Fintech and Bank competition: The role of screening technology and collateral requirements

Konstantinos Serfes* Kejia Wu† Panagiotis Avramidis‡

March 6, 2022§

Abstract

Using a theoretical model that assumes heterogeneity in lenders' screening ability and in borrowers' investment horizon, we show that fintech loans to entrepreneurs are more likely to be unsecured and short-term while bank loans are expected to be asset-backed and long-term. The findings suggest that fintech lenders substitute data for collateral to leverage their advantage in borrower screening. Nevertheless, as this advantage declines with loan's term, banks are able to leverage their own advantage stemming from lower collateral underwriting costs. The results offer a supply-side explanation for the recent proliferation of unsecured lending. We also provide theoretical justification for the empirical observations about credit availability and interest rates offered by fintechs and banks, drawn from the Federal Reserve's Small Business Credit Survey. The model can be used to derive predictions as borrowers' data availability and methods of analyzing these data improve.

Keywords: Screening; Collateral; Competition; Business Lending

JEL classifications: D80, G20, G21

*School of Economics, LeBow College of Business, Drexel University, Philadelphia PA, USA. ks346@drexel.edu.

†Federal Reserve Bank of Philadelphia, Philadelphia PA, USA, and School of Economics, LeBow College of Business, Drexel University. kejia.wu@phil.frb.org.

‡Alba Graduate Business School, The American College of Greece, Athens, Greece. pavramidis@alba.acg.edu.

§The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia, the Federal Reserve Board of Governors, or the Federal Reserve System.

1 Introduction

Technological advancements in recent years have had a significant impact on financial services offered to households and businesses. The growth of a new business model where lending decisions depend solely on technology, known as fintech, has been remarkable even though precise figures are hard to ascribe due to the variations in the definition. Nonetheless, what is equally remarkable is that fintech's growth is not uniform across all loan types. Specifically in the US, the largest volume of fintech loans involves consumer lending (Cornelli et al. (2020); Ziegler et al. (2021)) including refinancing real estate mortgages (Buchak, Matvos, Piskorski, and Seru (2018); Fuster, Plosser, Schnabl, and Vickery (2019)).[1] Fintech's business loans are also popular but they tend to be short term and unsecured (Cornelli et al. (2020); Beaumont, Tang, and Vansteenberghe (2021); Thakor (2020)).[2] In fact, the absence of required collateral is explicitly stated by the entrepreneurs in the Federal Reserve's Small Business Credit Survey (2019) as one of the main reasons for applying to a Fintech lender.

What explains this heterogeneity in the growth of fintech loans and what does this mean for the competing traditional lenders such as banks? In this study, we try to shed light on these questions. Specifically, we introduce a theoretical model that predicts that the observed growth in particular types of loans offered by fintech lenders to entrepreneurs could be explained by the advantages of fintech lenders' business model in comparison to the traditional lenders model. The literature has identified two such advantages (Berg, Fuster, and Puri (2021)). The first is the operational efficiency that engenders faster processing time.[3] The second is superiority in screening ability, for example, by using more hard data and more advance methods to analyze these data. We show that both of these characteristics induce fintech lenders to offer to entrepreneurs shorter-term, unsecured business loans. In contrast, traditional lenders who lack the screening ability of fintech lenders, but have a lower collateral underwriting cost, will offer to entrepreneurs longer-term, secured

[1] Buchak, Matvos, Piskorski, and Seru (2018) show that the fintech's mortgages are primarily refinancing loans which offer more scope for automation than home purchase loans. Similarly, when restricting the sample to FHA- or VA-insured loans for which underwriting is less amenable to automation, Fuster, Plosser, Schnabl, and Vickery (2019) find a lower advantage in loan processing times for fintechs. Thus, they conclude that FinTech lenders particularly focus on mortgage refinances.

[2] Similarly, Gopal and Schnabl (2020) observe that the main type of finTech loans in their sample are Merchant Cash Advance (MCA) loans that are short-term loans repaid through deductions from future credit card and debit card sales. Although many MCA lenders require a blanket lien covering receivables, effectively these loans are economically linked to the firm's future cash flows rather than the liquidation value of some collateral. Thus, many MCA loans are often marketed as unsecured loans.

[3] Berg, Fuster, and Puri (2021)) give several examples of fintech lenders that emphasize on their webpage fast application and funding processes as the key benefit offered to borrowers. The fast application and funding processes is explicitly stated by the entrepreneurs in the Federal Reserve's Small Business Credit Survey (2019) as a major reason for applying to a fintech lender.

(by some asset) loans. These findings essentially imply that data and collateral requirements are substitutes. Furthermore, the model predicts higher approval rates as well as higher interest rates for fintech's short-term loan offers. These findings explain the empirical observations from the Federal Reserve's Small Business Credit Survey (2019) that the fintech loan applications have a higher chance of being approved and that the fintech loans offered to entrepreneurs entail higher interest compared to bank loan offers.

Our model features a traditional and a fintech lender in competition with each other to offer loans to entrepreneurs. Competition in the credit market is modeled as a first-price sealed-bid common value auction with differentially informed bidders, e.g., Broecker (1990), Hauswald and Marquez (2003), Stroebel (2016) and He, Huang, and Zhou (2020). There are two types of entrepreneurs, those who have a short-term and those with a long-term project. Each borrower can have a good or a bad project, and the screening yields a binary imperfect signal of the project quality. An important feature of this market is the winner's curse (i.e., winning a borrower for whom the rival lender has observed an unfavorable signal of the borrower's quality). We assume that the fintech has a better screening ability than the traditional lender, but this superiority is diminishing when it comes to screening long-term projects, due to the inherent noisier predictions when the horizon increases. The lenders can also ask borrowers to post a collateral, which is liquidated if the borrower defaults. The role of the collateral in our model is to mitigate the winner's curse. We abstract away from signaling and moral hazard problems, where the collateral can also alleviate informational asymmetries.

We begin the analysis by assuming fixed collateral requirements, positive for the traditional lender and zero for the fintech. The fintech has a lower winner's curse in the short-term segment of the market due to its pronounced screening superiority, while the traditional lender has a lower winner's curse in the long-term, where the benefit from the collateral dominates the fintech's less pronounced screening superiority. The implication of this is that the fintech lender earns rents from the short-term segment, while in the long-term segment it only earns a competitive rate of return. The reverse is true for the traditional lender.

We solve for the (mixed strategy) equilibrium and derive a number of novel testable predictions. The fintech lender, when it makes an offer to the short-term borrowers, charges higher rates than the traditional lender (in the first-order stochastic dominance sense), and always makes an offer when it draws a good signal about the borrower's creditworthiness. The predictions are consistent with fintechs' competitive advantage in the short term segment drawn by screening superiority. In the long-term segment of the market, it is the traditional lender that is always making an offer when its signal is good, while the fintech with some probability does not. The traditional lender's interest rate distribution is more spread-out, in the second-order stochastic dominance sense, than the fintech's interest rate distribution. Equivalently, these predictions are consonant with traditional lenders' competitive advantage in the long term segment deriving from collateral. We conclude that the presence of collateral alters competition between lenders with diverse screening abilities.

We also examine how the collateral affects expected profits, interest rates and probability of offers in each borrower segment. In the short term segment of borrowers, higher collateral fosters more competition. Specifically, it implies lower interest rates charged by the traditional lender to short-term borrowers, and higher probability of the traditional lender making an offer. The fintech lender, who always makes an offer, responds by either lowering its rates or by increasing the spread, depending on the level of collateral. In the long-term segment, a higher collateral mitigates competition among lenders, allowing them to sustain higher interest rates and reducing the probability of the fintech making an offer.

Next, we endogenize collateral requirements, by assuming that collateral underwriting imposes a cost on the lender. The higher the winner's curse the higher the equilibrium collateral. When a lender's signal becomes more accurate the probability of a winner's curse decreases, while when the rival lender's signal becomes more accurate the probability of a winner's curse increases. Therefore, own screening ability and collateral requirements are substitutes, whereas rival screening ability and collateral are complements. We show, for a plausible range of parameter values, that, in equilibrium, the traditional lender asks for a higher collateral than the fintech lender. The asymmetry in equilibrium collateral requirements, which holds even if the lenders have the same cost of collateral underwriting, is driven by the differential screening ability across lenders for a given lending horizon and across lending horizons for a given lender.

The model allows us to make predictions about the use of collateral as data availability increases and methods of analyzing these data improve. First, if the screening ability gap between the two lenders increases, then the lenders' collateral requirements are expected to diverge further. On the other hand, if the traditional lender catches up with the fintech lender's screening ability, then their collateral requirements will converge too.

The closest paper to ours is He, Huang, and Zhou (2020), which also models competition between a fintech and a bank as a common value auction with differentially informed bidders. Their main focus is on credit information sharing between the lenders, but they also examine how the screening ability of lenders affects the supply of credit and profits. Our main contribution relative to He, Huang, and Zhou (2020) is the introduction of collateral requirements and two types of borrowers with demands for loans of different maturities. The interplay between screening capacity and collateral requirements for loans of different maturities yields new insights about how the different lenders compete in the credit market and the supply of credit.

