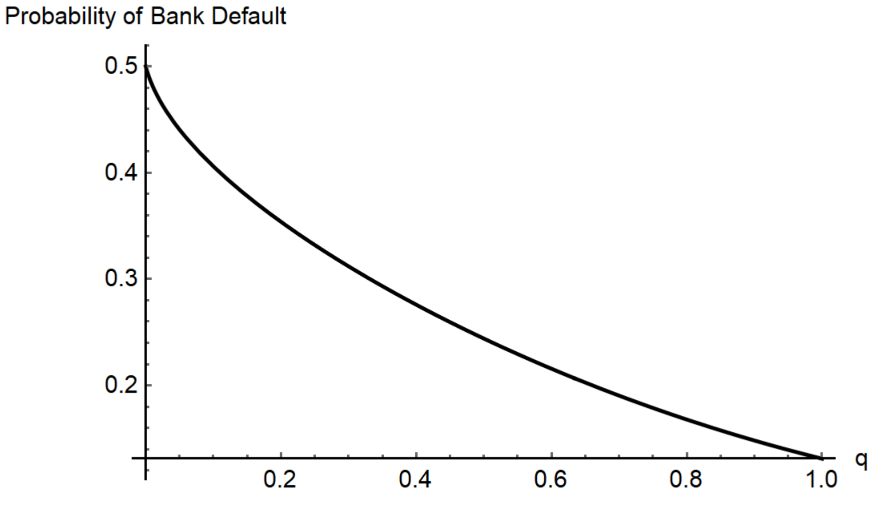

Figure 3: Banks' Probability of Default (wrt. q). This figure plots banks' probability of default against q. The parameter values are: $R = 10, f = 1, c = 10, V = 0, t = 1$.

The effect of changing c is also complex. As c increases, the direct effect is that monitoring becomes more expensive for banks, so banks should have incentive to decrease monitoring intensity, which tends to increase the default probability of banks. However, the indirect effect of increasing c is that the equilibrium loan rate r_i increases, which should decrease the default probability of banks. Whether banks become more stable or not depends on the net effect of changing c. Numerical study shows that the direct effect dominates this time, which means an increase in c increases the default probability of banks (seeing Figure 4).

3.2 Local Monopoly Equilibrium

In this subsection, we consider the local monopoly equilibrium where the two banks do not compete with each other directly. In this type of equilibrium, some entrepreneurs located far away from both banks cannot get financed by either bank. The local monopoly equilibrium arises typically because transportation is so costly that some entrepreneurs located in the middle cannot make a positive profit by approaching either bank. Therefore, in this subsection, we

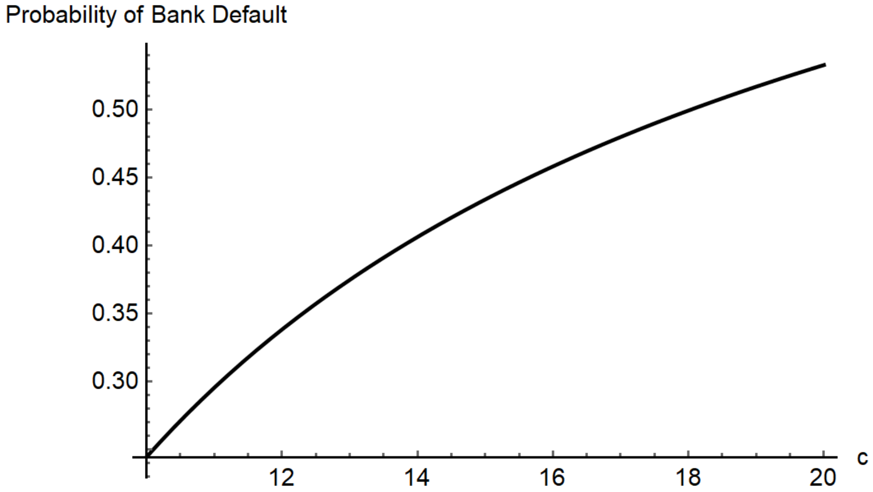

Figure 4: Banks' Probability of Default (wrt. c). This figure plots banks' probability of default against c. The parameter values are: $R = 10, f = 1, q = 0.1, V = 0, t = 1$.

assume that the marginal transportation cost, t, is large and entrepreneurs' intrinsic value of investment, V, is small.

The local monopoly equilibrium is obviously symmetric, therefore we focus only on bank 1. As before, we denote the mass of entrepreneurs that approach bank 1 as $\widetilde{x}$. Since there is no competition between the two banks, $\widetilde{x}$ is a function of r_1 with $\widetilde{x}(r_1) \leq \frac{1}{2}$. In the local monopoly case, it is easy to show that Lemma 1 still applies to bank 1 with $\widetilde{x}(r_1, r_1)$ replaced by $\widetilde{x}(r_1)$. Therefore, for a given r_1, bank 1's monitoring intensity $m_1(z)$ for entrepreneur $z \in [0, \widetilde{x}(r_1)]$ is still given by Lemma 2, i.e., $m_1(z) = \frac{r_1(1-qz)}{c}$.

To characterize the local monopoly equilibrium, we must determine $\widetilde{x}(r_1)$ first. $\widetilde{x}(r_1)$ is the location of the marginal entrepreneur who makes a zero expected profit when approaching bank 1. The condition that determines $\widetilde{x}(r_1)$ is

$$\pi_1^E(\widetilde{x}) = V + (R - r_1)\frac{r_1(1 - q\widetilde{x})}{c} - t\widetilde{x} = 0,$$

which yields

$$\widetilde{x}(r_1) = \frac{r_1(R - r_1) + cV}{q(R - r_1)r_1 + ct}.$$

With the expression of $\widetilde{x}(r_1)$, we can characterize the local monopoly equilibrium. The following proposition shows the existence of the local monopoly equilibrium.

Proposition 4. *When $\frac{R^2}{c} > f$, t is large and V is small, there exists a unique symmetric interior local monopoly equilibrium where the two banks do not compete with each other directly and choose the same loan rate $r_1 = r_2 = r_{Local}^U \in \left(\frac{R}{2}, R\right)$.*

Proposition 4 justifies the existence of the interior local monopoly equilibrium under certain conditions. If $\frac{R^2}{c} > f$ is not satisfied, then R is too small and banks will not serve any entrepreneurs. The condition that t is large and V is small makes sure that entrepreneurs located around the middle ($z = \frac{1}{2}$) find it not worthy to approach either bank. Meanwhile, the condition that V is small ensures that the local monopoly equilibrium is interior, which means $r_i \neq R$.

Comparative Statics. Next we study how the loan rates in the interior local monopoly case change with parameters. In particular, we care about how the development and diffusion of information technology affects the equilibrium. Since the two banks are symmetric, we focus on bank 1. The following proposition gives a relevant result.

Proposition 5. *In an interior local monopoly equilibrium, the equilibrium loan rate* r^U_{Local} *is independent of* t *when* $q = 0$.

Increasing t brings two opposing effects. First, an increase in t decreases bank 1's market share, which reduces bank 1's marginal benefit of raising the loan rate. From this perspective, bank 1 should have incentive to decrease its loan rate to extend market share. However, as t increases, bank 1's market share becomes less sensitive to its loan rate[11], which should give bank 1 incentive to increase its loan rate. Proposition 5 shows that when $q = 0$, the two opposing effects exactly offset each other. When $q > 0$, the two effects no long cancel each other. Numerical results show that when $q > 0$, the impact of t on the sensitivity of bank 1's market share to the loan rate is weakened, which means the equilibrium loan rate is decreasing in t when $q > 0$ (i.e., the first effect of t on r^U_{Local} dominates).

Increasing q has three effects. The first two effects are quite similar to those of increasing t. First, an increase in q directly decreases bank 1's market share, which reduces bank 1's marginal benefit of raising the loan rate. From this perspective, bank 1 should have incentive to decrease its loan rate to extend market share. Second, as q increases, bank 1's market share becomes less sensitive to its loan rate, which gives bank 1 to increase its loan rate. Third, increasing q makes monitoring more costly and therefore decreases bank 1's marginal benefit of financing an entrepreneur, which makes bank 1 less afraid of losing market share. As a result, bank 1 should increase its loan rate. Numerical study shows that the latter two effects dominate, so r^U_{Local} is increasing in q.

The three effects of increasing c are the same as those of increasing q, so we do not repeat

[11] Consider the limiting case that t is infinite. In this case, bank 1's market share is fixed at 0 and does vary with its loan rate.

them. Numerical study shows that r^U_{Local} is increasing in c.

Bank Stability. Next we study how bank stability, measured by bank 1's probability of default, varies with parameters. Lemma 4 still applies here.

As t increases, the direct effect is to decrease bank 1's market share, which is good for bank 1's stability because bank 1 can focus more on nearby entrepreneurs who are easier to monitor. According to Proposition 5, bank 1's loan rate r^U_{Local} does not vary with t when $q = 0$. Therefore, an increase in t will undoubtedly make bank 1 more stable when $q = 0$. When $q > 0$, however, previous numerical results show that an increase in t causes r^U_{Local} to decrease, which decreases bank 1's monitoring intensity and profit buffer, and therefore should hurt bank 1's stability. Numerical study shows that, even when $q > 0$, the effect of t on bank 1's market share dominates. In other words, banks still become more stable as t increases when $q > 0$.

