

Securitization and Lending Competition

DAVID M. FRANKEL

Iowa State University

and

YU JIN

Shanghai University of Finance and Economics

First version received November 2011; final version accepted January 2015 (Eds.)

We study the effects of securitization on interbank lending competition. An applicant's observable features are seen by a remote bank, while her true credit quality is known only to a local bank. Without securitization, the remote bank does not compete because of a winner's curse. With securitization, in contrast, ignorance is bliss: the less a bank knows about its loans, the less of a lemons problem it faces in selling them. This enables the remote bank to compete successfully in the lending market. Consistent with the empirical evidence, remote and securitized loans default more than observationally equivalent local and unsecuritized loans, respectively.

Key words: Banks, Securitization, Mortgage backed securities, Remote lending, Internet lending, Distance lending, Lending competition, Asymmetric information, Signalling, Screening, Adverse selection, Lemons problem, Residential mortgages, Default Risk

JEL Codes: D82, G14, G21

1. INTRODUCTION

Securitization of conventional home mortgages began in 1970 with the founding of the Federal Home Loan Mortgage Corporation.¹ The proportion of mortgages held in market-based instruments rose steadily from 20% in 1980 to 68% in 2008.² Earlier evidence indicates that securitization rose from 1975 to 1980 as well (Jaffee and Rosen, 1990, Table 2).

Remote lending has also grown. Petersen and Rajan (2002, Figures I and II) find an upward trend in distances between small firms and their lenders that began in about 1978 or 1979 and continued through the end of their data in 1992. The mean borrower–lender distance in a sample of small business loans studied by De Young *et al.* (2008, pp. 125–126) rose from 5.9 miles in 1984 to 21.5 miles in 2001. Remote lending of residential mortgages also rose from 1992 to 2007 (Loutskina and Strahan, 2011, p. 1477).

We show that securitization can lead to remote lending even when remote banks have an informational disadvantage vis-a-vis local banks. We assume that an applicant's soft information

1. A detailed history of securitization appears in Hill (1996).

2. The source is unpublished data underlying Figure 3 in Shin (2009).

is known only to a local bank while her hard information is known also to a remote bank. Without securitization, any profitable loan offer of the remote bank would be outbid by the local bank.³ Anticipating this, the remote bank cedes the entire market to the local bank. Under securitization, the remote bank's ignorance has an advantage: investors will not suspect it of choosing only its bad loans to sell.⁴ This enables the remote bank to compete successfully for applicants with strong enough observables.

Our model yields several empirical predictions that are confirmed by recent research. Securitization stimulates lending in general and remote lending in particular. Securitized loans have higher conditional default rates than unsecuritized loans. Remote lenders securitize a higher proportion of their loans. Remote borrowers have stronger observables than local borrowers and pay lower interest rates, but have higher conditional default rates.

Without securitization, lending is limited as the local bank cannot sell its loans. By lifting this limitation, securitization expands lending, which raises welfare. But it also encourages entry by the remote bank, which makes worse lending decisions as it lacks soft information. Despite this, securitization cannot lower welfare. Moreover, securitization raises welfare if, with securitization, either bank lends.

An intuition is as follows. The remote bank cannot be harmed by securitization as it can always choose not to lend. In practice, it ensures positive profits by lending only to agents with strong observables, thus ensuring that its proportion of low-quality borrowers will be small. Hence, securitization helps the remote bank when it lends and does not harm it otherwise.

As for the local bank and the agents, securitization affects them in two ways. It lowers the interest rate the local bank can charge because of competition from the remote bank. This is a pure transfer with no welfare effects. It also allows the local bank to resell some of its loans. This cannot harm the local bank, which can always choose not to securitize. We show, moreover, that the local bank will profitably securitize a portion of its portfolio if, under securitization, it lends at all. Finally, investors are assumed to be fully rational and competitive, so their payoffs are identically zero: they are unaffected by securitization. This completes the intuition.

Our finding that securitization does not harm investors conflicts with the popular narrative in which securitization enabled sophisticated finance professionals to profit by foisting toxic securities on unsuspecting, naive security buyers.⁵ However, the available scientific evidence does not support this narrative. Cheng *et al.* (2014) find that midlevel managers in securitized finance systematically overinvested in their own private housing in the years leading up to the crash. Ma (2014) finds that the chief executive officers of banks that lent more aggressively during the boom had a greater tendency to increase their own holdings of their banks' stock which, during the subsequent crash, fell more than the stock of less aggressive lenders.

The evidence for optimism among securitizers and lenders has two possible interpretations. First, it may be that beliefs were correct on average and the crash resulted from an unusually bad shock. In our model, a bad shock will lead many projects to fail. Investors who bought the banks' securities will lose money. Banks will be harmed by low prices for their loans and by poorly performing loans that remain on their books. In this way, the widespread losses experienced

3. This phenomenon was first studied theoretically by Hauswald and Marquez (2006), Rajan (1992), and Sharpe (1990). They show that if banks must hold their loans to maturity, then banks with superior information (or, in Hauswald and Marquez 2006, a lower cost of gathering information) about loan applicants will have a competitive advantage in lending because of a winner's curse.

4. In a prior empirical paper, Loutskina and Strahan (2011) suggest that banks may have an incentive to lend remotely in order to avoid private information at the time of securitization. They do not model this phenomenon theoretically.

5. The evidence for this consists mainly of selected emails from before the crash, as well as testimony from afterwards (e.g. Financial Crisis Inquiry Commission, 2011, pp. 3–24.)

during the 2008–9 crash are consistent with correct *ex ante* beliefs combined with an unusually bad shock.