Although the substitution effect between monitoring and collateral has been shown theoretically and empirically (e.g. Holmstrom and Tirole (1997); Manove, Padilla, and Pagano (2001)), the emergence of a new type of lender with superior screening ability has brought this relationship back to the spotlight. Inderst and Mueller (2007) posit that as transaction (distanced) lenders use of technology minimizes any information advantage of a local lender may have, the traditional (local) lender is forced to reduce the loan rate and raise the collateral requirement. They conclude that, following the widespread adoption of small business credit scoring, the use of collateral in lending relationships should increase. In a more recent study Gambacorta, Huang, Li, Qiu, and Chen (2020) compare how credit from a big tech firm and traditional bank lending correlate with local economic activity, house prices, and firm-specific characteristics. Using a unique random sample of more than 2 million Chinese firms, the paper finds that big tech credit does not correlate with local business conditions and house prices when controlling for demand factors. The authors conclude that the massive amounts of data by fintech lenders could reduce the need for collateral in solving asymmetric information problems in credit markets. Beaumont, Tang, and Vansteenberghe (2021) show empirically that firms use uncollateralized fintech loans to acquire assets that they later pledge to obtain bank collateralized loans. Our study explains theoretically the empirical evidence of the fintech's substitution of data for collateral and attributes it to the lender's superior ability in screening. Moreover, we argue that the substitution of data for collateral is not inexorably optimal but it actually depends on the loan maturity. Colloquially, our findings highlight the limits of data as a replacement of collateral.

Our paper also offers an alternative explanation for the observed decline of secured lending (Benmelech, Kumar, and Rajan (2020)) and the dominance of the cash flow-based lending (Lian and Ma (2021)).[4] The current literature tries to explain this trend from the demand-side arguing that borrowers are interested in

[4] Lian and Ma (2021) show that 20% of debt by value is based on tangible assets (asset-based lending), whereas 80% is based predominantly on cash flows from firms' operations (cash flow-based lending). Drawing from a century long bond-data sample, Benmelech, Kumar, and Rajan (2020) conclude that secured debt accounted for 98.5% of total bond issuance in 1900, declined to 66% by 1943, and drop below 5% of total bonds issued in the early 2000s.

retaining financial and operational flexibility or by evoking the shrinking role of traditional assets such as property, plant, and equipment in production (Benmelech, Kumar, and Rajan (2020)). Our finding of the substitution of data for collateral by fintech lenders provides an alternative, supply-side rationale for the observed decline of loans secured by the traditional assets and the equivalent ascend of unsecured loans that are backed by the firm's future cash flows. The distinction between the different debt types has important implications because it affects the transmission of the monetary policy and the propagation of the financial crisis through lenders' balance sheets. Specifically, if unsecured lending is the main conduit of monetary policy and of the financial crisis (Ivashina, Laeven, and Moral-Benito (2020)) then our model's prediction of fintech lenders' prominent role in this type of lending calls for further supervision of the non-bank financial intermediaries.

Finally, our paper contributes to a growing literature on the credit market structure and the competition between banks and non-bank lenders in business financing, see Vives (2019) for a recent survey. Buchak, Matvos, Piskorski, and Seru (2018) show that the growth of fintech lenders is attributed to regulatory differences and technological advantages. Avramidis, Mylonopoulos, and Pennacchi (2021) show that marketplace lenders absorb the unmet demand for unsecured consumer credit following a decline in the availability of bank credit due to the merger-induced bank branch closings. Similarly, using a regulatory change as an exogenous shock to bank credit supply, Tang (2019) shows that marketplace lending is a substitute for bank's consumer lending. Gopal and Schnabl (2020) show an increase in fintech lending to small businesses after the 2008 crisis in response to a reduction in lending by banks. Donaldson, Piacentino, and Thakor (2021) suggest that differences between bank and non-bank finance result from heterogeneity in financiers' cost of capital. We offer an alternative view of the complementarities between bank and non-bank lenders based on the business model differences. Our predictions are consonant with previous studies concluding that lenders specialize along two dimensions, in particular, relationship versus transaction lending, and short-term versus long-term lending (Jimenez, Salas, and Saurina (2006)).

The rest of this paper is organized as follows. Section 2 lays out the basic model. Section 3 focuses on the main findings under the assumption that loan offers comprise fixed collateral requirements. In Section 4, we relax this assumption by endogenizing the lenders' collateral requirements into their decisions. Section 5 concludes.

2 The model

We develop a model of credit market competition between a fintech and a traditional bank that represent two lenders with different borrower screening abilities and different costs of collateral underwriting. In the following subsections, we lay out the foundations of the theoretical model.

2.1 Basic setup

There is a continuum of risk neutral entrepreneurs (borrowers) of measure one. Each entrepreneur can have either a short-term (S) or a long-term project (L), and this is common knowledge. The fraction of entrepreneurs with short term projects is $\theta \in [0, 1]$. Each S (L) entrepreneur has an investment project that generates a return that is either $\overline{r}^S$ ($\overline{r}^L$) or 0, in case of a default, and requires one unit of capital the entrepreneur must borrow from a lender. We assume entrepreneurs differ in their default risk. A fraction μ_i has good projects (G) and a fraction $1 - \mu_i$ has bad (B) projects for $i \in \{S, L\}$. The probabilities of no default are given by $1 \geq p_G > p_B \geq 0$ and they are the same for S and L borrowers. We assume that neither the lenders nor the borrowers know the true type of a borrower. The main difference between S and L loans is the date at which the loan is repaid. An L borrower repays the loan at a later date than an S borrower. This will affect the accuracy of the signals lenders receive about the creditworthiness of borrowers, due to the difference in the length of the forecasting horizon. More on this in the next section.

Let $\tau^i \equiv \frac{\mu_i}{1-\mu_i}$ be the likelihood ratio of good over bad projects of the $i \in \{S, L\}$ borrowers in the population. We assume that the interest rate in the market never exceeds the project return $\overline{r}^i$.

2.2 Lenders, screening ability and collateral

There are two risk neutral lenders that compete in the market. One lender is a fintech (F) and the other lender a traditional lender (T), e.g., a bank. The two lenders differ in their screening ability and in the cost of collateral underwriting as we explain in detail below.

We assume that each lender receives an independent and private signal of a borrower's type via a credit screening. Let $\mathcal{S}_j^i \in \{g, b\}$ denote lender j's, $j \in \{F, T\}$, signal about borrower of type $i \in \{S, L\}$, which can be either good (g) or bad (b). The signal conditional probabilities are given by

$$q_j^{i,g} = \text{Prob}(\mathcal{S}_j^i = g|G) \geq \frac{1}{2} \text{ and } q_j^{i,b} = \text{Prob}(\mathcal{S}_j^i = b|B) \geq \frac{1}{2},$$

where $q_j^{i,g}$ and $q_j^{i,b}$ capture the accuracy of lender j's signals for borrower of type i. In order to reduce the number of parameters, and without loosing the main insights, we set $q_F^{S,g} = q_T^{S,g} = 1$ and $q_F^{L,g} = q_T^{L,g} = 1$. That is, an entrepreneur, either S or L, with a good project always generates good signals. Furthermore, we let

$$q_F^{S,b} \equiv q_F^S, q_T^{S,b} \equiv q_T^S, q_F^{L,b} \equiv q_F^L \text{ and } q_T^{L,b} \equiv q_T^L.$$

Therefore, a bad signal perfectly reveals that the borrower has a bad project and so no lender is willing to lend when it receives a bad signal. A good signal, on the other hand, is inconclusive. We also set, $p_G = 1$ and $p_B = 0$, i.e., a good borrower always repays a loan, while a bad borrower always defaults.

Let $\Delta q^i \equiv q_F^i - q_T^i$ denote the difference in the signal accuracy between the two lenders. We make the following assumption regarding the screening ability of lenders as a function of the lending horizon.

Assumption 1 $\Delta q^S > \Delta q^L \geq 0$ *and* $q_j^S \geq q_j^L$.

Assumption 1 derives from the higher screening ability which is explicitly stated in the definition of a fintech lender (Berg, Fuster, and Puri (2021)). Assumption 1 further implies that although the F lender has a superior screening ability than the T lender, as the forecasting horizon increases, i.e., going from S to L, the accuracy of all signals decreases and the F lender's prediction advantage over the T lender shrinks. This is a reasonable assumption given that screening ability is linked to model predictions based on backward-looking borrowers' historical data which have an inherent prediction error. The prediction error increases with the time horizon reducing the screening ability of all lenders. Thus, the screening ability advantage of the F lender will decline as both lenders prediction accuracy converge to zero for sufficiently large forecasting (lending) horizon.

In addition to the interest rate, lender j can ask borrowers to post a collateral $c_j < 1$. The collateral is used to mitigate the losses in case of default. That is, if borrower defaults the lender liquidates the collateral.

The timing of the model is as follows. Lenders receive their private signals, update their beliefs about the borrower's type and simultaneously make their interest rate offers to the S borrowers, r_j^S, and to the L borrowers, r_j^L. Lender j also asks borrowers to post a collateral c_j. Competition is on a borrower-by-borrower basis. Borrowers then choose the offer with the higher expected payoff that takes into account both the interest rates and the collateral requirement. When the two lenders offer the same deal, the borrower will randomly choose one. We assume that lenders do not observe each other's interest rate offers, or whether a lender made an offer. For simplicity we assume the lenders have the same cost of funds, which we normalize to one.

We assume that each lender is willing to lend to a borrower when the signal is good at the highest possible interest rate $\overline{r}^i$. Upon observing a good signal, the probability that the borrower will pay back the loan is

$$\frac{\mu_i}{\mu_i + (1-\mu_i)(1-q_j^i)} = \frac{\tau^i}{\tau^i + 1 - q_j^i}.$$

A lender is willing to lend if the probability of repayment times $1+\overline{r}^i$ plus the probability of no repayment times the collateral is higher than the cost 1. This requires

$$\overline{r}^i > \frac{(1-q_j^i)(1-c_j)}{\tau^i}, \tag{2.1}$$

for all possible values of c_j.