The effects of increasing q on bank stability are more complex. First, an increase in q makes monitoring more costly, which should decrease bank 1's monitoring intensity for a given loan rate, and therefore hurt bank stability. Second, increasing q decreases bank 1's market share, and make bank 1 focus more on its nearby entrepreneurs who are easier to monitor, which should be good for bank stability. Finally, previous numerical results show that an increase in q raises bank 1's loan rate r^U_{Local}, which should be good for bank stability. Numerical study shows that the first effect dominates. In other words, the development and diffusion of information technology makes banks more stable, which contrasts with the effect of q on bank stability in the equilibrium with direct competition.

Finally, the three effects of increasing c are the same as those of increasing q, so we do not repeat them. Numerical study shows that the net effect of increasing c is to make banks less stable.

4 Discriminatory Loan Rates

One further change the development and diffusion of information technology brings to the banking sector is that banks are able to offer discriminatory loan rates to different borrowers based on their personalised information. Therefore, in this section, we consider the case that banks offer discriminatory loan rates to different entrepreneurs. Specifically, the loan rate bank i offers to entrepreneur z is allowed to be a function of entrepreneurial location z, $r_i(z)$, in this section.

The method we adopt in this section is from Thisse and Vives (1988). Therefore, following

Thisse and Vives (1988), we assume that the non-pecuniary transportation costs are paid by banks in this section. For example, if bank 1 serves entrepreneur z, then entrepreneur z's transportation cost of approaching bank 1, tz, adds up to the bank 1's expenditure. The interpretation is that banks' service becomes more customer-oriented due to the progress of technology and therefore can absorb more personalised costs that are previously borne by entrepreneurs.

The timing of the lending game in this section is as follows. First, banks set the discriminating loan rates $r_i(z)$ simultaneously. Once the loan rates are chosen, entrepreneurs decide which bank to approach and the market share for each bank is determined. As before, the market share of bank 1 is denoted as $\widetilde{x}$, while that of bank 2 is $1-\widetilde{x}$. Given the market share and the loan rate $r_i(z)$, banks choose their optimal monitoring intensity in terms of entrepreneurial location, $m_i(z)$. Finally, depositors put their money into banks and ask for a deposit rate d_i based on $r_i(z)$ and their anticipation of $m_i(z)$.

As in the previous section, we first consider the case where the two banks compete with each other directly, and then move to the local monopoly case.

4.1 Equilibrium with Direct Competition

To make the results of the discriminatory case comparable to those of the case with uniform loan rate, we keep the assumption that R is large when looking at the equilibrium with direct competition. As in the previous section, we first need to derive the profit functions of the two banks, and then characterize the equilibrium. The following lemma gives the formula of bank i's expected profit.

Lemma 5. *Bank 1's expected profit is given by*

$$\pi_1 = \int_0^{\widetilde{x}} r_1(z)\, m_1(z)\, dz - \widetilde{x} f - \int_0^{\widetilde{x}} C_1(m_1(z), z) dz - \int_0^{\widetilde{x}} tz dz.$$

Symmetrically, bank 2's expected profit is given by

$$\pi_2 = \int_{\widetilde{x}}^1 r_2(z)\, m_2(z)\, dz - (1-\widetilde{x}) f - \int_{\widetilde{x}}^1 C_2(m_2(z), z) dz - \int_{\widetilde{x}}^1 t(1-z)\, dz.$$

The intuition behind Lemma 5 is similar to that behind Lemma 1, that is, the expected profit of a bank equals the aggregate expected value of the bank's loans less the funding cost evaluated with the risk-free rate, the aggregate costs of monitoring, and the total transportation costs. With Lemma 5 we can analyse the equilibrium through backward induction.

Optimal Choice of Monitoring Intensity. Bank i chooses its optimal monitoring intensity $m_i(z)$ to maximize π_i given in Lemma 5. According to the timeline, bank i takes as given $r_i(z)$ and $\widetilde{x}$. The following lemma gives the two banks' optimal choices of monitoring intensity.

Lemma 6. *Bank 1's optimal monitoring intensity for entrepreneur z is given by*

$$m_1(z) = \frac{r_1(z)(1-qz)}{c}.$$

Symmetrically, bank 2's optimal monitoring intensity for entrepreneur z is given by

$$m_2(z) = \frac{r_2(z)(1-q(1-z))}{c}.$$

Lemma 6 is the nearly same as Lemma 2 with r_i replaced by $r_i(z)$, so we do not explain the intuition again here.

Equilibrium Loan Rates. We solve the equilibrium following the method proposed by Thisse and Vives (1988). Since banks can offer discriminatory loan rates to different entrepreneurs, for each single entrepreneur, there is an independent Bertrand-fashion competition. Which bank is able to attract entrepreneur z depends on which bank can provide a better loan rate (also called "price" in order to match the terminology used by Thisse and Vives, 1988) to the entrepreneur. Before we proceed, we introduce a concept, "best loan rate", with the following definition in order to better convey our idea.

Definition 1. *The best loan rate bank i can offer to entrepreneur z is the loan rate that maximizes entrepreneur z's profit subject to bank i's budget.*

Following the idea of Thisse and Vives (1988), if a bank wants to win the competition for entrepreneur z, the bank must be able to offer a loan rate that is more attractive to entrepreneur z than its rival bank's best loan rate. The best loan rate is characterized by the following lemma.

Lemma 7. *When R is large, bank i's the best loan rate is $\frac{R}{2}$ for any z. Neither bank will offer a loan rate that is lower than $\frac{R}{2}$.*

To understand Lemma 7, we prove it here. Since the two banks are symmetric, we focus on bank 1. With lemma 6 and the assumption that transportation costs are absorbed by banks, we know that entrepreneur z's expected profit from approaching bank 1 is $\pi_1^E(z) = V + (R - r_1(z))\frac{r_1(z)(1-qz)}{c}$. The best loan rate that could be offered by bank 1 is the $r_1(z)$ that maximizes $\pi_1^E(z)$, and the result is exactly $\frac{R}{2}$. Bank 1's expected profit from financing entrepreneur z is

$$\underbrace{r_1(z)\frac{r_1(z)(1-qz)}{c}}_{\text{expected loan income}} - \underbrace{f}_{\text{funding costs}} - \underbrace{tz}_{\text{transportation costs}} - \underbrace{C_1(m_1(z), z)}_{\text{monitoring costs}},$$

which can be simplified to

$$\frac{(r_1(z))^2(1-qz)}{2c} - f - tz. \tag{2}$$

(2) is obviously positive when $r_1(z) = \frac{R}{2}$ and R is large. Therefore, the best loan rate is acceptable by bank 1. Since the two banks are symmetric, the best loan rate is $\frac{R}{2}$ for both banks.

Lemma 7 conveys the information that simply lowering the loan rate may not increase the attractiveness of a bank, and the lower bound for a bank's loan rate should be $\frac{R}{2}$. This results from the fact that a lower loan rate to entrepreneur z implies a lower monitoring intensity and a higher probability of failure to her, although it leaves her a higher payoff in case of success. When the loan rate is too low (lower than $R/2$), the effect of the loan rate on monitoring intensity becomes dominant, so banks cannot attract entrepreneur z by further decreasing the loan rate.

According to Lemma 7, the best loan rate is $\frac{R}{2}$ for both banks. Therefore, taking bank 1 as an example, if bank 1 wants to attract entrepreneur z, it must be able to offer a loan rate that is better than $\frac{R}{2}$ offered by bank 2. If bank 1 is indeed able to do so, then bank 1's best strategy is to maximize its own profit, subject to the constraint that entrepreneur z's profit is no less than what she would have gotten by accepting the best loan rate ($\frac{R}{2}$) offered by bank 2. Following this reasoning, we have the following proposition that gives the equilibrium discriminatory loan rates.

Proposition 6. *When R is large, there exists a unique interior symmetric equilibrium where bank 1 and bank 2's loan rates are respectively given by the following two equations:*

$$r_1^*(z) = \left(\frac{1}{2} + \frac{\sqrt{1-2z}}{2\sqrt{1-qz}}\sqrt{q}\right)R, z \in \left[0, \frac{1}{2}\right]$$

$$r_2^*(z) = \left(\frac{1}{2} + \frac{\sqrt{1-2(1-z)}}{2\sqrt{1-q(1-z)}}\sqrt{q}\right)R, z \in \left(\frac{1}{2}, 1\right]$$

Entrepreneurs located in $\left[0, \frac{1}{2}\right]$ are served by bank 1, while the other entrepreneurs are served by bank 2.

Similar to Proposition 1, Proposition 6 also states that when entrepreneurs' projects have sufficiently high payoffs in case of success (i.e, R is large enough), the interior equilibrium with direct bank competition exists. Different from Proposition 1, when price discrimination is allowed, the equilibrium loan rate $r_i^*(z)$ varies with entrepreneurial location z. It is easy to find that $r_1^*(z)$ ($r_2^*(z)$) is decreasing (increasing) in z when $z \in \left[0, \frac{1}{2}\right]$ ($z \in \left(\frac{1}{2}, 1\right]$), which means the equilibrium loan rate is lower for an entrepreneur that is similarly far away from both banks, but higher for an entrepreneur that is close to some bank (seeing Figure 5 for illustration). The intuition is that if entrepreneur z is quite close to a bank, e.g. bank 1, then bank 1 can easily find a loan rate that is more attractive to entrepreneur z than the best loan rate offered by bank 2, because bank 1's monitoring is more efficient than that of bank 2. As a result, bank 1 has more room to maximize its own profit by raising $r_1^*(z)$ when financing entrepreneur z. If entrepreneur z is located in the middle area (i.e., z is near $\frac{1}{2}$), however, neither bank has much room to maximize its own profit, and therefore competition is more fierce, which yields a lower equilibrium loan rate.