A second — and perhaps more likely — interpretation is that there was a housing bubble in the early 2000s that led to unrealistic expectations of continued house price appreciation among market participants.⁶ Our model is consistent with this theory if we assume that the players' prior beliefs are incorrect. Our results then imply that securitization raised expected social welfare under these incorrect beliefs. It may well have lowered welfare under correct beliefs. Unfortunately, it is not clear how to distinguish between the bursting of a bubble and a particularly bad shock.

This article contributes to the literature on security issuance under asymmetric information. In Leland and Pyle (1977), an issuer sells a security to a continuum of risk-neutral, uninformed investors. Before choosing how much to sell, the issuer sees private information about her security's value. In equilibrium, she varies the amount that she sells in order to signal her information to investors. This is very costly for her, as in equilibrium she must sell less of her security precisely when the gains from trade are higher.⁷ DeMarzo and Duffie (1999) show that these costs give an issuer an incentive to design a security whose payout is insensitive to her private information.⁸

A central insight of our article is that an issuer can accomplish the same goal by acquiring assets about which she has little private information. In particular, a bank may lend to a remote loan applicant about whom it knows only hard information such as the credit score and loan-to-value ratio. Since the bank lacks soft information, it can securitize this loan without costly signalling. This gives remote banks an advantage over local banks that can more than offset the remote banks' poorer screening ability at the lending stage.

In our base model, banks issue equity securities. We also consider an extension in which each bank instead designs a monotone security that is secured by its loans. The local bank can lessen its lemons problem by choosing standard debt, which is less informationally sensitive than equity. In contrast, security design does not help the remote bank, which does not face a lemons problem. By selectively helping the local bank, security design lessens the extent of remote lending but does not eliminate it.

The rest of the article is as follows. Our main model is presented in section 2. Section 3 analyses a base case without securitization; the full model is solved in section 4. Section 5 studies the welfare effects of securitization, while section 6 discusses the model's empirical implications. Three extensions are studied in section 7. Concluding comments appear in section 8.

2. THE MAIN MODEL

There is a single region that contains a unit measure of agents. Each agent is endowed with a project that requires one unit of capital and pays a fixed gross return of $\rho > 1$ if it succeeds and zero otherwise. An agent has no capital of her own, so in order to implement her project she must borrow a unit of capital from a bank. There are two banks: a local bank L and a remote bank R .⁹

6. In particular, the house price return forecasts in some analysts' reports in 2005 and 2006 were much higher than the long-run historical average, although they were in line with the lofty experience of the prior few years (Foote *et al.*, 2012, p. 18). Similarly, homebuyers' expectations of long-run house price appreciation were unusually high, relative to mortgage rates, at the height of the boom, and have fallen sharply since then (Case *et al.*, 2012).

7. Similarly, Myers and Majluf (1984) show that the lemons problem can prevent a privately informed firm from raising a fixed amount of capital to fund a worthwhile project.

8. This incentive exists also when it is the security buyers who have market power (Biais and Mariotti 2005) or private information about the security's value (Axelson, 2007; Dang *et al.*, 2013), and when the amount of capital to be raised is fixed (Myers and Majluf, 1984; Nachman and Noe, 1994).

9. The case of multiple local and remote banks is studied in section 7.3.

There is also a continuum of uninformed, deep-pocket investors. All participants are risk-neutral and fully rational.

There are three periods. Lending competition occurs in period 1. First, the remote bank publicly announces whether it is willing to lend to the agents and, if so, at what gross interest rate r . We assume r is not higher than the gross project return ρ , since an agent cannot pay more than ρ . If the remote bank declines to lend, we let r equal the gross project return ρ . With this convention, r is now the maximum interest rate that the agents are willing to pay the local bank. For each agent, the local bank can then announce an offer of its own. If it does so, it will offer the agent's willingness to pay r and the agent will agree. The measure of loans made by each bank is commonly observed.¹⁰

The success probability of an agent's project is the product of two independent random variables: the agent's idiosyncratic type θ and a common, region-specific macroeconomic shock ζ , both of which lie in $(0, 1)$. Project outcomes, conditional on these success probabilities, are mutually independent.¹¹ The unconditional mean of ζ is denoted $\bar{\zeta}$. While the shock ζ is realized in period 3, a signal of it will be seen by the local bank in period 2.

An agent's type θ is seen only by the local bank. It represents soft information about the agent's creditworthiness and project quality. The remote bank and investors see only the agents' hard information, which is summarized by a common parameter $\bar{\theta} \in (0, 1)$ that we call the agents' *credit score*. We treat the credit score $\bar{\theta}$ as an exogenous parameter to be varied. One interpretation is that $\bar{\theta}$ is the realization of a random variable, and that our analysis is contingent on this realization.¹²

Conditional on the credit score $\bar{\theta}$, the agents' types θ have a commonly known, increasing distribution function $G_{\bar{\theta}}$, which has a continuous density and support equal to $[0, 1]$. Higher credit scores $\bar{\theta}$ are good news about the agents' types, in the following sense.

Increasing Conditional Expectation (ICE). The expectation $E_{\bar{\theta}}[\theta | \theta \leq c]$ of θ conditional on $\theta \leq c$ is increasing in the credit score $\bar{\theta}$ for any constant $c > 0$. As $\bar{\theta}$ goes to zero and one, this expectation converges to zero and c , respectively.