3 Equilibrium characterization

In this section, we solve the model in closed-form by fully characterizing the mixed strategy equilibrium. We then derive our main results on how this mix depends on the level of screening ability and the collateral requirement. Following a step by step approach, in this section we assume that only the T lender asks for a collateral which is fixed for all borrowers i.e. $c_F = 0$ and $c_T = c > 0$. In section 4, we endogenize the collateral requirements and we show that this assumption holds under a wide and plausible range of parameter values.

3.1 Borrower signals

We first present various probabilities that apply to both S and L borrowers. Let

$$p_{gg}^{i} \equiv \mathrm{Prob}(\mathcal{S}_F^i = g, \mathcal{S}_T^i = g) = \mu_i + (1-\mu_i)(1-q_T^i)(1-q_F^i)$$

be the probability that both lenders observe good signals for an $i \in \{S, L\}$ borrower and let

$$\nu_{gg}^{i} = \frac{\mu_i}{p_{gg}^{i}} \tag{3.1}$$

be the probability of repayment of an i borrower, conditional on two good signals. Similarly, denote by

$$p_{gb}^{i} \equiv \mathrm{Prob}(\mathcal{S}_F^i = g, \mathcal{S}_T^i = b) = (1-\mu_i)q_T^i(1-q_F^i) \tag{3.2}$$

the probability that the F lender observes a good signal, while a T lender observes a bad signal and by

$$p_{bg}^{i} \equiv \mathrm{Prob}(\mathcal{S}_F^i = b, \mathcal{S}_T^i = g) = (1-\mu_i)(1-q_T^i)q_F^i \tag{3.3}$$

the probability that the F lender observes a bad signal, while a T lender observes a good signal for an i borrower. In either case, the expected repayment probability is zero. Note that $p_{bg}^i > p_{gb}^i$, i.e., the probability that an i borrower defaults when the F lender has received a bad signal and the T lender's signal is good is higher than the probability that an i borrower defaults when the T lender has received a bad signal, and the F lender's signal is good. This is because the F lender's signal is more accurate, $q_F^i > q_T^i$.

3.2 Borrower choices

Suppose a borrower of type i has received two interest rate offers, r_F^i and r_T^i from the fintech and the traditional lender, respectively. Then, the borrower knows that both lenders have received good signals. The probability of repayment is given by (3.1). The borrower will borrow from lender F if and only if

$$r_F^i < r_T^i + z_{gg}^i c, \tag{3.4}$$

where $z^i_{gg} \equiv \frac{1-\nu^i_{gg}}{\nu^i_{gg}} = \frac{(1-q^i_T)(1-q^i_F)}{\tau^i}$, is the likelihood ratio of no repayment over repayment, conditional on two good signals. The borrower chooses the offer with the lower expected cost after including the collateral requirement by the T lender. If the borrower receives only one offer, then we assume he accepts that offer.

3.3 Mixed strategy equilibrium

Competition in the credit market has a flavor of a first-price sealed-bid common value auction with differentially informed bidders, e.g., Broecker (1990), Hauswald and Marquez (2003), Stroebel (2016) and He, Huang, and Zhou (2020). A lender wins an entrepreneur if both lenders obtain good signals and the lender in question makes a better offer, or if the lender's signal is good and the other lender's signal is bad, in which case the other lender does not make an offer to the borrower. This implies that winning an entrepreneur entails a *winner's curse*.

Suppose for simplicity that lender T offers an interest rate r^i_T and lender F's offer is r^i_F so that borrower i is indifferent between the two offers, i.e., $r^i_T + z^i_{gg}c = r^i_F$. The F lender's expected profit from lending to an i entrepreneur is

$$p^i_{gg}\frac{1}{2}\left((1+r^i_F)\nu^i_{gg} - 1\right) - \underbrace{p^i_{gb}}_{\text{winner's curse}}. \tag{3.5}$$

Suppose the F lender has received a good signal. With probability p^i_{gg} both lenders' signals are good in which case the F lender has a 50% chance to win the borrower. With probability p^i_{gb} the T lender has received a bad signal which implies that the borrower will default. The F lender in this case only incurs the cost of 1.

On the other hand, the T lender's expected profit from lending to an i entrepreneur is

$$p^i_{gg}\frac{1}{2}\left((1+r^i_T)\nu^i_{gg} - 1\right) - \underbrace{p^i_{bg}(1-c)}_{\text{winner's curse}}. \tag{3.6}$$

If the T lender wins the borrower, then the interest rate is lower than the F lender's interest rate by $z^i_{gg}c$, due to the collateral requirement imposed on the borrower. However, the collateral mitigates the winner's curse.

We will construct the mixed strategy equilibrium.[5] Let m_j^i be the probability that lender j makes an offer to an i borrower upon drawing a good signal. Let $Z_F^i(r) \equiv \text{Prob}(r_F^i - z_{gg}^i c \leq r)$ be the probability distribution of lender F's interest rate offers, conditional on making an offer to an i borrower. Similarly, let $Z_T^i(r) \equiv \text{Prob}(r_T^i + z_{gg}^i c \leq r)$ be the probability distribution of lender T's interest rate offers, conditional on making an offer to an i borrower. Both interest rates are appropriately adjusted to account for the collateral requirement. Let π_j^i denote lender j's expected profit from lending to i borrower.

Following similar arguments as in He, Huang, and Zhou (2020), we can show that mixed strategy equilibria are well-behaved.[6] In addition, it can be easily seen that the supports of the two lenders' interest rate distributions should differ by the collateral requirement $z_{gg}^i c$.[7] In a mixed strategy equilibrium, the F lender's indifference condition when it lends to an i borrower is

$$p_{gg}^i \left(1 - m_T^i + m_T^i(1 - Z_T^i(r))\right) \left((1+r)\nu_{gg}^i - 1\right) - p_{gb}^i = \pi_F^i. \tag{3.7}$$

That is, suppose lender F receives a good signal about an i borrower and makes an offer r. Then, there are two possibilities. First, the T lender also receives a good signal, which occurs with probability p_{gg}^i, and the F lender lends to the i borrower if either the T lender does not make an offer with probability $1 - m_T^i$, or if the T lender makes an offer with probability m_T^i, but the interest rate of the T lender plus the collateral is above r, which occurs with probability $1 - Z_T^i(r)$. Second, the T lender receives a bad signal, which occurs with probability p_{gb}^i, in which case the borrower must have a bad project and lender F's cost is 1.

The T lender's indifference condition when it lends to an i borrower and offers an interest rate r is

$$p_{gg}^i \left(1 - m_F^i + m_F^i(1 - Z_F^i(r)\right) \left((1+r)\nu_{gg}^i - 1\right) - p_{bg}^i(1-c) = \pi_T^i. \tag{3.8}$$

[5] A consequence of the winner's curse is that a pure strategy equilibrium does not exist. For example, suppose the two lenders make different offers to a borrower $r_F^i \neq r_T^i + z_{gg}^i c$. Then, the lender making the better offer can raise the interest rate without affecting its demand. If the lenders make the same offer and earn non-negative profits then the first terms of (3.5) and (3.6) must be strictly positive and a lender has an incentive to unilaterally lower its interest rate.

[6] This means that they have the following properties: the supports share the same lower the same upper bounds, adjusted for the collateral requirement (see below); they have no gaps in their supports; and they have no mass points except that one of them can have one at the upper bound of its support.

[7] Suppose, for example, $\underline{r}_F^i < \underline{r}_T^i + z_{gg}^i c$. Then, lender F has a profitable deviation by raising the lowest interest rate without affecting its demand. If, one the other hand, $\underline{r}_F^i > \underline{r}_T^i + z_{gg}^i c$, then lender T can profitably raise its lowest interest rate. The highest interest rate cannot be higher than $\overline{r}^i$; otherwise the borrower will not be willing to accept the offer. This will be the upper bound of the interest rate support of lender F. Lender T's highest interest rate will be $\overline{r}^i - z_{gg}^i c$.

The interpretation is similar to the one for (3.7). Now T wins the borrower, when both lenders make offers, if F's interest rate minus the collateral requirement exceeds r, which occurs with probability $1 - Z_F^i(r)$. The collateral requirement $z_{gg}^i c$, however, will affect the scale but not the shape of the distributions since it represents a linear transformation.

We make the following assumptions that determine the magnitude of the winner's curse.

Assumption 2 $p_{bg}^S(1-c) \geq p_{gb}^S \Leftrightarrow c \leq \frac{\Delta q^S}{q_F^S(1-q_T^S)}$.

Assumption 3 $p_{bg}^L(1-c) \leq p_{gb}^L \Leftrightarrow c \geq \frac{\Delta q^L}{q_F^L(1-q_T^L)}$.

The above assumptions imply that the T lender faces a higher lending cost, due to a more severe winner's curse, than the F lender when they lend to the S borrowers (Assumption 2), but the reverse is true when they lend to the L borrowers (Assumption 3). There is a range of collateral requirement, c, where both assumptions are satisfied because the superiority of F lender's screening ability relative to T shrinks in the long-run (Assumption 1).[8]

The Bertrand-type competition between lenders for each S borrower, brings the T lender's expected profits down to zero and the F lender's expected profit is strictly positive and a function of the difference in the signal accuracies and the level of collateral. The opposite is true for the L borrowers, where the T lender has a lower winner's curse. We summarize the above discussion in the Lemma below.