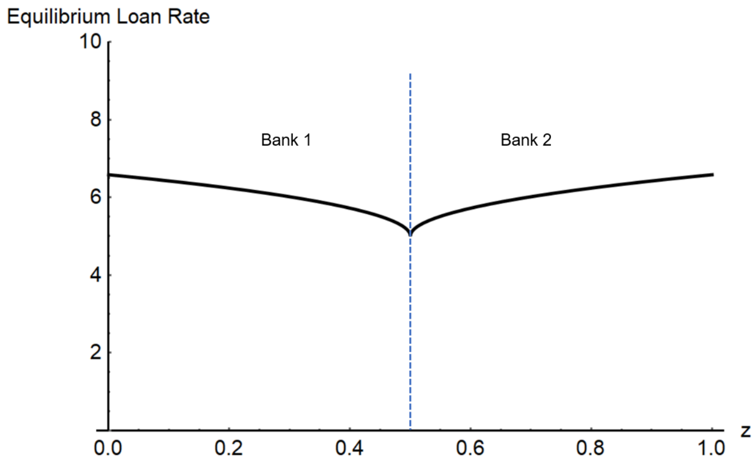

Figure 5: Equilibrium Loan Rates for Different Locations. This figure plots the equilibrium loan rate against the entrepreneurial location. The parameter values are: $R = 10, f = 1, c = 10, V = 0, t = 1, q = 0.1$.

Comparative Statics. Next we study how the equilibrium loan rates change with parameters. In particular, we care about how the development and diffusion of information technology can affect the equilibrium. Since the two banks are symmetric, we look at only bank 1. The following proposition gives relevant results.

Proposition 7. *When R is large, we have:*

i) Bank 1's equilibrium loan rate $r_1^*(z)$ is independent of the marginal transportation cost t.

ii) Bank 1's equilibrium loan rate $r_1^*(z)$ is increasing in q except for $z = \frac{1}{2}$.

We explain the intuition of Item ii) first. For $z \neq \frac{1}{2}$, as q increases, monitoring an entrepreneur located far away becomes more costly for a bank. Therefore, if entrepreneur z is close to a bank, e.g. bank 1, then bank 1 has more room to find a loan rate that dominates the best loan rate of its rival bank as q increases, which implies less competition and a higher equilibrium loan rate to entrepreneur z. For $z = \frac{1}{2}$, neither bank has the ability to offer a better loan rate, so the competition between the two banks is infinite, which pushes the equilibrium loan rate at very location to the best loan rate $\frac{R}{2}$ that is independent of q. Item ii) implies that the development and diffusion of information technology can decrease the equilibrium loan rates, which is consistent with Item iii) of Proposition 2.

Item i) looks counter-intuitive. In particular, in Thisse and Vives (1988), the equilibrium discriminatory prices do depend on t, which differs from the proposition here. This is because in the bank competition context, the best loan rate ($\frac{R}{2}$) does not depend on t (later we will explain why). When bank i chooses its loan rate for entrepreneur z, it maximizes its own bank profit, ensuring that the entrepreneur's profit is no less than what she could have earned from the best loan rate offered by the rival bank. Since transportation costs are absorbed by banks, entrepreneur z's profit from accepting the rival bank's best loan rate is independent of t. Meanwhile the transportation costs (of financing entrepreneur z) paid by bank i is always $t\left(1_{\{i=1\}}z + 1_{\{i=2\}}(1-z)\right)$, which is unaffected by bank i's choice about $r_i(z)$. Therfore, bank i's optimal choice, $r_i^*(z)$, must be independent of t.

A Comparison with Thisse and Vives (1988). The key difference between our bank competition context and Thisse and Vives (1988) is that in Thisse and Vives (1988), a firm's best price that maximizes a consumer's utility equals the firm's total marginal costs (production cost plus transportation cost) of serving the consumer, which of course depends on t, while in the bank competition context, a bank's best loan rate is not determined by marginal costs when R is large enough. In Thisse and Vives (1988), an increase in price always hurts consumers, so the best price of a firm must be the lowest acceptable (or say, affordable) price for the firm. Since no firms accept negative profits, the lowest acceptable price equals total marginal costs. In the bank competition context, however, an increase in loan rate does not always hurt entrepreneurs, because a higher loan rate also implies a higher monitoring intensity and thus a higher probability of success. Therefore, the best loan rate of a bank is not the lowest acceptable loan rate for the bank. Instead, Lemma 7 states that the best loan rate is $\frac{R}{2}$ when R is large, which guarantees positive profits for banks.

When R is not large enough, indeed the lowest acceptable loan rate for a bank may be determined by marginal costs, rather than $\frac{R}{2}$. In this case, the equilibrium loan rate is no longer independent of t, and the bank competition context shares more similarities with Thisse and Vives (1988). We discussed the case when R is not large enough in Appendix B.

Comparing Uniform Loan Rates with Discriminatory Loan Rates. Next we compare the equilibrium uniform loan rate r_C^U with the discriminatory loan rate $r_i^*(z)$. Since the two banks are symmetric, we compare r_C^U with $r_1^*(z)$ ($z \in [0, \frac{1}{2}]$) for simplicity. The comparison yields the following proposition.

Proposition 8. *When R is large and $z \in [0, \frac{1}{2}]$, we have:*

i) When $q = 0$ and $t = 0$, $r_C^U = r_1^*(z) = \frac{R}{2}$.

ii) When $q > 0$ or $t > 0$, $r_C^U > r_1^*\left(\frac{1}{2}\right) = \frac{R}{2}$.

iii) When $t > 0$ and q is small, $r_C^U > r_1^*(z)$.

iv) When q is large enough (or say, sufficiently close to 1), $r_1^*(0) > r_C^U > r_1^*\left(\frac{1}{2}\right)$.

Item i) conveys the basic result that competition is infinite in both uniform and discriminatory cases when moving long the city is frictionless. The intuition is straightforward. When $q = 0$ and $t = 0$, moving along the city is frictionless for all entrepreneurs, so no bank has advantage in attracting any entrepreneur, which means banks have no market power for any entrepreneur. As a result, both banks choose the best loan rate ($\frac{R}{2}$).

For Item i), we need to point out that even if the competition between the two banks is infinite when $q = 0$ and $t = 0$, banks can still make positive profits. This is because in the bank competition context, decreasing the loan rate, which always decreases a bank's profit, does not always increase the profit of entrepreneurs. When the loan rate is low enough (lower than $\frac{R}{2}$), further decreasing the loan rate actually hurts entrepreneurs because a low loan rate implies less monitoring and a low probability of success. Therefore, even if the competition between banks is infinite, the equilibrium loan rate will be driven to the best loan rate, $\frac{R}{2}$, defined in Lemma 7, rather than to level that leaves banks with zero profit. When R is large, the best loan rate $\frac{R}{2}$ is still large enough to cover banks' costs and leave banks with positive profits. Specifically, bank 1's profit from financing entrepreneur z is

$$\frac{(r_1(z))^2(1-qz)}{2c} - f - tz,$$

which is positive when $r_1(z) = \frac{R}{2}$ if R is large. In Appendix B we have a discussion for the case that R is not large.

Item ii) says that if moving along the city is costly due to positive q or t, the discriminatory loan rate at the location $z = \frac{1}{2}$, $r_1^*(\frac{1}{2})$, must be lower than the uniform loan rate r_C^U. The intuition is as follows. When $q > 0$ or $t > 0$, moving along the city is costly and therefore distance does matter for entrepreneurs, which brings banks market power in the case with uniform loan rate.

As a result, r_C^U must be higher than the best loan rate $\frac{R}{2}$. In the discriminatory case, however, bank competition at the middle point $z = \frac{1}{2}$ is always infinite regardless of the values of q or t, because neither bank has advantage at this location. Therefore, we always have $r_1^*\left(\frac{1}{2}\right) = \frac{R}{2}$, which implies the result of Item ii).

In the discriminatory case, transportation costs are absorbed by banks, so the only friction associated with distance is the information technology friction (represented by q) from the perspective of entrepreneurs. When q is small, such friction is small, so it is easy for entrepreneurs to move around the city, which means bank competition is fierce and the equilibrium discriminatory loan rate $r_1^*(z)$ must be close to the best loan rate $\frac{R}{2}$. In the case with uniform loan rate, however, transportation costs are paid by entrepreneurs themselves. In this case, even if q is small, banks still have significant market power if $t > 0$, because the transportation cost itself is able to make entrepreneurs reluctant to move around the city. Therefore, the equilibrium uniform loan rate must be significantly higher than the best loan rate $\frac{R}{2}$ when $t > 0$ and q is small, which causes the result $r_C^U > r_1^*(z)$ (Item iii).

Item iv) tells us that, in general, we cannot say the discriminatory loan rate must be higher or lower than the uniform loan rate. Item iv) has two sides: $r_C^U > r_1^*\left(\frac{1}{2}\right)$ and $r_1^*(0) > r_C^U$ when q is large enough. The first side is covered by Item ii) already, so we focus on the intuition of the second side. In the discriminatory case, the extent of competition between the two banks depends on the location of the entrepreneur they compete for (called "target entrepreneur"). If the target entrepreneur is located at $z = 0$, then extent of competition between banks is lowest because the information technology friction is very high if the entrepreneur moves to bank 2. As a result, bank 1 can set quite high a loan rate for the entrepreneur located at 0 because of the lack of competition. In the limiting case where $q = 1$, an entrepreneur located at 0 would never approach bank 2, because the monitoring intensity the entrepreneur would have received from bank 2 is 0, which implies a zero profit for the entrepreneur. The entrepreneur has no choice but approaching bank 1, and bank 1 will offer the entrepreneur a loan rate equal to R, which must be higher than r_C^U because r_C^U is lower than R (Proposition 1). Therefore, when q is high enough, we must have $r_1^*(0) > r_C^U$.