By ICE, the agents' mean type $E_{\bar{\theta}}[\theta]$ is also increasing in the credit score $\bar{\theta}$.¹³ Henceforth we reparametrize the credit score, if necessary, so that it equals this mean type: $\bar{\theta} = E_{\bar{\theta}}[\theta]$. We also restrict to parameters for which the *ex ante* expected return of a random agent's project exceeds the cost of funding that project:

$$\rho \bar{\theta} \bar{\zeta} > 1. \quad (1)$$

If the local bank could be certain to sell all its loans to investors, it would not care about the types of its borrowers. To rule this out, we assume that there is an infinitesimal chance that the securitization market will be disrupted, forcing each bank to hold its loans to maturity.¹⁴ Under these beliefs, a threshold strategy must be optimal for the local bank: it will offer loans to the set of agents whose types θ exceeds some cutoff θ_1 that will, in general, depend on the agents'

10. Regulation C (enacted in 1989) of the U.S. Home Mortgage Disclosure Act requires lenders to report the amount of each mortgage loan as well as other data such as loan type (conventional loan, FHA loan, VA loan, etc.).

11. That is, a type θ agent's project succeeds with probability $\theta \zeta$ regardless of the outcomes of the other projects in the region.

12. In practice, loan applicants with different credit scores coexist. A model with this feature is studied in the working paper version of this article (Frankel and Jin, 2011). The essential results are analogous to those of the present model.

13. This follows directly from ICE with $c = 1$.

14. For instance, the crisis of 2008–9 caused such a disruption in the markets for subprime/Alt-A and jumbo mortgage loans (Keys *et al.*, 2012, Figs. 1 and 2).

willingness to pay r . Since the distribution function $G_{\bar{\theta}}$ is increasing, investors can infer the local bank's lending threshold θ_1 from the measure $1 - G_{\bar{\theta}}(\theta_1)$ of its loans which, as noted above, is commonly observed.

In period 2, the local bank sees a private signal $t \in [0, 1]$, $t \sim \Psi$ of the macroeconomic shock ζ .¹⁵ Arbitrarily low signals can occur: for any $t_0 > 0$, the probability $\Psi(t_0)$ that the signal is at most t_0 is positive. Let $\Phi(\zeta|t)$ denote the distribution of the shock conditional on the signal. We assume that Ψ and Φ are continuously differentiable in their arguments and have no atoms.¹⁶ Moreover, higher signals are good news:

First Order Stochastic Dominance (FOSD). For any $\zeta_0 \in (0, 1)$, the probability $\Phi(\zeta_0|t)$ that the shock does not exceed the cutoff ζ_0 is decreasing in the signal t .

We also assume that the expectation of the shock ζ , conditional on the signal t taking its minimum value of zero, is strictly positive: $E[\zeta|t=0] > 0$. Intuitively, even if the local bank sees the lowest signal, it cannot be sure that all projects will fail.

After the local bank sees its signal t , each bank simultaneously selects a proportion of its loans to securitize.^{17, 18} These proportions are commonly observed.¹⁹ Since the remote bank knows nothing about its borrowers' types, it must securitize each loan with the same probability $q_R \in [0, 1]$. The measure of loans that the remote bank securitizes is thus $q_R G_{\bar{\theta}}(\theta_1)$. As for the local bank, it sees the type θ of each of its loans while investors do not. Thus, it will securitize its lowest quality loans:

Proposition 1. *Suppose the local bank has two loans of types $\theta' > \theta''$. For any signal t , if the bank securitizes the type θ' loan, then it must also securitize the type θ'' loan.*

Proof Suppose not. On seeing the signal t , let the local bank now secretly securitize the type θ'' loan instead of the type θ' loan. As this deviation cannot be detected, its only effect is to lower the bank's expected payment to the holders of its security from $r\theta' E[\zeta|t]$ to $r\theta'' E[\zeta|t]$: the bank is better off. Hence, its original strategy is not optimal. \parallel

Let \hat{q}_L be the proportion of its loans that the local bank securitizes. As this proportion is commonly observed, investors can infer that the local bank has securitized the set of local loans whose types θ lie in $[\theta_1, \theta_2]$, where θ_2 is the local bank's *securitization threshold* and is given implicitly by $\hat{q}_L = \frac{G_{\bar{\theta}}(\theta_2) - G_{\bar{\theta}}(\theta_1)}{1 - G_{\bar{\theta}}(\theta_1)}$.²⁰

In period 3, the macroeconomic shock ζ is realized. Each borrower's project then succeeds with probability $\theta\zeta$ and fails with probability $1 - \theta\zeta$. If her project succeeds, an agent pays the interest rate r to the bank that financed it; her payoff is thus $\rho - r$. If her project fails or was not

15. A model with no macroeconomic signal t is discussed in section 7.1.

16. A distribution F on $[0, 1]$ is atomless if F is continuous and $F(0) = 0$.

17. We restrict here to equity securities; an extension to general monotone securities appears in section 7.2.

18. The assumption of simultaneous securitization is without loss of generality. Why? In equilibrium, the remote bank will realize its full gains from trade with investors. This is its theoretical maximum securitization profit. Hence, it cannot benefit from delay. Moreover, the issuance choice of the remote bank is uninformative and thus does not affect the outcome of the signalling game played between the local bank and investors. Thus, delaying would not help the local bank either.

19. Under the SEC's Regulation AB (enacted in 2005), issuers of mortgage backed securities are required to report a "mortgage loan schedule" that lists, for each loan, information such as the loan amount, interest rate, loan-to-value ratio, loan purpose, and property type (Wang, 2009, p. 47).