Lemma 1 *In any mixed-strategy equilibrium, the F lender makes a strictly positive profit $\pi_F^S > 0$, while the T lender makes a zero profit $\pi_T^S = 0$, when lending to S borrowers. When lending to L borrowers, $\pi_T^L > 0$ and $\pi_F^L = 0$.*

3.3.1 Equilibrium for S borrowers

We begin by deriving the mixed strategy equilibrium that characterizes the competition in the credit market for the S borrowers.

[8] As it will become clearer later Assumptions 2 and 3 ensure that no lender dominates both the short- and the long-run segments of the market.

The F lender must always be making an offer when it obtains a good signal, $m_F^S = 1$, because of its strictly positive expected profits. Then, (3.8) becomes

$$p_{gg}^S \left(1 - Z_F^S(r)\right) \left((1+r)\nu_{gg}^S - 1\right) - p_{bg}^S(1-c) = 0. \tag{3.9}$$

We define

$$\phi^S(r) \equiv \frac{p_{bg}^S(1-c)}{p_{gg}^S \left((1+r)\nu_{gg}^S - 1\right)} = \frac{q_F^S(1-c)}{\frac{\tau^S}{1-q_T^S} r - (1-q_F^S)}, \tag{3.10}$$

which is the $1 - Z_F^S(r)$ that solves (3.9).

Proposition 1 *The equilibrium in the competition between the fintech (F) and the traditional (T) lender for short-term (S) borrowers is characterized as follows:*

- *the F lender makes an expected profit $\pi_F^S = (1-\mu_S)[\Delta q^S - c q_F^S(1-q_T^S)]$ and the T lender makes zero profits $\pi_T^S = 0$,*
- *the F lender always makes an offer upon drawing a good signal, $m_F^S = 1$, and its interest rate r_F^S is randomly drawn from the distribution $\phi^S(\underline{r}_F^S) - \phi^S(r_F^S)$, with support $[\underline{r}_F^S, \overline{r}^S]$, where $\underline{r}_F^S = \frac{(1-q_T^S)[1-c(2q_F^S-1)]}{\tau^S}$. The distribution has a mass point of size $1 - [\phi^S(\underline{r}_F^S) - \phi^S(\overline{r}^S)]$ at $\overline{r}^S$, and*
- *the T lender makes an offer with probability $m_T^S = 1 - \phi^S(\overline{r}_T^S)$ upon seeing a good signal, and when it makes an offer the interest rate r_T^S is randomly drawn from the distribution*

$$\frac{1 - \phi^S(r_T^S)}{1 - \phi^S(\overline{r}_T^S)}$$

which has support $[\underline{r}_T^S, \overline{r}_T^S]$, where $\underline{r}_T^S = \frac{(1-q_T^S)(1-q_F^S c)}{\tau^S}$ and $\overline{r}_T^S = \overline{r}^S - \frac{(1-q_T^S)(1-q_F^S)}{\tau^S} c$.

For $r \in [\underline{r}_F^S, \overline{r}_T^S]$, where the supports of the lenders' distributions overlap, the two distributions satisfy $\frac{1-\phi^S(r)}{1-\phi^S(\overline{r}_T^S)} > \phi^S(\underline{r}_F^S) - \phi^S(r)$. Moreover, the F lender does not offer an interest rate in the lower portion of T's support, $[\underline{r}_T^S, \underline{r}_F^S)$. And the T lender does not offer an interest rate in the upper portion of the F's support, $(\overline{r}_T^S, \overline{r}^S]$.

Therefore, the F lender offers higher interest rates than the T lender in the First Order Stochastic Dominance (FOSD) sense. The reason is two-fold: first, the T lender knows that due to its low screening ability a good signal is not accurate enough to indicate that the borrower has a good project. The response to this is that it chooses not to lend sometimes. The F lender, then, becomes a monopoly credit supplier and charges a higher interest rate. Second, the T lender asks borrowers to post a collateral which imposes an added cost to the borrowers. To remain competitive, the T lender offers lower interest rates.

The interest rate dispersion that arises in equilibrium is dispersion *within* a credit score bucket, i.e., borrowers for which a bank has drawn a good signal.

Example 1 *Let* $\mu^S = 0.6$, $q_F^S = 0.9$, $q_T^S = 0.6$, $c = 0.6$ *and* $\overline{r}^S = 0.4$. *Then, the support of the T lender's interest rate distribution is* $[0.123, 0.384]$ *and the support of the F lender's distribution is* $[0.139, 0.4]$. *The T lender makes an offer upon seeing a good signal with probability* $m_T^S = 73.1\%$, *while the F lender always makes an offer after observing a good signal. The F lender has a mass point at* $\overline{r}_F^S = 0.4$ *of size* 40%, *which represents the likelihood of F offering this interest rate. Assumption 2 is satisfied for* $c \leq 0.8333$.

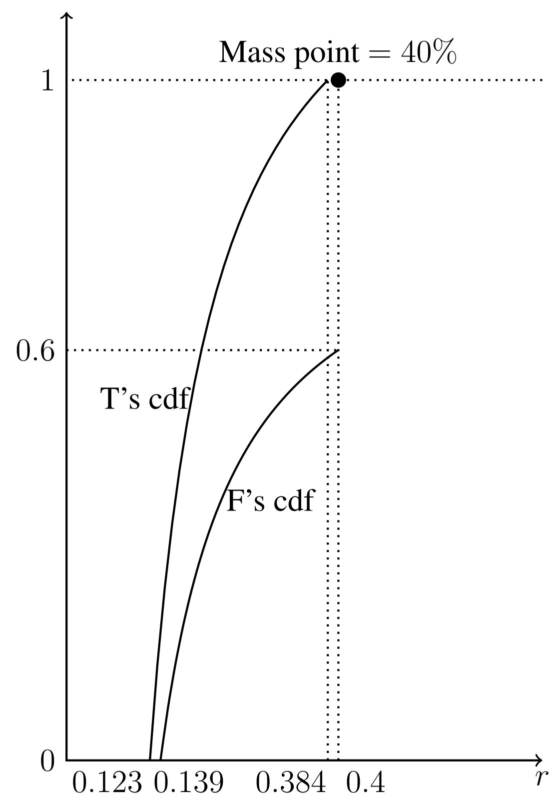

Figure 1: Equilibrium interest rate cumulative distribution functions (cdf) for the S borrowers.

In the remaining of the analysis we will encounter interest rate distributions that differ in terms of their "dispersion". We will require a measure of "riskiness" to rank these distributions. We will use the concept of a (not necessarily mean-preserving) spread. Consider a family of densities $f_s(x)$ parameterized by s. An increase in s results in a spread if it moves density away from the center of $f_s(x)$ and toward the upper and lower tails. A spread results in a clockwise rotation of the distribution function (for more details see Definition 1 in Johnson and Myatt (2006)).

The following Corollary states how the collateral requirement affects the equilibrium credit supply, i.e., probability of making an offer and interest rates.

Corollary 1 *In the equilibrium that involves the short-term borrowers, when the T lender's collateral requirement c increases,*

1. *the probability of T making an offer upon observing a good signal increases, while its distribution function shifts to the left, so lender T offers lower interest rates (in the FOSD sense),*

2. *if the collateral level is higher than the threshold given by* (A.1) *the distribution function of the F lender rotates clockwise, which implies that the spread of rates increases; if the collateral is lower than that threshold, the distribution of F shifts to the left (in the FOSD case), which implies that F charges lower interest rates and*

3. *the profits of the F lender decrease, while the T lender's profits remain zero.*

Since higher collateral mitigates the loss in the event a borrower defaults, the T lender is more willing to make an offer. Higher probability of T making an offer implies a more intense competition between the lenders, which is a force towards lower interest rates. However, an increase in collateral, especially when the collateral requirement is already high, could make the T lender's offer less competitive, notably at high interest rates, which allows the F lender to raise its interest rates. Overall, a higher collateral requirement reduces the rents of the F lender, while the profits of the T lender from the short-run segment remain zero.

The following Corollary states how the lenders' screening abilities affect the equilibrium loan supply, i.e., probability of making an offer and interest rates.

Corollary 2 *In the equilibrium that involves the short-term borrowers, the effect of the lenders' screening abilities is described as follows.*

1. *Suppose the screening ability, q_T^S, of the T lender increases. Then, the probability of T lender making an offer increases and its interest rate distribution rotates clockwise, implying higher spread. The distribution of F shifts to the left implying lower interest rates.*

2. *Suppose the screening ability, q_F^S, of the F lender increases. Then, the probability of T making an offer increases if and only if the collateral is higher than the threshold given by* (A.2)*. The distribution of F shifts to the left, implying lower interest rates, if the collateral requirement is higher than the threshold given by* (A.3)*. If, instead, lender T's collateral requirement is below the threshold, then the distribution of F rotates clockwise, implying a higher interest rate spread. The distribution of T rotates clockwise, implying a higher interest spread.*

3. *The profits of F increase as its screening advantage over the T lender increases, but this effect is less pronounced the collateral requirement is higher.*

When $c = 0$ the results in Corollary 2 are the same as those in He, Huang, and Zhou (2020). For example, a higher screening accuracy of lender F relative to the T lender, would imply higher interest rates charged by F and a lower probability of lender T making an offer. But the introduction of collateral requirements, $c > 0$, makes the results qualitatively different. Specifically, an increase in F lender's screening ability, q_F^S, can actually increase the probability with which T makes an offer and forces lender F to offer lower interest rates. The mechanism is described as follows.