Since transportation costs are absorbed by banks in the discriminatory case, while are not in the uniform-pricing case, one may want to compare the uniform loan rate plus transportation cost with discriminatory loan rates. In Appendix B, we also have this comparison, and the result is not quite different from Proposition 8, so we do not present it here.

Bank Stability. As in the previous section, we care about how bank stability, measured by a bank's probability of default, is affected by parameter change. Especially, we want to find out how the development and diffusion of information technology affect bank stability. The following lemma gives the way to pin down the probability of bank default in case with discriminatory loan rates. Since the two banks are symmetric, we look at only bank 1's probability of default.

Lemma 8. *If entrepreneurs located within* $[0, \widetilde{x}]$ *approach bank 1, and the loan rate of bank 1,* $r_1(z)$*, is decreasing in* z *for* $z \in [0, \widetilde{x}]$*, then bank 1's default probability* θ^* *is given by the following equation:*

$$\int_{1-\frac{r_1(0)}{c}}^{\theta^*} \int_0^{z(\theta)} r_1(z)\,dz d\theta + (1-\theta^*) \int_0^{z(\theta^*)} r_1(z)\,dz = \widetilde{x}r,$$

where $z(\theta)$ *is an increasing function that is implied by*

$$c - r_1(z(\theta))(1 - qz(\theta)) = c\theta.$$

In this subsection, we have that $\widetilde{x} = \frac{1}{2}$ and $r_1(z)$ is characterized by Proposition 6. Therefore, we can use Lemma 8 to calculate bank 1's probability of default, θ^*. Lemma 8 does not yield a closed form solution for θ^*, so we analyse how parameters affect bank 1's default probability with numerical methods.

Since t does not affect the equilibrium loan rate $r_1^*(z)$, monitoring intensity $m_1(z)$ or bank 1's market share (which is always $\frac{1}{2}$ in the equilibrium with direct competition), obviously bank 1' probability of default does not depends on t.

The effect of q is more complex. One the one hand, increasing q decreases banks' efficiency of monitoring (i.e., increases banks' monitoring cost for a given monitoring intensity), which is bad for bank stability; on the other hand, according to Proposition 7, increasing q causes $r_1^*(z)$ to increase (except for $z = \frac{1}{2}$), and therefore can help raise bank 1's monitoring intensity since $m_1(z)$ is increasing in $r_1(z)$ (Lemma 6), which is good for bank stability. Numerical study shows that the second effect dominates (seeing Figure 6). In other words, the development and diffusion of information technology can hurt bank stability, which is consistent with the comparative statics result about q in the uniform-pricing case.

The effect of c is straightforward. According to Proposition 7, increasing c has no effect on the equilibrium loan rate $r_1^*(z)$. However, a higher c make monitoring more expensive, which causes bank 1 to decrease monitoring intensity. Therefore, bank 1 becomes more unstable as c increases (seeing Figure 7). Thus result is also consistent with the comparative statics result about c in the uniform-pricing case.

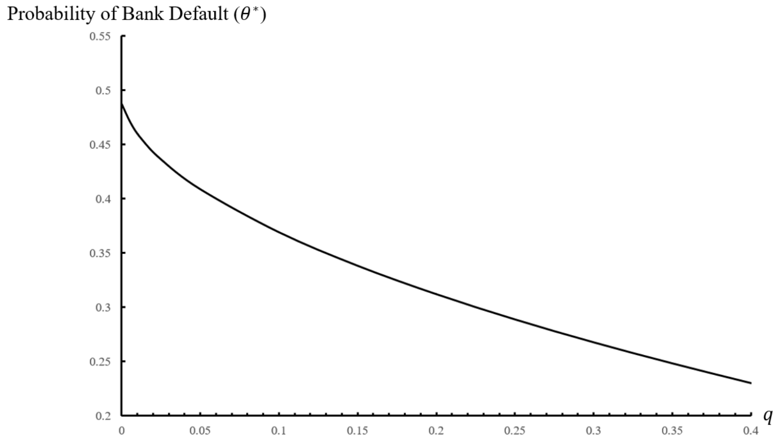

Figure 6: Bank 1's Probability of Default (wrt. q). This figure plots bank 1's probability of default against q when banks can offer discriminatory loan rates. The parameter values are: $R = 10, f = 1, c = 10, V = 0, t = 1$.

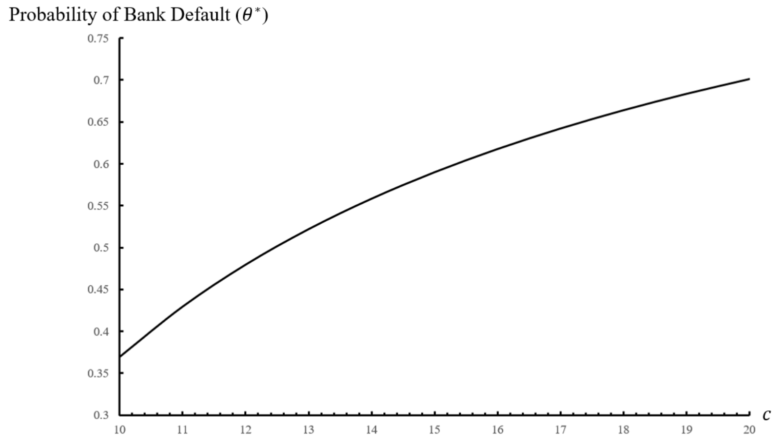

Figure 7: Bank 1's Probability of Default (wrt. c). This figure plots bank 1's probability of default against c when banks can offer discriminatory loan rates. The parameter values are: $R = 10, f = 1, q = 0.1, V = 0, t = 1$.

4.2 Local Monopoly Equilibrium

In this subsection, we consider the case where the two banks do not compete with each other, and are able to offer discriminatory loan rates $r_i(z)$. Since the two banks are symmetric, we focus on bank 1 for simplicity. If entrepreneur z is a target client of bank 1, bank 1 would choose $r_1(z)$ in order to make entrepreneur z break even. An entrepreneur's break-even profit should be 0 since there is no bank competition. For a given $r_1(z)$, entrepreneur z's expected profit is

$$\pi_1(r_1(z), z) \equiv V + (R - r_1(z)) \frac{r_1(z)(1 - qz)}{c},$$

which is always non-negative for $r_1(z) \in [0, R]$. Therefore, for any target entrepreneur, bank 1 would choose $r_1(z) = R$. With this pricing strategy, bank 1's expected profit from serving entrepreneur z is

$$R\frac{R(1-qz)}{c} - f - tz - C_1\left(\frac{R(1-qz)}{c}, z\right),$$

which is non-negative iff

$$z \leq \frac{R^2 - 2cf}{qR^2 + 2ct}. \tag{3}$$

Inequality (3) implies that bank 1 is willing to serve all entrepreneurs in $[0, \frac{R^2-2cf}{qR^2+2ct}]$. To make sure that the equilibrium is indeed a local monopoly, bank 1's market share must be smaller than $\frac{1}{2}$. Therefore, the local monopoly equilibrium exists iff

$$\frac{R^2 - 2cf}{qR^2 + 2ct} < \frac{1}{2}.$$

Meanwhile, we want to rule out the uninteresting case where banks do not serve any entrepreneur, so we require the following inequality

$$\frac{R^2 - 2cf}{qR^2 + 2ct} > 0$$

to ensure that banks' market shares are positive.

We summarize the analysis above with the following proposition.

Proposition 9. *When* $0 < \frac{R^2-2cf}{qR^2+2ct} < \frac{1}{2}$*, there exists a local monopoly equilibrium with*

$$r_1(z) = r_2(z) = R.$$

Bank 1 serves entrepreneurs in $[0, \frac{R^2-2cf}{qR^2+2ct}]$.

In the local monopoly equilibrium, there is no competition between banks, so each bank actually owns a monopoly market. In the discriminatory case, banks absorbs transportation costs, so entrepreneurs are always willing to borrow from a bank, even if the bank offers a loan rate equal to R. As a result, banks will set loan rates to be R because increasing the loan rate (to the upper bound) does not affect the demand of entrepreneurs.

Since the equilibrium local monopoly loan rate is actually fixed at the upper bound, there is no need to analyse how changing parameters may affect the equilibrium loan rate. However, bank stability is still worth study.

Bank Stability. Since the equilibrium loan rate is actually fixed at a constant, we can use Lemma 4 to analyse how bank stability is affected by parameters. As before, we focus on bank 1 due to the symmetry of the two banks. The following proposition gives relevant results.

Proposition 10. *When* $0 < \frac{R^2-2cf}{qR^2+2ct} < \frac{1}{2}$*, we have:*

i) bank 1's probability of default is decreasing in t*;*

ii) bank 1's probability of default is increasing in c*;*

iii) bank 1's probability of default is increasing in q *for* $t > 0$*. For* $t = 0$*, bank 1's probability of default does not vary with* q*.*

Item i) is straightforward. As t increases, bank 1's loan rate stays at R. Meanwhile, bank 1's monitoring intensity is not affected. However, since financing far-away entrepreneurs becomes more costly due to an increase in t, bank 1's market share will shrink, which makes bank 1 focus more on its nearby entrepreneurs who are easier to monitor. Therefore, bank 1 becomes more stable as t increases. We need to point out that Item i) relies on the assumption that transportation costs are non-pecuniary, which means an increase in transportation costs will not directly hurt bank 1's solvency.