20. This equation has a unique solution as $G_{\bar{\theta}}(\theta_2)$ is increasing in θ_2 . (As previously noted, investors can infer the local bank's lending threshold θ_1 from the measure of its loans.)

funded, she pays nothing and her payoff is zero. By the law of large numbers, if the remote bank lent in period 1, then in period 3 it receives aggregate loan repayments of

$$Y_R = \int_{\theta=0}^{\theta_1} [r\theta\zeta] dG_{\bar{\theta}}(\theta) \quad (2)$$

from its borrowers and pays $q_R Y_R$ to its security holders. As for the local bank, in period 3 it receives aggregate loan repayments of

$$Y_L = \int_{\theta=\theta_1}^1 [r\theta\zeta] dG_{\bar{\theta}}(\theta) \quad (3)$$

from its borrowers and pays $\int_{\theta=\theta_1}^{\theta_2} [r\theta\zeta] dG_{\bar{\theta}}(\theta)$ to its security holders. The latter quantity can be written as $q_L Y_L$ where

$$q_L = \frac{\int_{\theta=\theta_1}^{\theta_2} \theta dG_{\bar{\theta}}(\theta)}{\int_{\theta=\theta_1}^1 \theta dG_{\bar{\theta}}(\theta)} \in [0, 1] \quad (4)$$

is the proportion of its aggregate loan repayments that the local bank must pay to investors. Since there is an increasing, one to one relationship between the securitization threshold θ_2 and the quantity q_L , we may assume that the local bank chooses q_L rather than θ_2 .

Of the two quantity choices q_R and q_L , only the latter can convey information about the local bank's signal t . Let

$$p_i(q_L) = E[Y_i | q_L] \quad (5)$$

denote investors' posterior expected value of the loan portfolio of bank $i = R, L$ given the quantity q_L .²¹ Since they are competitive and risk-neutral, investors pay bank i a total of $E[q_i Y_i | q_L] = q_i p_i(q_L)$ for its security.

We now specify the payoffs of the banks and investors. While periods 1 and 2 occur at the same point of real time, there is a unit of delay between periods 2 and 3. The banks are liquidity constrained: the discount factor of investors, which we normalize to one, exceeds the discount factor of the banks, which is denoted $\delta \in (0, 1)$. This assumption, common in the prior literature, is thought to capture the typical reason cited that banks sell loans: the availability of attractive alternative investments together with the existence of regulatory capital ratios (e.g. Gorton and Haubrich, 1990).

Both banks have the same unitary cost of capital. A bank's cost of lent funds is thus the measure of its loans: $C_L = 1 - G_{\bar{\theta}}(\theta_1)$ for the local bank and $C_R = G_{\bar{\theta}}(\theta_1)$ for the remote bank (if it lent in period 1). Bank i 's direct lending profits are just its discounted loan repayments δY_i less its cost C_i of lent funds. Its securitization profits are the payment $q_i p_i(q_L)$ from its security buyers in period 2, less its discounted repayment $\delta q_i Y_i$ to the same buyers in period 3. Its realized payoff Π_i is the sum of these two types of profits:

$$\Pi_i = \underbrace{\delta Y_i - C_i}_{\text{direct lending profits}} + \underbrace{q_i(p_i(q_L) - \delta Y_i)}_{\text{securitization profits}}. \quad (6)$$

The payoff of bank i 's security buyers equals their payment $q_i Y_i$ from the bank in period 3 less the amount $q_i p_i(q_L)$ they pay in period 2. The joint surplus of bank i and its security buyers is thus $\delta Y_i - C_i + (1 - \delta) q_i Y_i$. It is increasing in the bank's period-3 payment $q_i Y_i$ to its security buyers as the bank discounts this payment while investors do not.

21. This pricing function is endogenous; it depends on the local bank's equilibrium issuance strategy.

3. COMPETITION WITHOUT SECURITIZATION

We first analyse a base case without securitization: each bank must hold all of its loans to maturity. If a bank lends, at an interest rate r , to an agent of type θ , its expected profit is $\delta r \theta \bar{\zeta} - 1$: the discounted interest payment δr times the *ex ante* probability $\theta \bar{\zeta}$ of project success, less the unitary cost of capital.

In the base case, only the local bank lends and it extracts the full surplus. This is due to a winner's curse. Suppose the remote bank offers r . In the absence of securitization, the two banks have common values: the profit from lending to an agent is simply her discounted expected repayment less the banks' common cost of capital. Thus, the local bank will slightly underbid the remote bank on its profitable offers and not compete for its unprofitable ones. As a result, only unprofitable agents will accept the remote bank's offer. Knowing this, the remote bank will not make any offer. But then the local bank can charge an agent the maximum possible interest rate of ρ . It will do so if and only if the resulting discounted expected repayment, $\delta \rho \theta \bar{\zeta}$, exceeds the banks' unitary cost of capital. We have proved the following result.

Theorem 1. *Without the option of securitization, only the local bank lends. The agents' payoffs are zero: the gross interest rate on each loan equals the gross project return ρ . An agent of type θ is financed if and only if her project's discounted expected gross return, $\delta \rho \theta \bar{\zeta}$, exceeds the unitary cost of capital.*

Without securitization, an agent gets a loan if and only if her discounted expected project return exceeds the banks' common cost of capital. Hence, the allocation of loans is efficient: one agent is funded while another is not if and only if the first agent's project has a higher expected return than the second's. This efficiency property will not hold with securitization: a bank may prefer not to lend to a creditworthy agent whom it knows well, since the agent's loan is harder to securitize.²²

Our conclusion that all lending is local and the loan allocation is efficient relies on our assumption that the remote bank makes the first offer, followed by the local bank. A similar order of offers is used by Dell'Ariccia *et al.* (1999) and Dell'Ariccia and Marquez (2004). Others have instead assumed simultaneous offers. They generally find that the uninformed bank plays a mixed strategy and sometimes wins, while earning zero expected profits.²³ The extension of our model to this case might be an interesting topic for future research.