There are two opposing effects as q_F^S increases. First, the T lender's winner's curse increases, making the lender more reluctant to make a loan offer. Second, the highest interest rate lender T can offer increases. This is because the probability of borrower's default, and consequently the probability with which the collateral will be exercised, decreases allowing lender T to increase the maximum interest rate. This effect, which is absent when there is no collateral, incentivizes lender T to make a loan offer, and dominates the first effect when c is high.

3.3.2 Equilibrium for L borrowers

The T lender must always be making an offer when it obtains a good signal, $m_T^S = 1$, because of its strictly positive expected profits. Then, (3.7) becomes

$$p_{gg}^L \left(1 - Z_T^L(r)\right)\left((1+r)\nu_{gg}^L - 1\right) - p_{gb}^L = 0. \tag{3.11}$$

We define

$$\phi^L(r) \equiv \frac{p_{gb}^L}{p_{gg}^L\left((1+r)\nu_{gg}^L - 1\right)} = \frac{q_T^L}{\frac{\tau^L}{1-q_F^L} r - (1-q_T^L)}, \tag{3.12}$$

which is the $1 - Z_T^L(r)$ that solves (3.11).

Proposition 2 *The equilibrium in the competition between the fintech (F) and the traditional (T) lender for long-term (L) borrowers is characterized as follows:*

- *the T lender makes an expected profit $\pi_T^L = (1-\mu_L)[-\Delta q^L + cq_F^L(1-q_T^L)] > 0$ and the F lender makes zero profits $\pi_F^L = 0$,*
- *the T lender always makes an offer upon drawing a good signal, $m_T^L = 1$, and its interest rate r_T^L is randomly drawn from the distribution $1 - \phi^L(r_T^L)$, with support $\left[\underline{r}_T^L, \overline{r}_T^L\right]$, where $\underline{r}_T^L = \frac{1-q_F^L}{\tau^L}$ and $\overline{r}_T^L = \overline{r}^L - \frac{(1-q_T^L)(1-q_F^L)}{\tau^L}c$. The distribution has a mass point of size $\phi^L(\overline{r}_T^L)$ at $\overline{r}_T^L$, and*
- *the F lender makes an offer with probability $m_F^L = \phi^L(\underline{r}_F^L) - \phi^L(\overline{r}^L)$ upon seeing a good signal, and when it makes an offer the interest rate r_F^L is randomly drawn from the distribution*

$$\frac{\phi^L(\underline{r}_F^L) - \phi^L(r_F^L)}{\phi^L(\underline{r}_F^L) - \phi^L(\overline{r}^L)} \tag{3.13}$$

which has support $\left[\underline{r}_F^L, \overline{r}^L\right]$, where $\underline{r}_F^L = \frac{(1-q_F^L)[1+(1-q_T^L)c]}{\tau^L}$.

The support of T's interest rate distribution shifts to the left relative to F's distribution to account for collateral requirements. Moreover, and unlike the ranking of distributions in the short-run loan segment, no distribution dominates the other in the FOSD sense. Specifically, the distribution of T is a clockwise rotation relative to the distribution of F meaning the T lender places more weight on extreme interest rates relative to the F lender. It does so in the low range in order to stay competitive given the collateral disadvantage. But also offers high rates with a relatively high probability, given its advantage over the F lender, due to a lower winner's curse. The F lender does not always makes an offer, bestowing lender T some monopoly power.

Example 2 *Let* $\mu^L = 0.7$*,* $q_F^L = 0.7$*,* $q_T^L = 0.6$*,* $c = 0.6$ *and* $\overline{r}^L = 0.5$*. Then, the support of the F lender's interest rate distribution is* $[0.16, 0.5]$ *and the support of the T lender's distribution is* $[0.13, 0.45]$*. The F lender makes an offer upon seeing a good signal with probability* $m_F^L = 54\%$*, while the T lender always makes an offer after observing a good signal. The T lender has a mass point at* $\overline{r}_T^L = 0.45$ *of size* 19.4%*, which represents the likelihood of T offering this interest rate. Assumption* (3) *is satisfied for* $c > 0.357$*. Figure 2 depicts the two distribution functions.*

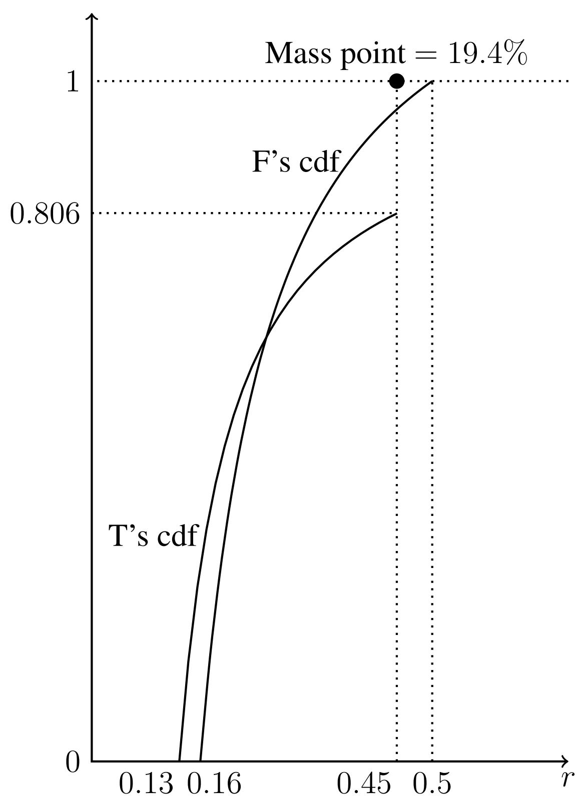

Figure 2: Equilibrium interest rate cumulative distribution functions (cdf) for the L borrowers.

The following Corollary states how the collateral requirement c affects the equilibrium loan supply, i.e., probability of an offer and interest rates.

Corollary 3 *In the equilibrium that involves the long-term borrowers, when the T lender's collateral requirement c increases,*

1. *the probability of F making an offer upon observing a good signal decreases, while its distribution function shifts to the right, which implies that F offers higher rates,*
2. *the distribution function of the T lender shifts to the right and the mass point increases, implying that T offers higher interest rates, and*
3. *the profits of the T lender increase, while the F lender's profits remain zero.*

A notable difference with the short-run loan segment of the market, is that in the long-run segment a higher collateral mitigates competition between lenders, resulting in higher interest rates and a lower probability of an offer. This can be understood as follows. The T lender has an advantage over the F lender in the long-run loan segment. This advantage is a consequence of the collateral requirement, relative to the not so pronounced screening superiority of F. A higher collateral increases the advantage even further and lenders compete less intensively.

The following Corollary states how the lenders' screening abilities affect the equilibrium loan supply, i.e., probability of making an offer and interest rates.

Corollary 4 *In the equilibrium that involves the long-term borrowers, the effect of the lenders' screening abilities is described as follows.*

1. *Suppose the screening ability, q_T^L, of the T lender increases. Its interest rate distribution shifts to the right, implying higher interest rates. Moreover, the distribution of F shifts to the left implying lower interest rates and the probability of F making an offer increases, if and only if the collateral is greater than the threshold given by* (A.4).
2. *Suppose the screening ability, q_F^L, of the F lender increases. The probability of F making an offer increases, while its interest rate distribution shifts to the left implying lower interest rates. The interest rate distribution of the T lender also shifts to the left, implying lower interest rates.*
3. *The expected profits of T increase as the screening ability of T increases, and this effect is less pronounced for higher collateral requirements.*

3.4 Comparison across different loan maturity segments

We now combine the results from Corollaries 2 and 4 to present the effect of improved screening abilities on the supply of credit and the interest rate distributions. In doing so we assume that $q_F^L = \rho_T q_F^S$ and $q_T^L = \rho_T q_T^S$, for some fixed $\rho_T, \rho_F < 1$. Naturally, an improvement in a lender's screening ability applies to both segments. Let $q_F^S \equiv q_F$ and $q_T^S \equiv q_T$. To be consistent with our assumptions so far, we assume that $q_F > q_T$ and $\rho_F \leq \rho_T$.

Corollary 5 *Suppose the screening ability of the F lender, q_F, increases.*

- *In the S segment*
  - *the F lender increases its interest rate offers if and only if the level of the collateral is below a threshold;*
  - *the T lender increases the spread of its interest rate offers and*
  - *the T lender decreases the probability with which it makes loan offers, if and only if the level of the collateral is below a threshold.*
- *In the L segment*
  - *the F lender decreases its interest rate offers;*
  - *the F lender increases the probability with which it makes loan offers and*
  - *the T lender decreases its interest rate offers.*

Corollary 6 *Suppose the screening ability of the T lender, q_T, increases.*

- *In the S segment*
  - *the F lender decreases its interest rate offers;*
  - *the T lender increases the spread of its interest rate offers and*
  - *the T lender increases the probability with which it makes loan offers.*
- *In the L segment*

– *the F lender decreases its interest rate offers;*

– *the F lender decreases the probability with which it makes loan offers, if and only if the level of the collateral is below a threshold and*

– *the T lender increases its interest rate offers.*

4 Collateral competition

So far, we have assumed that only the T lender asks for a fixed collateral. In this section we relax this assumption by endogenizing the collateral requirements. By doing so, we aim at exploring the dynamic effect of borrower screening ability on equilibrium interest rates and collateral requirements.