Item ii) is more complex. An increase in c directly makes monitoring more costly, which decreases bank 1's monitoring intensity and therefore make bank 1's entrepreneurs more likely to fail. However, as c increases, bank 1's market share shrinks, which is good for bank 1's stability because bank 1 focuses more on nearby entrepreneurs. Item ii) means the first effect always dominates.

The intuition of Item iii) is quite similar to that of Item ii). Increasing q directly makes monitoring more costly, which is bad for bank stability. However, as q increases, bank 1's market share shrinks, which is good for bank 1's stability. The magnitude of the second effect is negatively correlated with the value of t. Which effect dominates depends on t. As t increases, bank 1's market share will be less sensitive to q. Therefore, the first effect of q on bank stability (the direct effect) dominates when $t > 0$. When $t = 0$, however, bank 1's market share is sensitive enough to q that the two opposing effects of q cancel each other.

5 The Entry of a BigTech

In recent years, BigTechs gradually evolve and and become an important participant in the lending market. In this section, we want to analyse the impact of BigTech entry. We assume in the city there is a BigTech that is also able to raise funds from depositors and provide loans to entrepreneurs as banks. However, the BigTech is located at the heart of the circular city, which means the distance between the BigTech and each entrepreneur is $\frac{1}{\pi}$. This assumption captures the idea that the BigTech connects entrepreneurs with the Internet, so the physical distance does not matter. Similarly to a bank, the BigTech is also able to monitor entrepreneurs, and we denote the BigTech's monitoring intensity as $m_b(z)$ for entrepreneur z. The BigTech's non-pecuniary monitoring cost is given by the following quadratic function

$$C_b(m_b(z)) = \frac{c}{2(1-\frac{q_b}{\pi})}(m_b(z))^2,$$

where q_b inversely measures the information technology owned by the BigTech. Different from traditional banks, we assume that finance from the BigTech incurs no transportation costs. The interpretation is that a BigTech usually has direct access to big customer data and can process the information automatically. Therefore, the due diligence costs of BigTech finance should be much lower than those of traditional bank finance, and thus are assumed to be zero for simplicity. Like a bank, the BigTech also needs to raise funds from the public in order to finance its loans. Since the BigTech is not a traditional investment platform, we assume that the cost of capital required by depositors in the BigTech is $k \geq f$. In other words, the BigTech must ensure that its depositors' expected gross return is at least k.

The timeline is the same as that of previous sections, with the only difference that now entrepreneurs choose from the two banks and a BigTech. We assume banks and the BigTech offer discriminatory loan rates as in the Section 4.

Optimal Choice of Monitoring Intensity. To solve the equilibrium by backward induction, we first look at the optimal monitoring intensity of banks and the BigTech. Assuming that the loan rate of bank i (the BigTech) for entrepreneur z is $r_i(z)$ ($r_b(z)$), the following lemma gives the optimal monitoring intensity of banks and the BigTech.

Lemma 9. *Bank 1's optimal monitoring intensity for entrepreneur z is given by*

$$m_1(z) = \frac{r_1(z)(1-qz)}{c}.$$

Symmetrically, bank 2's optimal monitoring intensity for entrepreneur z is given by

$$m_2(z) = \frac{r_2(z)(1-q(1-z))}{c}.$$

The BigTech's optimal monitoring intensity for entrepreneur z is given by

$$m_b(z) = \frac{r_b(z)\left(1-\frac{q_b}{\pi}\right)}{c}.$$

The formulas of $m_1(z)$ and $m_2(z)$ here are the same as those in Lemma 6, so we do not explain them again here. What is new in Lemma 9 is the monitoring intensity of the BigTech, $m_b(z)$. Like banks' monitoring intensity, $m_b(z)$ is increasing in the BigTech's loan rate $r_b(z)$, because a higher $r_b(z)$ implies a higher marginal benefit of monitoring for the BigTech. Meanwhile, a higher q_b, which means less advanced information technology, hurts the BigTech's monitoring efficiency and therefore decreases $m_b(z)$. Different from banks' monitoring intensity, $m_b(z)$ does not directly depend on entrepreneurial location z, although z can indirectly affect $m_b(z)$ through the loan rate $r_b(z)$. This is because the BigTech is located in the heart of the city and equally far away from all entrepreneurs.

Equilibrium Loan Rates. In previous sections, we consider both the equilibrium with direct competition and local monopoly equilibrium. However, the next lemma shows that whenever there is a BigTech providing loans to entrepreneurs, there does not exist a local monopoly equilibrium.

Lemma 10. *If there exists an entrepreneur that approaches the BigTech and gets a loan, the local monopoly equilibrium does not exist.*

Lemma 10 says if the BigTech enters the loan market (offering loans to some entrepreneurs), all entrepreneurs of the market must be served in equilibrium. The intuition is as follows. Since the BigTech is equally far away from all entrepreneurs, if it can serve one entrepreneur of the city, it must be able to finance any entrepreneur and ensure her a non-negative profit. Therefore, it is impossible that there exists entrepreneurs that are not served by either banks or the BigTech. Due to Lemma 10, in the interesting case that the BigTech indeed enters, we do not need to consider the possibility of the local monopoly equilibrium, which is a big simplification for our analysis.

Although, the local monopoly equilibrium does not exist after the BigTech entry, before the BigTech entry, the equilibrium can be either competitive or local monopolistic. In this section, we focus on the case that banks directly compete with each other before the BigTech entry, and keep the assumption that R is large. In Appendix B, we present the case that the equilibrium is local monopoly before the BigTech entry, which means R is not large enough.

As in the previous section, we solve the equilibrium following the method proposed by Thisse and Vives (1988). The following lemma is a direct extension of Lemma 7 that characterizes the best loan rate of lenders.

Lemma 11. *When R is large, the best loan rate of banks and the BigTech is $\frac{R}{2}$ for any z. Neither banks nor the BigTech will offer a loan rate that is lower than $\frac{R}{2}$.*

With those lemma above, we can characterize the equilibrium with the following proposition.

Proposition 11. *When R is large. The BigTech enters the lending market if and only if*

$$\frac{q_b}{q\pi} \leq \frac{1}{2}.$$

When the BigTech enters, there exists a unique interior symmetric equilibrium where entrepreneurs located within $\left[0, \frac{q_b}{q\pi}\right)$ approach bank 1, entrepreneurs located within $\left[\frac{q_b}{q\pi}, 1 - \frac{q_b}{q\pi}\right]$ approach the BigTech, while entrepreneurs located within $\left(1 - \frac{q_b}{q\pi}, 1\right]$ approach bank 2.

The loan rate of bank 1 is

$$r_{1b}^{*}\left(z\right) = \left(\frac{1}{2} + \frac{\sqrt{\frac{q_b}{q\pi} - z}}{2\sqrt{1 - qz}}\sqrt{q}\right) R, z \in \left[0, \frac{q_b}{q\pi}\right)$$

while the loan rate of bank 2 is

$$r_{2b}^{L*}\left(z\right) = r_{1b}^{L*}\left(1 - z\right), z \in \left(1 - \frac{q_b}{q\pi}, 1\right]$$

The loan rate of the BigTech is

$$r_{b}^{*}\left(z\right) = \begin{cases} \left(\frac{1}{2} + \frac{\sqrt{z - \frac{q_b}{q\pi}}}{2\sqrt{1 - \frac{q_b}{\pi}}}\sqrt{q}\right) R & \text{if} \quad z \in \left[\frac{q_b}{q\pi}, \frac{1}{2}\right] \\ \left(\frac{1}{2} + \frac{\sqrt{1 - z - \frac{q_b}{q\pi}}}{2\sqrt{1 - \frac{q_b}{\pi}}}\sqrt{q}\right) R & \text{if} \quad z \in \left(\frac{1}{2}, 1 - \frac{q_b}{q\pi}\right] \end{cases}.$$

According to Proposition 11, the BigTech enters only if its information technology is sufficiently advanced, which requires a small enough q_b. This entry condition is quite intuitive. If the information technology of the BigTech is not advanced enough, entrepreneurs will not choose the BigTech even if the BigTech offers the best loan rate $\frac{R}{2}$, because its monitoring intensity (and the corresponding probability of success) is too low. Proposition 11 further states that the entry of the BigTech will divide entrepreneurs into three groups based on entrepreneurial locations, and only those located in the middle area ($z \in \left[\frac{q_b}{q\pi}, 1 - \frac{q_b}{q\pi}\right]$) approach the BigTech. This is because the monitoring efficiency of the BigTech does not depend on entrepreneurial location, while banks have lower efficiency to monitor entrepreneurs located in the middle area. Therefore, the BigTech has advantage to attract entrepreneurs in the middle. In contrast, if an entrepreneur is close to a bank, then information technology friction is small if the entrepreneur approaches the bank, which means the bank has advantage to attract the entrepreneur compared with the BigTech.

Note that the city is still symmetric around the middle point after the BigTech entry. In the region $[0, \frac{1}{2}]$, bank 2 is dominated by bank 1 in terms of monitoring efficiency, so it is bank 1 that competes with the BigTech in this region. Symmetrically, bank 2 competes with the Bigtech in the region $(\frac{1}{2}, 1]$. We look at only the region $[0, \frac{1}{2}]$ due to the symmetry. Note that bank 1's (the BigTech's) loan rate is decreasing (increasing) in z when $z \in [0, \frac{q_b}{q\pi})$ ($z \in [\frac{q_b}{q\pi}, \frac{1}{2}]$). This is because the closer an entrepreneur is to the indifference point $z = \frac{q_b}{q\pi}$, the less technological advantage and market power bank 1 and the BigTech have. At the indifference point $z = \frac{q_b}{q\pi}$, the competition between bank 1 and the BigTech is infinite, so the equilibrium loan rate at this point equals the best loan rate $\frac{R}{2}$. Seeing Figure 8 for an illustration.