4. COMPETITION WITH SECURITIZATION

We now permit securitization. Suppose first that the remote bank offers an interest rate r while the local bank makes no offers: its lending threshold θ_1 is at least one. Then all agents will accept the remote bank's offer. As there is symmetric information and positive gains from trade between the remote bank and the investors, this bank will sell all of its loans: its securitization proportion q_R will equal one. By (2) and (5), investors assign the value $p_R = E[Y_R] = r \theta \bar{\zeta}$ to the remote bank's loan portfolio. Hence, by (2) and (6), the remote bank's expected securitization profits $E[q_R(p_R - \delta Y_R)]$ equal the gains from trade, $(1 - \delta)r \theta \bar{\zeta}$: the difference in discount rates times the unconditional expected payout of the portfolio.

Now assume instead that the local bank makes some loans: its lending threshold θ_1 is less than one. Bank L 's expected securitization profit from selling the quantity q_L , conditional on its

22. A full welfare analysis appears in section 5.

23. See, in particular, Rajan (1992, pp. 1380–1381) and von Thadden (2004, pp. 17–18).

signal t , is

$$\pi_L(q_L, t) = q_L \cdot (p_L(q_L) - \delta E[Y_L|t]), \quad (7)$$

which equals the revenue it gets now, $q_L p_L(q_L)$, less its discounted expected future payment to investors, $\delta q_L E[Y_L|t]$.

Assume bank R also lends, and sells the quantity q_R . In equilibrium, bank R knows the quantity $q_L(t)$ that bank L sells as a function of the signal t . By analogy to (7), bank R 's expected securitization profits, conditional on t , are simply $q_R \cdot (p_R(q_L(t)) - \delta E[Y_R|t])$. Bank R 's expected securitization profits when it chooses q_R are just the integral of this expression over all signals t :

$$\pi_R(q_R) = \int_{t=0}^1 q_R \cdot (p_R(q_L(t)) - \delta E[Y_R|t]) d\Psi(t). \quad (8)$$

We use the following definition of equilibrium in this subgame.

Definition 1. A Bayesian Nash equilibrium of the subgame that begins in period 2, if the local bank made some loans in period 1, is a measurable quantity function $q_L(t)$ chosen by the local bank, a quantity q_R chosen by the remote bank, and a pair $p_L(q_L)$, $p_R(q_L)$ of measurable price functions chosen by investors such that:

- (1.) Best Response: $q_L(t) \in \arg \max_{q \in [0,1]} \pi_L(q, t)$ and $q_R \in \arg \max_{q \in [0,1]} \pi_R(q)$, almost surely;
 - (2.) Bayesian Updating: for $i = R, L$, $p_i(q_L(t)) = E[Y_i|q_L(t)]$ almost surely.
- The equilibrium is separating if the following condition also holds.

- (3.) Separation: $p_L(q_L(t)) = E[Y_L|t]$ almost surely.

We restrict to separating equilibria, which satisfy all three conditions. This restriction uniquely determines the banks' behaviour and profits. By (2), (8), condition 2 of Definition 1, and the law of iterative expectations, the remote bank's securitization profits are

$$\pi_R(q_R) = q_R(1 - \delta)E[Y_R] = q_R(1 - \delta) \left(\int_{\theta=0}^{\theta_1} [r\theta\bar{\zeta}] dG_{\bar{\theta}}(\theta) \right).$$

As the right-hand side is proportional to the quantity q_R , the remote bank securitizes all its loans as before: $q_R = 1$. This proves part 1 of the following result. It also implies that the remote bank's optimal securitization decision is invariant to the behaviour of the local bank, which therefore acts as a single issuer. The single issuer problem was previously analysed by DeMarzo and Duffie (1999, Proposition 2). Their results imply that the local bank issues the quantity $q_L(t) = \left(\frac{E[Y_L|t=0]}{E[Y_L|t]} \right)^{\frac{1}{1-\delta}}$ and the investors' price function is $p_L(q_L) = \frac{E[Y_L|t=0]}{(q_L)^{1-\delta}}$. Using (3) to simplify the quantity function $q_L(t)$, we obtain part 2 below. The local bank's securitization profits, which appear in part 3, follow immediately using equations (3) and (7).

Proposition 2. The subgame that begins in period 2, if the local bank lent in period 1, has a unique separating Bayesian Nash equilibrium, with the following properties.

- (1.) The remote bank securitizes all its loans in period 2: $q_R = 1$. Its expected securitization profits are

$$(1 - \delta) \left(\int_{\theta=0}^{\theta_1} [r\theta\bar{\zeta}] dG_{\bar{\theta}}(\theta) \right).$$

This equals the difference $1 - \delta$ in discount factors times the unconditional expected gross return $E[Y_R]$ of the remote bank's loans.

(2.) Conditional on its signal, the local bank sells the quantity $q_L(t) = \left(\frac{E[\zeta|t=0]}{E[\zeta|t]}\right)^{\frac{1}{1-\delta}}$. The investors' price function is given by $p_L(q_L) = \frac{E[Y_L|t=0]}{(q_L)^{1-\delta}}$.

(3.) The local bank's expected securitization profits, conditional on its signal, are

$$\pi_L(q_L(t), t) = (1 - \delta) \left(\int_{\theta=\theta_1}^1 [r\theta] dG_{\bar{\theta}}(\theta) \right) \left(\frac{E[\zeta|t=0]}{E[\zeta|t]^\delta} \right)^{\frac{1}{1-\delta}}.$$

This equals the difference $1 - \delta$ in discount factors times the value of trade $p_L q_L$ between the local bank and the investors for the given signal t .