4.1 Collateral requirements

We add a stage in timeline of the model, prior to the interest rate offers, where lenders choose, non-cooperatively, their collateral requirements. The indifference conditions (3.7) and (3.8) are modified as follows. The F lender's indifference condition when it lends to an i borrower is

$$p^i_{gg}\left(1-m^i_T+m^i_T(1-Z^i_T(r))\right)\left((1+r)\nu^i_{gg}-1\right)-p^i_{gb}(1-c_F)=\pi^i_F. \tag{4.1}$$

The T lender's indifference condition when it lends to an i borrower and offers an interest rate r is

$$p^i_{gg}\left(1-m^i_F+m^i_F(1-Z^i_F(r)\right)\left((1+r)\nu^i_{gg}-1\right)-p^i_{bg}(1-c_T)=\pi^i_T. \tag{4.2}$$

Lender T's winner's curse is more severe than F's winner's curse for the i borrowers if and only if $\frac{1-c_T}{1-c_F}>\frac{q^i_T(1-q^i_F)}{q^i_F(1-q^i_T)}$.

We will search for an equilibrium where lender F has an advantage (lower winner's curse) in the S borrower and lender T has an advantage in the L borrower of the market. The equilibrium collateral choices must satisfy the following condition

Assumption 4 $\frac{q^L_T(1-q^L_F)}{q^L_F(1-q^L_T)}\geq\frac{1-c_T}{1-c_F}\geq\frac{q^S_T(1-q^S_F)}{q^S_F(1-q^S_T)}$,

which is the extension of Assumptions 2 and 3 to the case where both lenders ask for collateral.

4.2 Equilibrium for the S borrowers

The F lender must always be making an offer when it obtains a good signal, $m_F^S = 1$, because of its strictly positive expected profits. Then, (4.2) becomes[9]

$$p_{gg}^S \left(1 - Z_F^S(r)\right) \left((1+r)\nu_{gg}^S - 1\right) - p_{bg}^S(1 - c_T) = 0. \tag{4.3}$$

We define

$$\phi^S(r) \equiv \frac{p_{bg}^S(1 - c_T)}{p_{gg}^S \left((1+r)\nu_{gg}^S - 1\right)} = \frac{q_F^S(1 - c_T)}{\frac{\tau^S}{1-q_T^S} r - (1 - q_F^S)}, \tag{4.4}$$

which is the $1 - Z_F^S(r)$ that solves (4.3).

The equilibrium profits are

$$\pi_F^S = (1 - \mu_S)(\Delta q^S + c_F q_T^S(1 - q_F^S) - c_T q_F^S(1 - q_T^S)) \text{ and } \pi_T^S = 0. \tag{4.5}$$

4.3 Equilibrium for the L borrowers

The T lender must always be making an offer when it obtains a good signal, $m_T^L = 1$, because of its strictly positive expected profits. Then, (4.1) becomes

$$p_{gg}^L \left(1 - Z_T^L(r)\right) \left((1+r)\nu_{gg}^L - 1\right) - p_{gb}^L(1 - c_F) = 0. \tag{4.6}$$

We define

$$\phi^L(r) \equiv \frac{p_{gb}^L(1 - c_F)}{p_{gg}^L \left((1+r)\nu_{gg}^L - 1\right)} = \frac{q_T^L(1 - c_F)}{\frac{\tau^L}{1-q_F^L} r - (1 - q_T^L)}, \tag{4.7}$$

which is the $1 - Z_F^L(r)$ that solves (4.6).

The equilibrium profits are

$$\pi_T^L = (1 - \mu_L)(-\Delta q^L - c_F q_T^L(1 - q_F^L) + c_T q_F^L(1 - q_T^L)) \text{ and } \pi_F^L = 0. \tag{4.8}$$

[9] The derivations follow closely the proofs of Propositions 1 and 2 and hence are omitted.

4.4 Equilibrium collaterals

We assume lenders ask the same collateral requirements, regardless of the loan maturity.[10] Lender j chooses its own collateral c_j to maximize $\Pi_j = \theta\pi_j^S + (1-\theta)\pi_j^L - C(c_j)$ where $C_j(c_j)$, the cost of collateral for lender j, is an increasing and convex function. We assume for simplicity that $C_j(c_j) = \frac{c_j^2}{2\gamma_j}$, with $\gamma_T \geq \gamma_F > 0$.

This assumption states that fintech lenders have a higher cost of collateral underwriting, due to their incentive of faster application process. Since the main incentive for fintech lender is the speed in application processing times, it is reasonable to assume that the cost of tangible collateral underwriting, which is often less amenable to automation, will be higher compared to the traditional lender that can do the same job but at a longer time frame. Moreover, fintech's business model, which emphasizes on streamlining the lending process, does not have the operational capacity and the legal manpower required for underwriting collateral, especially if the collateral is highly specialized. Finally, fintech lenders, being distant online lenders, do not have local branches that could examine and monitor the quality of a tangible collateral such as real estate. In contrast, banks have a legacy system of collateral management and an army of legal advisors so the incremental overhead for any additional collateral pledged to the banks is marginal. Finally, with the mortar and bricks branches, banks have local representatives who are able to examine the quality of the collateral more easily.[11]

The following Proposition states the equilibrium collateral requirements.

Proposition 3 *The equilibrium collateral requirements are*

$$c_F^* = \theta(1-\mu_S)\gamma_F q_T^S(1-q_F^S) \textit{ and } c_T^* = (1-\theta)(1-\mu_L)\gamma_T q_F^L(1-q_T^L). \tag{4.9}$$

[10] We can relax this assumption by allowing for c_j^i, i.e., the collateral requirement of lender j, be a function of loan maturity i. The main results would not be affected because, given the Bertrand nature of competition, each lender earns its rents only from one borrower segment that is, the F lender from segment S and the T lender from segment L. Hence, lender F would set $c_F^L = 0$ and lender T would set $c_T^S = 0$, since there is no need to incur the cost and ask for a collateral in the segment where the profits are zero. Thus, the profit functions (4.5) and (4.8) would be affected but the equilibrium c_F^S and c_T^L would be the same as the values given in (4.9).

[11] For example, in real estate, we argue that a bank is more likely to have access to a developer's information about the construction's quality that are hard for buyers and online lenders to observe (see also Stroebel (2016) for a similar argument about vertically integrated lenders). Moreover by guiding a buyer through the home purchase process a bank branch might also acquire relevant information about buyer's characteristics such as their propensity to maintain the property.

The collateral requirement of lender j depends on: i) the cost of lender j of underwriting the collateral, as captured by the parameter γ_j and ii) the likelihood of lender j's winner's curse, $(1-\mu_i)q^i_{-j}(1-q^i_j)$, in the segment in which it earns its rents.

The collateral mitigates lender j's loss due to the winner's curse. The loss occurs when lender j receives a good signal and the rival lender receives a bad signal about the borrower's creditworthiness, which implies that the borrower will default. The more accurate lender j's signal is the lower the need for a collateral, because the lender trusts more its good signal and hence the likelihood of a winner's curse decreases. On the other hand, a more accurate signal of the rival lender $-j$ increases lender j's collateral value, because it increases the likelihood of a winner's curse. As a result, when q^i_j and q^i_{-j}, are more balanced the need for a collateral increases. This is because the entropy regarding the winner's curse increases. The winner's curse and hence the collateral requirements also depend on the risk of each segment of borrowers as this is captured by the fraction of bad borrowers $1-\mu_i$. Finally, the size of the borrower group with short-term projects, θ, also affects the collateral requirements.

Corollary 7 *The relationship between equilibrium collateral requirements and the screening ability of lenders is described as follows:*

- *Collateral requirements and screening ability of a lender are substitutes. A higher screening ability implies a lower collateral.*
- *A higher screening ability of a lender j induces the rival lender to increase its collateral requirements.*

Moreover, Assumption 1 can imply that $c^*_F < c^*_T$. To see this suppose $q^S_F = 1$, while all other three signal accuracies are strictly less than one and are chosen so that Assumptions 1 and 4 are satisfied. Then $c^*_F = 0$ and $c^*_T = (1-\mu_L)q^L_F\gamma_T(1-q^L_T) > 0$. Therefore, the T lender chooses a higher collateral requirement than the F lender even when both face the same cost collateral underwriting, i.e. $\gamma_T = \gamma_F$. The difference is driven by the differential screening ability of the two lenders both for the S and the L borrowers.

Example 3 *Suppose $\mu_S = \mu_L = 0.7$, $q^S_F = 1$, $q^S_T = 0.8$, $q^L_F = q^L_T = 0.7$ and $\gamma_F = \gamma_T = 1$. The equilibrium collaterals are $c^*_F = 0$ and $c^*_T = 0.063$. The equilibrium net profits are $\Pi_F = 0.056$ and $\Pi_T = 0.002$. The bounds in Assumption 4 are 0 and 1. Lender T cannot overturn lender F in the S segment for any*

$c_T \leq 1$, because even if it sets $c_T = 1$ we have $\frac{1-c_T}{1-c_F^*} = 1 - c_T \leq 1$. But lender F can overturn lender T in the L segment by setting $c_F = c_T^* = 0.063$ or higher. The net profits of F from the L segment if it sets $c_F \geq 0.063 = c_T^*$, is negative and decreasing. Hence, such a deviation is unprofitable.

5 Conclusion

We develop an equilibrium model in which banks and fintechs coexist and cater to different types of borrowers. Specifically, with superior screening ability, fintechs are more likely to attract entrepreneurs with short term financing needs and no collateral. In contrast, with lower collateral underwriting costs, banks are more likely to provide asset-backed loans to entrepreneurs with longer term projects. Our theory is consistent with a number of stylized facts about bank and fintech's financing. It also offers an interpretation on the recent preponderance of unsecured lending.