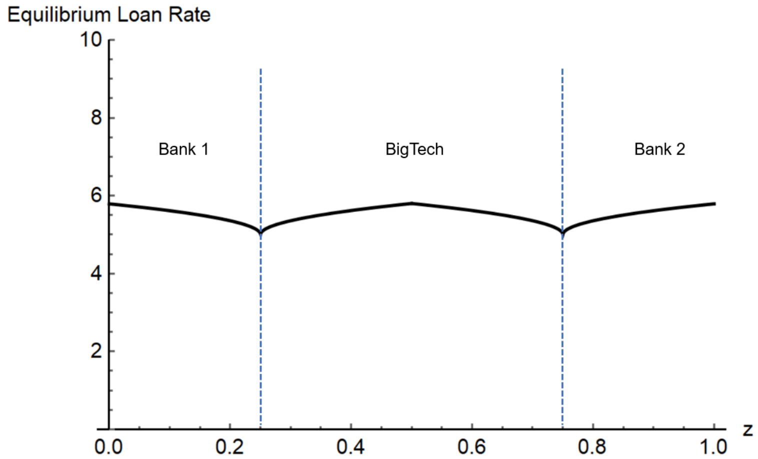

Figure 8: Equilibrium Loan Rates for Different Locations with BigTech. This figure plots the equilibrium loan rate against the entrepreneurial location in the presence of a BigTech. The parameter values are: $R = 10, f = 1, c = 10, V = 0, t = 1, q = 0.1, q_b = \frac{q\pi}{4}$.

Comparative Statics. Next we study how the equilibrium loan rates change with parameters. Especially, we care about how the development and diffusion of information technology affect the equilibrium. The following proposition gives relevant results.

Proposition 12. *When R is large and $\frac{q_b}{q\pi} < \frac{1}{2}$, we have:*

i) the equilibrium loan rates $r^*_{ib}(z)$ and $r^*_b(z)$ are independent of the marginal transportation cost t.

ii) the equilibrium loan rates of banks, $r^*_{ib}(z)$, are decreasing in q and increasing in q_b.

iii) the equilibrium loan rate of the BigTech, $r^*_b(z)$, is increasing in q and decreasing in q_b.

Item i) of the proposition shares the same intuition with Item i) of Proposition 7. The best loan rate ($\frac{R}{2}$) that can be offered by the BigTech does not depend on t (Lemma 11). When bank i chooses its loan rate for entrepreneur z, it maximizes its own bank profit, ensuring that the entrepreneur's profit is no less than what she could have earned from the best loan rate offered by the BigTech. Since entrepreneurs do not need to pay transportation costs, entrepreneur z's expected profit by accepting the best loan rate of the BigTech is also independent of t. Meanwhile, the transportation costs (of financing entrepreneur z) paid by bank i is always $t\left(1_{\{i=1\}}z + 1_{\{i=2\}}(1-z)\right)$, which is unaffected by bank i's choice about $r_i(z)$. Therefore, bank i's optimal choice, $r_{ib}^*(z)$, must be independent of t. By the same reasoning, $r_b^*(z)$ is also independent of t.

Next we explain the intuition behind Item ii). As q increases, the information technology of the BigTech is unaffected, and therefore entrepreneurs do not feel more reluctant to approach the BigTech. As a result, the only effect of increasing q is to hurt the information technology owned by banks and reduce their competitiveness, which limit banks' ability to raise the loan rates and make more profits. Therefore, an increase in q will cause $r_{ib}^*(z)$ to decrease. By the same reasoning, an increase in q_b will hurt the competitiveness of the BigTech while leave the information technology of banks unaffected, which bring banks more room to increase their loan rates and make more profits. Therefore, an increase in q_b will cause $r_{ib}^*(z)$ to increase.

Item iii) is the mirror result of Item ii) and therefore shares the same intuition.

Note that Item ii) of Proposition 12 is interesting if we compare it with Item ii) of Proposition 7. When there is no BigTech in the market, banks' discriminatory loan rates are increasing in q for $z \neq \frac{1}{2}$. However, when the BigTech enters, the result flips. This is because the entry of the BigTech disrupts the direct competition between banks. When there is no BigTech, the two banks compete with each other directly. In this case, an increase in q for both banks does not bring technological advantage or disadvantage to either bank in the competition, but makes monitoring a far-away entrepreneur more costly for both banks, which increases banks' market power when they set loan rates for nearby entrepreneurs. Therefore, banks' discriminatory loan rates are increasing in q for $z \neq \frac{1}{2}$ when there is no BigTech in the market. When the BigTech disrupts the competition between banks, banks directly compete with the BigTech. In this case, increasing q actually brings disadvantage to banks in their competition with the BigTech because the information technology of the BigTech, q_b, remains unchanged. Therefore, an increase in q cannot bring more market power to banks, and banks' loan rates must decrease due to the disadvantage brought by a higher q.

Bank Stability. Next we study how bank stability (banks' probability of default) varies with parameters. As before, we focus only on bank 1's probability of default because the two banks are symmetric. Note that Lemma 8 still applies here. When using Lemma 8, we need to specify $\widetilde{x}$ and $r_1(z)$. In this subsection, $\widetilde{x} = \frac{q_b}{q\pi}$ while $r_1(z)$ is characterized by $r_{1b}^*(z)$ of

Proposition 11. Due to the complexity of $r_{1b}^*(z)$, Lemma 8 cannot yield a closed-form solution for bank 1's probability of default (θ^*), so we characterize θ^* with numerical methods.

Since t does not affect the equilibrium loan rate $r_{1b}^*(z)$, monitoring intensity $m_1(z)$ or bank 1's market share (which is $\frac{q_b}{q\pi}$), obviously bank 1' probability of default does not depends on t.

The effect of q is complex. In the presence of a BigTech, increasing q brings bank 1 technological disadvantage, which forces the bank to decrease its loan rate (i.e., $r_{1b}^*(z) < r_1^*(z)$ for $z \in \left[0, \frac{q_b}{q\pi}\right)$)[12]. Lower bank loan rates imply lower monitoring intensity and profit buffer, which is bad for bank stability. However, as q increases, bank 1's market share shrinks (i.e., bank 1 serves a smaller group of entrepreneurs), and therefore the bank borrows less funding from depositors and focuses more on nearby entrepreneurs who are easier to monitor, which is good for bank stability. Numerical results show that two opposing effects exactly offset each other, so bank 1's probability of default does not vary with q. In other words, the progress of banks' information technology may not have a significant impact on bank stability after the BigTech enters.

The effect of c is quite straightforward. According to Proposition 11, increasing c has no effect on bank 1's equilibrium loan rate $r_{1b}^*(z)$. Also, c does not affect bank 1's market share ($\frac{q_b}{q\pi}$) that depends only on the ratio of the BigTech's and the bank's information technology. However, a higher c make monitoring more expensive, which causes bank 1 to decrease monitoring intensity. Therefore, bank 1's probability of default is increasing in c (seeing Figure 9).

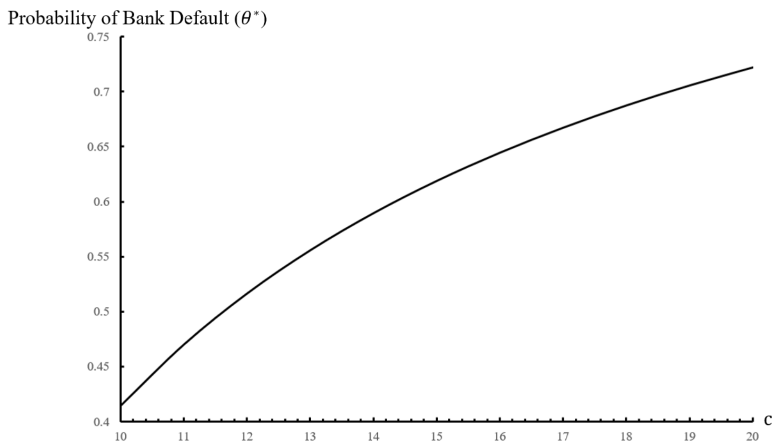

Figure 9: Bank 1's Probability of Default (wrt. c). This figure plots bank 1's probability of default against c when there is a BigTech entry. The parameter values are: $R = 10, f = 1, q = 0.1, V = 0, t = 1, q_b = 0.15$.

The effect of q_b has two opposing effects on bank 1's stability. On the one hand, increasing q_b hurts the BigTech's competitiveness and increases bank 1's loan rate $r_{1b}^*(z)$ (Proposition 12),

[12]Later we will formally present this result in Proposition 13.

which raises bank 1's monitoring intensity and profit buffer, and therefore is good for bank 1's stability; on the other hand, increasing q_b brings bank 1 more market share, so bank 1 will borrow more funding from depositors and cover more far-away entrepreneurs who are harder to monitor, which hurts the bank's stability. Numerical results show that the first positive effect dominates (seeing Figure 10). In other words, the development of the BigTech's information technology can make banks less stable.