By part 1, the remote bank always sells its entire portfolio and thus realizes its full potential gains from trade. The local bank does so only when $t = 0$: when its signal is the lowest possible (part 2). As its signal t rises, the local bank sells less in order to signal higher quality. Indeed, its quantity q_L falls so fast that its securitization profits are decreasing in t (part 3): it sells less, and profits less, precisely when the potential gains from trade are larger. In this sense, the signalling outcome is quite inefficient (first noted by DeMarzo and Duffie 1999).²⁴

We now compute the banks' payoffs in the full game as functions of their actions in period 1: before the local bank sees its signal t . The local bank's direct lending profits are $\int_{\theta=\theta_1}^1 (\delta r \theta \bar{\zeta} - 1) dG_{\bar{\theta}}(\theta)$: the integral, over all types θ to whom it lends, of the discounted expected gross loan return $\delta r \theta \bar{\zeta}$ minus the unitary cost of capital. The expectation over signals t of the local bank's securitization profits in part 3 of Proposition 2 may be written

$$\int_{\theta=\theta_1}^1 (1 - \delta) [r\theta] \Lambda dG_{\bar{\theta}}(\theta) \tag{9}$$

where we define the parameter

$$\Lambda = E \left[\left(\frac{E[\zeta|t=0]}{E[\zeta|t]^\delta} \right)^{\frac{1}{1-\delta}} \right] \tag{10}$$

which lies in $(0, E[\zeta|t=0])$.²⁵ (The outer expectation in (10) is over signals t .) An increase in the conditional expectation $E[\zeta|t]$ of the shock relative to its lowest possible value $E[\zeta|t=0]$ may be interpreted as a rise in the informativeness of the signal t . Hence, the parameter Λ — and thus the local bank's securitization profits — are lower when the local bank is more informed about

24. The assumption that the local bank sees a signal t after lending is just one way to create a cost advantage for the remote bank in the securitization market; section 7.1 presents another approach. If the model is interpreted literally, the local bank might avoid its costly signalling problem by contracting to sell its entire portfolio of loans before learning its signal t . Such contracts, which we rule out, are probably infeasible in practice. Investors generally do not know when a bank receives private information about its existing loans. Hence, the offer of such a contract by the bank would likely signal to investors that the bank has already received bad news.

25. The parameter Λ is positive since $E[\zeta|t=0] > 0$. The conditional expectation $E[\zeta|t]$ can be written $\int_{z=0}^1 z d[\Phi(z|t) - 1]$ as $d1 = 0$. Integrating by parts, it equals $\int_{z=0}^1 [1 - \Phi(z|t)] dz$ which, by FOSD, is increasing in t . Hence, Λ is also bounded above by $\left(\frac{E[\zeta|t=0]}{E[\zeta|t=0]^\delta}\right)^{\frac{1}{1-\delta}} = E[\zeta|t=0]$.

local economic conditions. Intuitively, having more information worsens the lemons problem the bank faces at the securitization stage.

Bank L 's payoff Π_L is the sum of its expected direct lending and securitization profits:

$$\Pi_L(\theta_1|r, \bar{\theta}, \mu) = \int_{\theta=\theta_1}^1 (r\theta\mu - 1) dG_{\bar{\theta}}(\theta) \tag{11}$$

where we will refer to

$$\mu = (1 - \delta)\Lambda + \delta\bar{\zeta} \tag{12}$$

as the *local profitability parameter*. By (10) and FOSD, μ lies in $(\Lambda, \bar{\zeta})$. By (11), the local bank's optimal lending threshold is

$$\theta_1 = (r\mu)^{-1}. \tag{13}$$

This is the type θ for whom $r\theta\mu$ — the sum of the local bank's expected lending revenue $\delta r\theta\bar{\zeta}$ and securitization revenue $(1 - \delta)[r\theta]\Lambda$ — equals the unitary cost of capital.

If the remote bank lends, it sells all of its loans. Its payoff from offering an interest rate $r \leq \rho$, given the agents' credit score $\bar{\theta}$, is just its expected direct lending profits $\int_{\theta=0}^{\theta_1} (\delta r\theta\bar{\zeta} - 1) dG_{\bar{\theta}}(\theta)$ plus its expected securitization profits from part 1 of Proposition 2. Substituting for θ_1 using (13), the remote bank's payoff is

$$\Pi_R(r|\bar{\theta}, \mu) = \int_{\theta=0}^{(r\mu)^{-1}} (r\theta\bar{\zeta} - 1) dG_{\bar{\theta}}(\theta). \tag{14}$$

If the remote bank competes, it will charge an interest rate r that maximizes $\Pi_R(r|\bar{\theta}, \mu)$. Since the integral is at most $r\bar{\theta}\bar{\zeta} - 1$, the remote bank will not choose an interest rate below $(\bar{\theta}\bar{\zeta})^{-1}$. And since Π_R is continuous on $r \in [(\bar{\theta}\bar{\zeta})^{-1}, \rho]$, an optimal interest rate exists in this interval.²⁶

Let $\Pi_R^*(\bar{\theta}, \mu)$ equal the remote bank's payoff $\Pi_R(r|\bar{\theta}, \mu)$ at an optimal interest rate r , and let

$$\bar{\theta}^* = \inf \{ \bar{\theta} : \Pi_R^*(\bar{\theta}, \mu) \geq 0 \} \tag{15}$$

denote the greatest lower bound on the set of credit scores for which the remote bank can profitably lend. The remote bank will lend if and only if the agents' credit score $\bar{\theta}$ lies in $(\bar{\theta}^*, 1)$, which is non-empty as $\bar{\theta}^*$ is less than one:

Theorem 2. (1.) *The threshold $\bar{\theta}^*$ lies in $(0, 1)$ and is non-decreasing in the local profitability parameter μ .*

(2.) *If $\bar{\theta} < \bar{\theta}^*$, the remote bank does not compete and agents with types θ below $(\rho\mu)^{-1}$ do not borrow. Agents with types above $(\rho\mu)^{-1}$ borrow from the local bank at an interest rate r equal to the gross project return ρ . On seeing its signal t , the local bank securitizes its loans to all types $\theta \in [(\rho\mu)^{-1}, \theta_2]$, where its securitization threshold θ_2 , which is decreasing in t , is determined implicitly by (4) using $\theta_1 = (\rho\mu)^{-1}$ and $q_L = \left(\frac{E[\zeta|t=0]}{E[\zeta|t]} \right)^{\frac{1}{1-\delta}}$.*

26. The interval is non-empty by (1). The remote bank's payoff at its optimal interest rate may be negative, in which case it will not lend. This motivates equation (15), which follows.

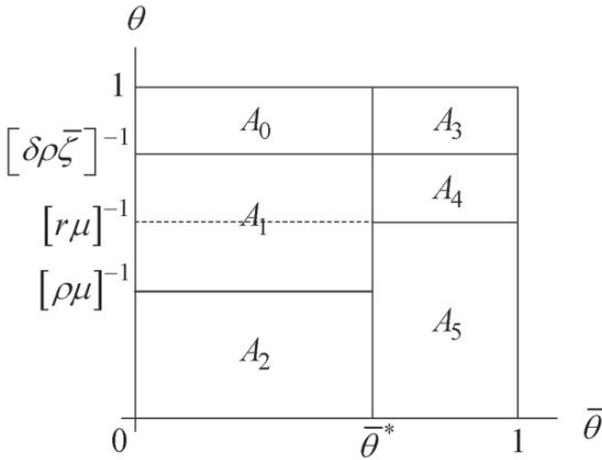


FIGURE 1

Illustration of Theorems 1 and 2. The figure assumes (a) the local bank lends without securitization ($[\delta\rho\bar{\zeta}]^{-1} < 1$) and (b) the remote bank’s optimal interest rate r is less than the gross project return ρ and independent of the credit score $\bar{\theta}$. Without securitization, the local bank lends to agents in areas A_0 and A_3 . With securitization, the local bank lends to agents in areas $A_0, A_1, A_3,$ and A_4 , while the remote bank lends to those in area A_5

- (3.) If $\bar{\theta} > \bar{\theta}^*$, all agents borrow. The remote bank offers an interest rate r in the non-empty interval $[(\bar{\theta}\bar{\zeta})^{-1}, \rho]$ that maximizes $\Pi_R(r|\bar{\theta}, \mu)$. If an agent’s type θ exceeds $(r\mu)^{-1}$, she borrows from the local bank; else she borrows from the remote bank. In either case, she pays the interest rate r . The remote bank securitizes all of its loans. On seeing its signal t of the macroeconomic shock ζ , the local bank securitizes its loans to all types $\theta \in [(r\mu)^{-1}, \theta_2]$, where its securitization threshold θ_2 , which is decreasing in t , is determined implicitly by
- (4) using $\theta_1 = (r\mu)^{-1}$ and $q_L = \left(\frac{E[\zeta|t=0]}{E[\zeta|t]}.$

Proof Appendix. ||

In equilibrium, the remote bank follows a threshold policy: it competes if and only if the agents’ credit score $\bar{\theta}$ lies in the non-empty interval $(\bar{\theta}^*, 1)$. Moreover, $\bar{\theta}^*$ is non-decreasing in the local profitability parameter μ . Intuitively, given the interest rate r , the remote bank lends to those agents whose types θ lie below the local bank’s lending threshold $(r\mu)^{-1}$. This threshold does not depend on the credit score $\bar{\theta}$: as the local bank knows an agent’s actual type θ , it does not care *additionally* about her credit score. Hence, ICE implies that the remote borrowers’ mean type $E_{\bar{\theta}}[\theta|\theta \leq (r\mu)^{-1}]$ is increasing in the credit score $\bar{\theta}$. It is also clearly non-increasing in the local profitability parameter μ . So the remote bank’s profits from offering any given interest rate r are increasing in $\bar{\theta}$ and non-increasing in μ . Thus, bank R ’s profits from its *best* offer r must also be increasing in $\bar{\theta}$ and non-increasing in μ : the remote bank must use a credit score threshold, which is non-decreasing in μ .

Theorem 2 is illustrated in Figure 1. The Figure assumes that without securitization, the local bank lends ($[\delta\rho\bar{\zeta}]^{-1} < 1$) and that the remote bank’s optimal interest rate r is less than the gross project return ρ and does not vary with the credit score $\bar{\theta} \geq \bar{\theta}^*$. An agent’s type θ , which only the

local bank sees, appears on the vertical axis. The credit score $\bar{\theta}$, which all see, is depicted on the horizontal axis.

Without securitization, the local bank lends to agents whose types θ exceed the threshold $[\delta\rho\bar{\zeta}]^{-1}$ by Theorem 1: only agents in areas A_0 and A_3 are funded. Securitization extends funding to those in areas A_1 , A_4 , and A_5 . Why? First suppose the credit score $\bar{\theta}$ lies below $\bar{\theta}^*$. Only the local bank lends as before, but the ability to securitize some loans entices the bank to lower its lending threshold to $(\rho\mu)^{-1}$: it extends funding to agents in area A_1 .²⁷ If instead the credit score $\bar{\theta}$ exceeds $\bar{\theta}^*$, bank R offers some optimal interest rate $r \leq \rho$. (The Figure assumes $r < \rho$.) The local bank extends funding to those in area A_4 , while the remote bank funds agents in area A_5 .