Our theoretical model can be extended in three important dimensions offering some opportunities for future research. First, the presented model does not consider the role of relationship lending which is likely to interact with both the screening ability and the collateral requirements. Related to the first, the second extension is to consider borrowers with multiple lenders and with different project horizons. Finally, the third extension would be to introduce a role for regulation. By this term, we do not refer solely to liquidity or capital requirements but also to data-related regulation. For example, the emerging paradigm of open banking where borrowers own their data and the proliferation of data-protection laws like GDPR, which limits the screening ability by limiting the data availability, could have a profound impact on the competition in credit markets in general and on the data vs collateral quandary in particular. We hope that our theoretical model's findings pave the way for more research in these important questions.

References

Avramidis, P., N. Mylonopoulos, and G. G. Pennacchi (2021). The role of marketplace lending in credit markets: Evidence from bank mergers. *Management Science*.

Beaumont, P., H. Tang, and E. Vansteenberghe (2021). The role of fintech in small business lending. Technical report, Working paper.

Benmelech, E., N. Kumar, and R. Rajan (2020). The decline of secured debt. Technical report, National Bureau of Economic Research.

Berg, T., A. Fuster, and M. Puri (2021). Fintech lending. Technical report, National Bureau of Economic Research.

Broecker, T. (1990). Credit-worthiness tests and interbank competition. *Econometrica*, 429–452.

Buchak, G., G. Matvos, T. Piskorski, and A. Seru (2018). Fintech, regulatory arbitrage, and the rise of shadow banks. *Journal of Financial Economics 130*(3), 453–483.

Cornelli, G. et al. (2020). Fintech and big tech credit: a new database.

Donaldson, J. R., G. Piacentino, and A. Thakor (2021). Intermediation variety. *The Journal of Finance 76*(6), 3103–3152.

Fed.Reserve (2019). Small business credit survey. Technical report, Federal Reserve.

Fuster, A., M. Plosser, P. Schnabl, and J. Vickery (2019). The role of technology in mortgage lending. *The Review of Financial Studies 32*(5), 1854–1899.

Gambacorta, L., Y. Huang, Z. Li, H. Qiu, and S. Chen (2020). Data vs collateral.

Gopal, M. and P. Schnabl (2020). The rise of finance companies and fintech lenders in small business lending. *NYU Stern School of Business*.

Hauswald, R. and R. Marquez (2003). Information technology and financial services competition. *The Review of Financial Studies 16*(3), 921–948.

He, Z., J. Huang, and J. Zhou (2020). Open banking: Credit market competition when borrowers own the data. Technical report, National Bureau of Economic Research.

Holmstrom, B. and J. Tirole (1997). Financial intermediation, loanable funds, and the real sector. *the Quarterly Journal of economics 112*(3), 663–691.

Inderst, R. and H. M. Mueller (2007). A lender-based theory of collateral. *Journal of Financial Economics 84*(3), 826–859.

Ivashina, V., L. Laeven, and E. Moral-Benito (2020). Loan types and the bank lending channel. Technical report, National Bureau of Economic Research.

Jimenez, G., V. Salas, and J. Saurina (2006). Determinants of collateral. *Journal of Financial Economics 81*(2), 255–281.

Johnson, J. P. and D. P. Myatt (2006). On the simple economics of advertising, marketing, and product design. *American Economic Review 96*(3), 756–784.

Lian, C. and Y. Ma (2021). Anatomy of corporate borrowing constraints. *The Quarterly Journal of Economics 136*(1), 229–291.

Manove, M., A. J. Padilla, and M. Pagano (2001). Collateral versus project screening: A model of lazy banks. *Rand Journal of Economics*, 726–744.

Stroebel, J. (2016). Asymmetric information about collateral values. *The Journal of Finance 71*(3), 1071–1112.

Tang, H. (2019). Peer-to-peer lenders versus banks: substitutes or complements? *The Review of Financial Studies 32*(5), 1900–1938.

Thakor, A. V. (2020). Fintech and banking: What do we know? *Journal of Financial Intermediation 41*, 100833.

Vives, X. (2019). Digital disruption in banking. *Annual Review of Financial Economics 11*, 243–272.

Ziegler, T. et al. (2021). The global alternative finance market benchmarking report. *The Global Alternative Finance Market Benchmarking Report (January 22, 2021)*.

A Appendix: Detailed Proofs

A.1 Proof of Lemma 1

Suppose first that, in equilibrium, $\pi_F^S > 0$ and $\pi_T^S > 0$. Then, both lenders will make an offer with probability one when they receive a good signal, $m_T^S = 1$ and $m_F^S = 1$. From the two lenders' indifference conditions, (3.7) and (3.8), we can see that as $r_F^S \uparrow \overline{r}^S$ and $r_T^S \uparrow \overline{r}^S - z_{gg}^S c$ at least one of $1 - Z_T^i(r)$ and $1 - Z_F^i(r)$ must be zero, since it is not possible that both distributions have a mass point at the upper bounds of their supports. If that was the case, then one lender could profitably deviate by lowering marginally its interest rate. But if at least one probability is zero, then at least one lender must be making negative profits, a contradiction.

Suppose next that $\pi_T^S \geq \pi_F^S = 0$. Then at $r_F^S = \underline{r}^S$ and $r_T^S = \underline{r}^S + z_{gg}^S c$, we must have $1 - Z_T^i(r_F^S) = 1$ and $1 - Z_F^i(r_T^S) = 1$. But then to make both indifference conditions hold we need $p_{bg}^S(1-c) < p_{gb}^S$, which contradicts Assumption 2. Hence, the only remaining possibility is $\pi_F^S > \pi_T^S = 0$.

Following similar steps, we can show that for the L borrowers $\pi_T^L > \pi_F^L = 0$.

A.2 Proof of Proposition 1

The upper bound of the support distribution of the F lender is $\overline{r}_F^S = \overline{r}^S$ and of the T lender is $\overline{r}_T^S = \overline{r}^S - z_{gg}^S c$. We set $\phi^S(\underline{r}) = 1$ and we solve for $\underline{r} = \frac{(1-q_T^S)(1-q_F^S c)}{\tau^S}$. This will be the lower bound of the support of T's interest rate distribution. The lowest interest rate for F must be the T's lowest rate plus the cost of collateral, i.e., $\underline{r}_F^S = \frac{(1-q_T^S)(1-q_F^S c)}{\tau^S} + z_{gg}^S c = \frac{(1-q_T^S)[1-c(2q_F^S-1)]}{\tau^S}$. Hence, the distribution of r_F^S is $\phi^S(\underline{r}_F^S) - \phi^S(r_F^S)$. Note that $\underline{r}_F^S$ becomes $\frac{1-q_T^S}{\tau^S}$ when $c = 0$. Moreover, it can be easily verified that $\frac{d\underline{r}_F^S}{dc} < 0$. (2.1) then implies that $\overline{r}^S > \underline{r}_F^S$. Because $\phi^S(\underline{r}_F^S) < 1$ and $\phi^S(r) > 0$ is decreasing in r, we have $\phi^S(\underline{r}_F^S) - \phi^S(\overline{r}^S) < 1$. Thus, the distribution of F's interest rate has a mass point at $\overline{r}^S$ of size $1 - [\phi^S(\underline{r}_F^S) - \phi^S(\overline{r}^S)]$. By setting $r = \underline{r}^S$ in (3.7) and (3.8), taking the difference in expected profits $\pi_F^S - \pi_T^S$, and setting $\pi_T^S = 0$ we obtain $\pi_F^S = p_{bg}^S(1-c) - p_{gb}^S = (1-\mu_S)[(q_F^S - q_T^S) - c q_F^S(1-q_T^S)] > 0$, due to Assumption 2. By setting $r = \overline{r}_T^S = \overline{r}^S - z_{gg}^S c$ in (3.7), using $\pi_F^S = p_{bg}^S(1-c) - p_{gb}^S$, we solve for m_T^S to obtain $m_T^S =$

$1-\frac{p_{bg}^S(1-c)}{p_{gg}^S\left((1+\overline{r}^S-z_{gg}^S c)\nu_{gg}^S-1\right)}=1-\phi^S(\overline{r}^S-z_{gg}^S c)$. Next, the distribution of T is obtained from (3.7) and is given by

$$Z_T^S(r)=1-\frac{\phi^S(r)-\phi^S(\overline{r}^S-z_{gg}^S c)}{1-\phi^S(\overline{r}^S-z_{gg}^S c)}=\frac{1-\phi^S(r)}{1-\phi^S(\overline{r}^S-z_{gg}^S c)}.$$

Finally, $\underline{r}_T^S=\frac{(1-q_T^S)(1-q_F^S c)}{\tau^S}$.

A.3 Proof of Corollary 1

1. We differentiate m_T^S with respect to c. This yields

$$\frac{dm_T^S}{dc}=\frac{((-2q_F^S+2)q_T^S+\overline{r}^S\tau^S+2q_F^S-2)(1-q_T^S)q_F^S}{((-1+q_F^S)(c+1)q_T^S-(1+c)q_F^S-r\tau^S+c+1)^2}.$$

   The above derivative is positive if and only if $\overline{r}^S>\frac{2(1-q_T^S)(1-q_F^S)}{\tau^S}$, which is satisfied given (2.1) and the fact that $2(1-q_j^S)<1$.

   First, note that the support of the distribution of T shifts to the left as c increases. Given that the distribution approaches 1 continuously as the interest rate approaches the upper bound and the cdf is concave, it follows that the cdf shifts to the left as c increases.