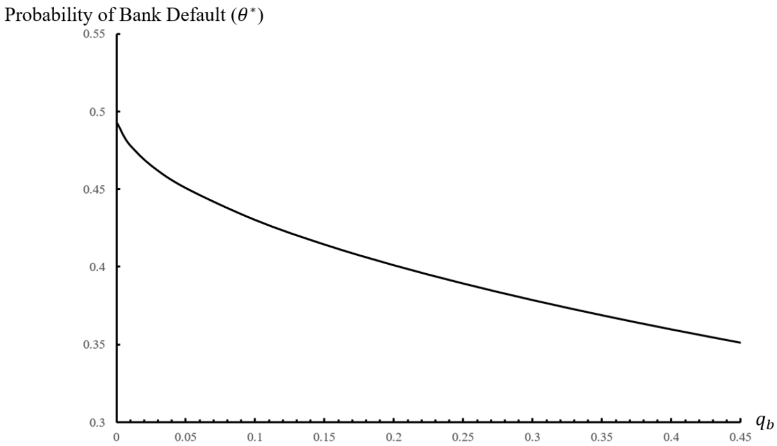

Figure 10: Bank 1's Probability of Default (wrt. q_b). This figure plots bank 1's probability of default against q_b when there is a BigTech entry. The parameter values are: $R = 10, f = 1, q = 0.1, c = 10, V = 0, t = 1$.

How does the BigTech change equilibrium loan rates? Next we want to analyse how the entry of the BigTech affects the equilibrium loan rates. We have shown in Lemma 10 that there does not exist a local monopoly equilibrium when the BigTech enters. In the absence of the BigTech, however, the equilibrium can be either competitive or local monopolistic depending on parameters. Since the local monopoly discriminatory equilibrium (without a BigTech) is a corner equilibrium ($r_1(z) = r_2(z) = R$) that is not interesting, we do not consider it during the comparison. In other words, we keep the assumption that R is large during the comparison, so the equilibrium without a BigTech is described by Proposition 6, while the equilibrium with a BigTech is described by Proposition 11.

The following proposition compares the equilibrium bank loan rates with and without a BigTech.

Proposition 13. *When R is large and $\frac{q_b}{q\pi} \leq \frac{1}{2}$, the disruption of a BigTech decreases the loan rates of banks. In other words,*

$$r_{1b}^*(z) < r_1^*(z), z \in \left[0, \frac{q_b}{q\pi}\right)$$

Proposition 13 results from the fact that the entry of a BigTech increases the level of competition, which forces banks to charge lower prices (loan rates). The following corollary can help us understand why the entry of the BigTech increases the competition facing banks.

Corollary 1. *When R is large and $\frac{q_b}{q\pi} = \frac{1}{2}$, the disruption of a BigTech strictly decreases the loan rates of banks. In other words,*

$$r_{1b}^*(z) < r_1^*(z), z \in \left[0, \frac{1}{2}\right)$$

When $\frac{q_b}{q\pi} = \frac{1}{2}$, the BigTech's information technology only marginally satisfies the entry condition of the BigTech; that is, the BigTech can only serve the entrepreneur located exactly at $z = \frac{1}{2}$. All entrepreneurs at $z \in \left[0, \frac{1}{2}\right) \cup \left(\frac{1}{2}, 1\right]$ still go to banks. Corollary 1 states that even if the mass of entrepreneurs served by the BigTech is only 0, banks' loan rates significantly decrease due to the (marginal) entry of the BigTech. In other words, the influence of the BigTech is discontinuous.

The reason is that the entry of the BigTech changes the form of competition, no matter how small the BigTech's market share is. In the absence of a BigTech, the two banks compete with each other directly. In this case, if entrepreneur z is located close to bank i, she must be far away from the bank j $(j \neq i)$, which brings the bank i "double advantages" in the competition for entrepreneur z: bank i's own monitoring efficiency (due to the short distance) and bank j's monitoring inefficiency (due to the long distance). The double advantages enable bank i to set a quite high loan rate for entrepreneur z. After the BigTech enters, however, the double advantages no longer exist. No matter how close entrepreneur z is to bank i, the distance between entrepreneur z and bank i's rival, the BigTech, is constant. Therefore, even if entrepreneur z is quite close to bank i, bank i can have only a "single advantage" in the competition for entrepreneur z, which is bank i's own monitoring efficiency (due to the short distance). Switching from "double advantages" to a "single advantage" effectively increases the competition, and therefore reduces banks' ability to set quite high loan rates for their nearby entrepreneurs. As a result, we see that banks significantly decreases their loan rates when the BigTech enters, even if the market share of the BigTech is infinitely small.

When $\frac{q_b}{q\pi} < \frac{1}{2}$, which means the market share of the BigTech is positive, the loan rates in the region $\left[\frac{q_b}{q\pi}, 1 - \frac{q_b}{q\pi}\right]$ do not necessarily decrease after the entry of the BigTech. Before the BigTech disruption, banks' competition is most fierce for the entrepreneur located at $z = \frac{1}{2}$, therefore, we can see that $r_1^*\left(\frac{1}{2}\right) = r_2^*\left(\frac{1}{2}\right) = \frac{R}{2}$, which is the best loan rate. After the entry of the BigTech and when $\frac{q_b}{q\pi} < \frac{1}{2}$, the BigTech has some market power at $z = \frac{1}{2}$. Therefore, we can see that $r_b^*\left(\frac{1}{2}\right)$ (given in Proposition 11) is higher than $\frac{R}{2}$, which means the BigTech disruption increases the equilibrium loan rates around the location $z = \frac{1}{2}$.

How does the BigTech entry affect bank stability? Here we analyse how the the entry of the BigTech affect banks' probability of default. As before, we keep the assumption that R is large during the comparison. We start from the special case that the BigTech marginally enters and get 0 market share.

Proposition 14. *When R is large and $\frac{q_b}{q\pi} = \frac{1}{2}$, the disruption of a BigTech increases banks' probability of default.*

When $\frac{q_b}{q\pi} = \frac{1}{2}$, the BigTech's entry condition is exactly satisfied, and market share of the BigTech is 0. In this case, Corollary 1 shows that banks' loan rates strictly decrease in the region $z \in \left[0, \frac{1}{2}\right) \cup \left(\frac{1}{2}, 1\right]$. As a result, from the perspective of banks, the entry of the BigTech changes nothing except that banks set lower loan rates, which of course will increase banks' probability of default.

So far we have answered how the BigTech affects bank stability when the BigTech's market share is 0. Then, what if the market share of the BigTech is positive? To answer the question, we need to recall the numerical results (seeing Figure 10) that the probability of bank default increases as q_b decreases in the presence of a BigTech. Proposition 14 shows that the BigTech entry increases bank's probability of default when the BigTech's market share is 0. If the BigTech wants to have a positive market share, its q_b must decrease (i.e., change from $\frac{q_b}{q\pi} = \frac{1}{2}$ to $\frac{q_b}{q\pi} < \frac{1}{2}$), which shall further increase banks' probability of default compared with the case $\frac{q_b}{q\pi} = \frac{1}{2}$ according to numerical results (Figure 10). As a result, the entry of a BigTech who can get a positive market share also increases banks' probability of default. Overall, the entry of a BigTech makes banks less stable.

6 Welfare Analysis

In this section, we do the welfare analysis. We care about how the disruption of the BigTech affects social welfare. We focus on the case where the two banks compete directly with each other and can offer discriminatory loan rates before the disruption of the BigTech. In Appendix B, we also consider the case where banks do not compete with each other before the BigTech entry.

Social welfare consists of several parts: the (aggregated) expected payoff of entrepreneurs' projects, transportation costs, monitoring costs and depositors' cost of capital. Since the economy is symmetric, we can focus on entrepreneurs located within $\left[0, \frac{1}{2}\right]$ when calculating welfare.

Before the disruption of the BigTech, social welfare is given by

$$W^{NB}=2\left(\underbrace{\int_0^{\frac{1}{2}} Rm_1(z)\,dz}_{\text{Project Value}}-\underbrace{\int_0^{\frac{1}{2}} ztdz}_{\text{Transportation Costs}}-\underbrace{\int_0^{\frac{1}{2}} C_1(m_1(z))\,dz}_{\text{Monitoring Costs}}\right)-f,$$

where $m_1(z)$ is the monitoring intensity of bank 1 in the absence of the BigTech. After the disruption of the BigTech, social welfare is given by

$$W^B=2\left(\int_0^{\frac{q_b}{q\pi}} Rm_1^B(z)\,dz+\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} Rm_b(z)\,dz-\int_0^{\frac{q_b}{q\pi}} ztdz-\int_0^{\frac{q_b}{q\pi}} C_1\left(m_1^B(z)\right)dz-\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} C_b(m_b(z))dz\right)-f,$$

where $m_1^B(z)$ is the monitoring intensity of bank 1 after the BigTech enters, and $m_b(z)$ is the monitoring intensity of the BigTech. Given the expressions of social welfare (W^{NB} and W^B), we can easily know that the socially optimal levels of monitoring intensity for bank 1 and the BigTech are given by

$$m_1^{opt}(z)=\frac{(1-qz)R}{c} \text{ and } m_b^{opt}(z)=\frac{(1-\frac{q_b}{\pi})R}{c}$$

respectively. The socially optimal monitoring intensity can be chosen by banks and the BigTech only when the their loan rates equal R, so any equilibrium loan rate that is lower than R is inefficiently low from the perspective of social welfare.

The difference between W^{NB} and W^B (i.e., $W^{NB}-W^B$) is given by

$$\underbrace{2\left(\int_0^{\frac{q_b}{q\pi}} Rm_1(z)\,dz-\int_0^{\frac{q_b}{q\pi}} C_1(m_1(z))\,dz\right)-2\left(\int_0^{\frac{q_b}{q\pi}} Rm_1^B(z)\,dz-\int_0^{\frac{q_b}{q\pi}} C_1\left(m_1^B(z)\right)dz\right)}_{\text{Difference in Project Value (Net of Monitoring Costs) for } z\in\left[0,\frac{q_b}{q\pi}\right]\text{: Positive}}$$

$$\underbrace{+2\left(\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} Rm_1(z)\,dz-\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} C_1(m_1(z))\,dz\right)-2\left(\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} Rm_b(z)\,dz-\int_{\frac{q_b}{q\pi}}^{\frac{1}{2}} C_b(m_b(z))dz\right)}_{\text{Difference in Project Value (Net of Monitoring Costs) for } z\in\left[0,\frac{q_b}{q\pi}\right]\text{: Positive or Negative}}$$

$$\underbrace{-2\int_0^{\frac{1}{2}} ztdz+2\int_0^{\frac{q_b}{q\pi}} ztdz}_{\text{Difference in Aggregate Transportation Costs: Negative}}.$$

Based on the expression of $W^{NB}-W^B$ above, The entry of the BigTech has the following effects.

First of all, entrepreneurs located within $\left[0,\frac{q_b}{q\pi}\right)$ are still financed by bank 1. However, the equilibrium loan rates of bank 1 decrease due to the entry of the BigTech (i.e., $r_{1b}^{*}(z) < r_{1}^{*}(z)$ for $z \in \left[0, \frac{q_b}{q\pi}\right)$. Seeing Proposition 13). This is because the entry of the BigTech increases the competition facing banks, and therefore decreases the loan rates that banks can charge. As a result, $m_1(z)$ is higher than $m_1^B(z)$, which means $m_1(z)$ is closer to the optimal monitoring intensity of bank 1, $m_1^{opt}(z)$, than $m_1^B(z)$ is. In other words, the monitoring efficiency in $\left[0, \frac{q_b}{q\pi}\right)$ is decreased due to the entry of the BigTech, which hurts social welfare. Due to the symmetry of the economy, the monitoring efficiency in $\left(1 - \frac{q_b}{q\pi}, 1\right]$ is also decreased by the BigTech entry. This effect is described by the first line of the expression of $W^{NB} - W^{B}$, which is always positive.

Second, entrepreneurs located within $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$ approach the BigTech. In this region, the effect of the BigTech disruption is complex. The first effect is a cost-saving effect. The BigTech enters the market because of its better information technology for entrepreneurs around the middle area, which helps save monitoring cost. Therefore, from the angle of technological improvement, the BigTech entry should increase the welfare of the region $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$. However, the entry of the BigTech also changes the state of competition, which may hurt social welfare because a low loan rate (due to high competition) implies a low level of monitoring intensity. We call this effect the competition effect[13]. How the welfare changes in the region $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$ due to the BigTech entry is determined by the net effect of the cost-saving and competition effects. According to numerical results, the overall effect depends on the parameters q and q_b. When q is small, the BigTech's advantage in information technology is not significant, which makes the cost-saving effect small. Meanwhile, the BigTech faces a high-level competition after its entry because banks' monitoring costs do not increase fast with the distance when q is small, which makes the competition effect large. As a result, the overall effect is that the welfare decreases due to the BigTech entry when q is small. By a similar logic, when q_b is large, the cost-saving effect is still not significant, so the welfare also decreases due to the BigTech entry. When q is big and q_b is small, the BigTech's advantage in information technology is significant, which makes the cost-saving effect large. Meanwhile, due to the BigTech's overwhelming information technology, the BigTech's market power becomes high, which weakens the competition effect brought by the BigTech entry. As a result, the overall effect is that the welfare increases due to the BigTech entry when q is big and q_b is small. The welfare change in the region $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$ is reflected by the second line of expression

[13]The existence of the competition effect does not imply that the entry of the BigTech unambiguously decreases the equilibrium loan rates in $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$. Actually, for an entrepreneur located close to $z = \frac{q_b}{q\pi}$, the BigTech decreases the equilibrium loan rates (i.e., $r_b^{*}\left(\frac{q_b}{q\pi}\right) < r_1^{*}\left(\frac{q_b}{q\pi}\right)$), because the competition between the BigTech and bank 1 is fierce around $z = \frac{q_b}{q\pi}$. However, the BigTech increases the equilibrium loan rates around $z = \frac{1}{2}$ (i.e., $r_b^{*}\left(\frac{1}{2}\right) > r_1^{*}\left(\frac{1}{2}\right)$), because the BigTech has advantage and market power around $z = \frac{1}{2}$, while the direct competition between the two banks in the absence of the BigTech is most fierce at $z = \frac{1}{2}$. The competition effect reflects the overall influence of the BigTech on the state of competition in the region $\left[\frac{q_b}{q\pi}, \frac{1}{2}\right]$.

of $W^{NB} - W^B$, which can be either positive or negative depending on parameters.

Finally, the entry of the BigTech saves transportation costs, because a BigTech has access to big data and can perform due diligence with its automation technology whose marginal cost is nearly zero. Therefore, from the angle of transportation costs, the BigTech increases social welfare, which is reflected by the third line of the expression of $W^{NB} - W^B$.

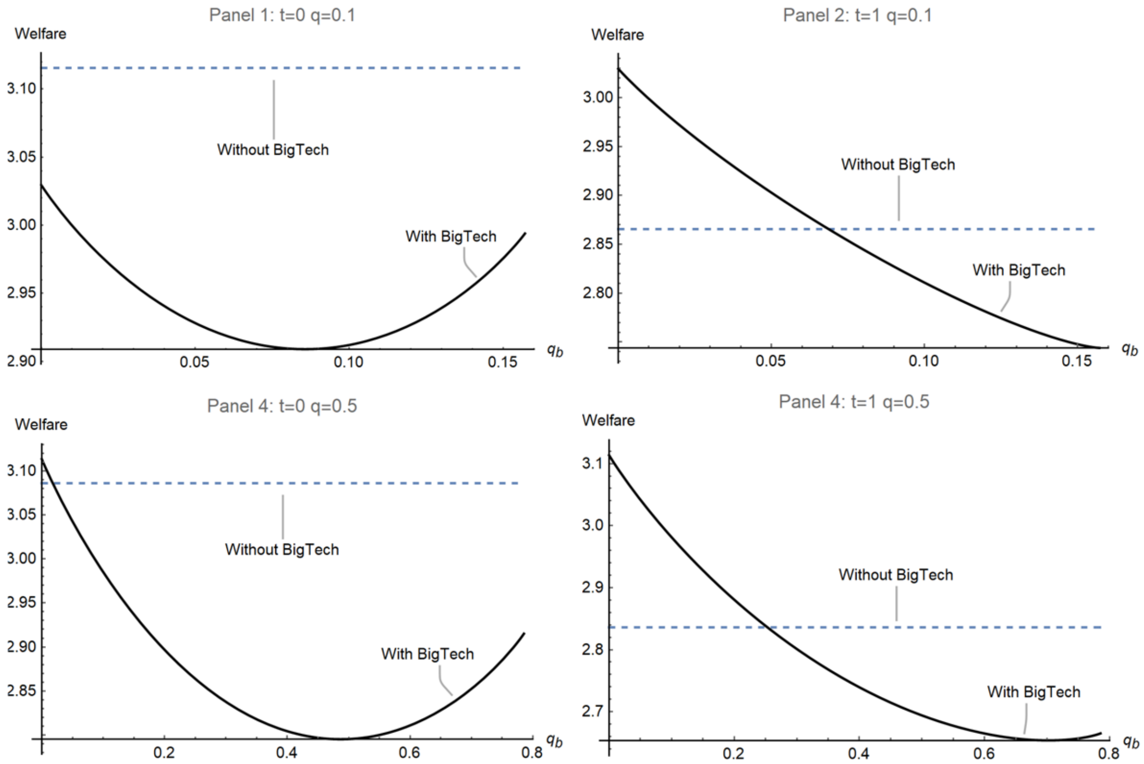

Figure 11: Social Welfare. This figure plots the social welfare with and without a BigTech against the BigTech's information technology q_b. The parameter values are: $R = 10, f = 1, c = 10, V = 0$.

How the entry of the BigTech affects the overall social welfare depends on the net effect of all those effects above. Numerical studies (seeing Figure 11) show that when t is significant, or when q is large, the BigTech entry can increase social welfare if q_b is small enough. If both t and q are small, the entry of the BigTech does not save a lot of transportation costs, and the the BigTech's advantage in information technology is not significant enough (i.e., cost-saving effect is small). Meanwhile, the BigTech significantly increases the overall level of competition, which pushes the overall monitoring intensity of the market away from the optimal level. Therefore, the overall effect is that the BigTech entry decreases social welfare when both t and q are small. When t is large, the BigTech entry can save a lot of transportation costs if it serves a large number of entrepreneurs. In this case, social welfare increases if a significant part of entrepreneurs approach the BigTech, which happens when q_b is small enough[14] (i.e., when the BigTech's

[14]When q_b is small, the BigTech will have significant market power due to its technological advantage, which

advantage in information technology is big enough). When q is large, the BigTech's advantage in information technology is significant when q_b is small enough. A significant advantage in information technology implies a large cost-saving effect of the BigTech entry, which leads to the result that social welfare increases due to the BigTech entry when q is large and q_b is small enough.

helps increase the overall loan rates and monitoring efficiency. This is another welfare-improving effect of a small q_b.

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