2. Note that $\underline{r}_F^S$ decreases as c increases, while $\overline{r}_F^S$ does not change. Then, we differentiate the mass point $1-[\phi^S(\underline{r}_F^S)-\phi^S(\overline{r}^S)]$ with respect to c. The derivative is positive if and only if

$$c>\frac{\sqrt{(1-q_T^S)(1-q_F^S)((1-q_T^S)q_F^S+\overline{r}^S\tau^S+q_T^S-1)}+q_F^S(-1+q_T^S)}{(1-q_T^S)(1-2q_F^S)}. \tag{A.1}$$

   If (A.1) is satisfied then F's cdf rotates clockwise as c increases. This is because the mass point is higher the higher the c, which implies that in such a case the cdf attains a lower value as r approaches the upper bound, which in turn suggests that the cdfs must cross. If (A.1) is not satisfied, then the cdf of F shifts to the left as c increases.

3. Easy to see using the expected profits functions.

A.4 Proof of Corollary 2

1. The derivative of m_T^S is given below

$$\frac{dm_T^S}{dq_T^S} = \frac{q_F^S \overline{r}^S \tau^S (1-c)}{((-1+q_T^S)(c+1)q_F^S + c(1-q_T^S) - \overline{r}^S\tau^S - q_T^S + 1)^2} > 0.$$

The lower bound of the distribution of F decreases when q_T^S increases, but the upper bound is not affected. Moreover, the derivative of the mass point of the distribution of F with respect to q_T^S is $\frac{(-1+c)q_F^S\overline{r}^S\tau^S}{((1-q_T^S)q_F^S+\overline{r}^s\tau^S+q_T^S-1)^2} < 0$. These imply that the cdf of F shifts to the left when q_T^S increases. The lower bound of the T's support decreases, while the upper bound increases, when q_T^S increases. Given that the shape of the cdf is not affected, then it follows that the cdf with a higher q_T^S rotates clockwise and crosses the one with a lower q_F^S once.

2. The derivative of m_T^S with respect to q_F^S is given below

$$\frac{dm_T^S}{dq_F^S} = \frac{(1-q_T^S)((1+c)(1-q_T^S) - \overline{r}^S\tau^S)(1-c)}{((-1+q_F^S)(c+1)q_T^S + (1-q_F^S)c - \overline{r}^S\tau^S - q_F^S + 1)^2} > 0$$

if and only if

$$c > \frac{\overline{r}^S\tau^S}{1-q_T^S} - 1. \tag{A.2}$$

The lower bound of the F's support $\underline{r}_F^S$ decreases with q_F^S. If the mass point at $\overline{r}^S$ decreases, then the cdf with a higher q_F^S is first order stochastically dominated by the one with the lower q_F^S. We differentiate the mass point of the distribution of F with respect to q_F^S. The derivative is negative if and only if

$$c > \frac{(3(q_F^S)^2-1)(q_T^S)^2 + ((4(q_F^S)^2-2)\overline{r}^S\tau^S - 6(q_F^S)^2+2)q_T^S - (\overline{r}^S)^2\tau^2 + (-4(q_F^S)^2+2)\overline{r}^S\tau^S + 3(q_F^S)^2 + \sqrt{A} - 1}{8(\overline{r}^S\tau^S + q_T^S - 1)(-1+q_T^S)(q_F^S-1/2)^2} \tag{A.3}$$

where $A \equiv ((1-q_T^S)q_F^S + \overline{r}^S\tau^S + q_T^S - 1)^2(8(1-q_T^S)(\overline{r}^S\tau^S + 7q_T^S/8 - 7/8)(q_F^S)^2 + 2(-1+q_T^S)(\overline{r}^S\tau^S + q_T^S - 1)q_F^S + (\overline{r}^S\tau^S + q_T^S - 1)^2)$. If (A.3) does not hold, then the cdf, as q_F^S increases, rotates clockwise. The lower bound of the T's support decreases, while the upper bound increases, when q_F^S increases. Given that the shape of the cdf is not affected, then it follows that the cdf with a higher q_F^S rotates clockwise and crosses the one with a lower q_F^S once.

3. The derivative of π_F^S with respect to q_F^S is $(1-\mu_S)(1-c(1-q_F^S)) > 0$. The higher the c the smaller the increase. An analogous result holds when q_T^S changes.

A.5 Proof of Proposition 2

The proof is very similar to the proof of Proposition 1, with the difference being that the 'strong' lender is now lender T, instead of F. The T lender's distribution is $1-\phi^L(r)$, where $\phi^L(r)$ is given by (3.12). We set $\phi^L(\underline{r}^L) = 1$ and we solve for $\underline{r}^L = \frac{1-q_F^L}{\tau^L}$. This is the lower bound of T lender's distribution. The profit of T is calculated as follows. By setting $r = \underline{r}^L$ in (3.7) and (3.8), taking the difference in expected profits $\pi_T^L - \pi_F^L$, and setting $\pi_F^L = 0$ we obtain $\pi_T^L = p_{gb}^L - p_{bg}^L(1-c) = (1-\mu_L)[-\Delta q^L + q_F^L(1-q_T^L)c] > 0$, due to Assumption 3. The rest is similar to the proof of Proposition 1.

A.6 Proof of Corollary 3

1. We differentiate m_L^F with respect to c. This yields

$$\frac{dm_F^L}{dc} = -\frac{q_T^L(1-q_T^L)}{((c-1)q_T^L - c)^2} < 0.$$

   The lower bound of F's support $\underline{r}_F^L$ increases with c while the upper bound $\overline{r}^L$ does not change. Moreover, the cdf approaches continuously 1 as r approaches the upper bound and the shape of the cdf is not affected by c. Hence, the cdf must shift to the right.

2. As c increases, $\overline{r}_T^L$ decreases. This implies that the mass point $\phi^L(\overline{r}_T^L)$ increases. Given that the lower bound of the support of T's cdf does not change while the upper bound decreases and the mass point increases, the cdf must shift to the right as c increases.

3. Easy to see using the expected profits.

A.7 Proof of Corollary 4

1. The derivative of m_F^L with respect to q_T^L is positive if and only if

$$c > \frac{((q_T^L)^2-1)(q_F^L)^2+2(q_T^L-1)(q_T^L+1)(\overline{r}^L\tau^L-1)q_F^L-(\overline{r}^L)^2(\tau^L)^2+(-2(q_T^L)^2+2)\overline{r}^L\tau^L+(q_T^L)^2+\sqrt{B}-1}{2(q_T^L-1)^2(-1+q_F^L)(\overline{r}^L\tau^L+q_F^L-1)}, \tag{A.4}$$

where $B \equiv (-4(\tau^L\overline{r}^L+3q_F^L/4-3/4)(-1+q_F^L)(q_T^L)^2+2(-1+q_F^L)(\overline{r}^L\tau^L+q_F^L-1)q_T^L+(\overline{r}^L\tau^L+q_F^L-1)^2)((1-q_F^L)q_T^L+\tau^L\overline{r}^L+q_F^L-1)^2$.

The lower bound of T's distribution is not a function of q_T^L, while the upper bound is an increasing function. The derivative of the mass point of T's distribution with respect to q_T^L is

$$\frac{(1+q_F^L)((c+1)q_F^L+\tau^L\overline{r}^L-c-1)}{((q_T^L-1)(c+1)q_F^L+(1-q_T^L)c-\tau^L\overline{r}^L-q_T^L+1)^2}. \tag{A.5}$$

The above is positive if and only if $c < \frac{\overline{r}^L\tau^L+q_F^L-1}{1-q_F^L}$. This is always satisfied given (2.1). Hence, as q_T^L increases, the cdf of T shifts to the right.

The lower bound of the F's support $\underline{r}_F^L$ decreases with q_T^L, while the upper bound is fixed. Since the cdf approaches 1 continuously as r approaches the upper bound and the shape is concave it implies that the cdf shits to the left.

2. The derivative of m_F^L with respect to q_F^L is

$$\frac{dm_F^L}{dq_F^L} = \frac{\overline{r}^L q_T^L \tau^L}{((1-q_F^L)q_T^L+\tau^L\overline{r}^L+q_F^L-1)^2} > 0.$$

The lower bound of the F's support $\underline{r}_F^L$ decreases with q_F^L, while the upper bound is fixed. Since the cdf approaches 1 continuously as r approaches the upper bound and the shape is concave it implies that the cdf shits to the left. The lower bound of the T's support decreases, while the upper bound increases, when q_F^L increases. The derivative of the mass point of T's distribution with respect to q_F^L is

$$-\frac{\overline{r}^L\tau^L q_T^L}{((-1+q_F^L)(c+1)q_T^L-(c+1)q_F^L-\tau^L\overline{r}^L+c+1)^2} < 0. \tag{A.6}$$

Given that the shape of the cdf is not affected by q_F^L and is concave, it implies that the cdf shifts to the left.

3. Easy to see using the expected profits.

A.8 Proof of Proposition 3

We use (4.5) and (4.8) to derive lender F's and T's aggregate profit functions Π_F and Π_T, respectively. We differentiate them with respect to c_F and c_T, respectively. The solutions are given by (4.9). First, the equilibrium must satisfy Assumption 4. Second, no lender should find a deviation profitable. The first-order conditions ensure that no lender has an incentive to deviate locally. We would have to ensure that there are no incentives for a global deviation. By global we mean that a lender increases its collateral so much so that Assumption 4 is violated and the lender dominates both segments of the market. We do not provide explicit conditions that make a global deviation unprofitable as they would not add anything to the understanding of our problem. We do check whether these conditions are satisfied in the numerical Example 3.