4.1. *Bidding on one another's securities*

Our model assumes that one bank cannot bid on the other's security. Clearly, only the local bank might profit from doing so since only it has an informational advantage (via its signal t) that offsets its greater impatience vis-a-vis investors. When the remote bank lends, it sells its entire portfolio to investors for a price equal to the portfolio's expected payout $r\bar{\zeta} \int_{\theta=0}^{\theta_1} \theta dG_{\bar{\theta}}(\theta)$. The local bank's valuation of this portfolio is at most $\delta r E[\zeta | t = 1] \int_{\theta=0}^{\theta_1} \theta dG_{\bar{\theta}}(\theta)$. Hence, in the above equilibrium, the local bank can never profit from bidding on the remote bank's portfolio if

$$\delta < \frac{\bar{\zeta}}{E[\zeta | t = 1]}. \tag{16}$$

This condition states that the bank's degree of patience δ is less than the maximum informational advantage that it gets from its private signal t of the macroeconomic shock ζ . If (16) holds, then the above outcome remains an equilibrium if banks can bid on each others' securities.

5. WELFARE

The remote bank cannot screen on an agent's type. Hence, when it lends, some of its borrowers will have types that are close to zero. Under symmetric information, these agents would not be financed. This is an efficiency cost of securitization. On the other hand, securitization allows a welfare-enhancing exchange between patient investors and impatient banks. We now show that the cost never exceeds the benefit: securitization cannot lower welfare. And if, with securitization, either bank lends, then it raises welfare for generic parameters.

Formally, we analyse social welfare as follows. Let U denote *ex ante* agent welfare: the integral of the agents' expected payoff $(\rho - r)\theta\bar{\zeta}$ over all types θ that receive loans. Let Π_L and Π_R denote the *ex ante* payoffs of the local and remote bank, which are given in equations (11) and (14).

Our model is non-standard as the banks are less patient than the investors and the agents. So in constructing the welfare function we consider two alternative weighting schemes. In scheme A, we simply sum the players' payoffs: $SW^A = U + \Pi_L + \Pi_R$. As the investors' payoff is identically zero, it is omitted.

Scheme A puts unit weight on the income of all players in all periods *except* the banks' period-3 income, which is given the weight $\delta < 1$. Thus, scheme A favours changes (such as a decline in the interest rate) that transfer income from the banks to the agents in period 3. However, our motivation for the bank's lower discount factor is that the bank faces capital

27. Its threshold is lower since, by (12), $\mu > \delta\bar{\zeta}$.

requirements that prevent it from making profitable investments in periods 1 and 2. Thus, instead of underweighting the banks' period-3 income, it may be more reasonable to overweight their income in the earlier periods. This is accomplished with the following welfare function: $SW^B = U + (\Pi_L + \Pi_R)/\delta$. Scheme B puts unit weight on the income of all players in all periods *except* the banks' income in periods 1 and 2, which receives the weight $\omega = 1/\delta$. The weight ω captures the expected gross return of the banks' profitable alternative investments and can take on any value in $(1, \infty)$.

Under either scheme, securitization raises welfare as long as it leads to some lending.

Theorem 3. *Securitization does not lower welfare. And if, under securitization, either bank lends, then securitization generically raises welfare. These claims hold for both weighting schemes.*

Proof There are two cases.

- (1.) Under securitization, neither bank lends. Then the local bank's profit $\rho\bar{\mu}\bar{\zeta}$ from lending to the highest type ($\theta = 1$) must be non-positive. But then without securitization, the local bank does not lend either: its profit $\delta\rho\bar{\zeta}$ from lending to the highest type must be negative by (12). Thus, social welfare is identically zero both with and without securitization.
- (2.) Under securitization, some bank lends. There are two subcases.

- (a.) The remote bank does not lend under securitization. Then it gets zero: it is unaffected by securitization. The interest rate r remains equal to the gross project return ρ by part 2 of Theorem 2. So the agents are also unaffected by securitization. As for the local bank, there are two possibilities. In the first, it does not lend without securitization. With securitization, it lends by hypothesis, so its payoff is generically positive: securitization raises welfare. In the second, the local bank lends without securitization. Securitization then changes its profit on a loan to a type θ agent from $\delta\rho\theta\bar{\zeta} - 1$ to $\rho\theta\mu - 1$, which is higher by (12) and since $\Lambda > 0$. So securitization raises welfare here as well.
- (b.) The remote bank lends under securitization. Then for generic parameters, securitization must raise its payoff Π_R , which is zero without securitization. It thus suffices to show that securitization cannot lower the remainder of the social welfare function: $U + \Pi_L$ under scheme A and $U + \Pi_L/\delta$ under scheme B. We will refer to this remainder as the "partial surplus". An outline is as follows; a rigorous proof appears in the Appendix.

Securitization affects the agents and the local bank in three distinct ways when it entices the remote bank to lend. First, agents to whom the local bank does not lend can now borrow from the remote bank. Second, the interest rate r falls from ρ to some $r_0 \leq \rho$ that is chosen by the remote bank. Third, the local bank gains access to the securitization market. Consider the following thought experiment, in which these steps occur sequentially:

- (i.) *The remote bank first offers loans to all agents at the interest rate ρ .* As the interest rate is, by assumption, held constant at ρ , the agents' payoffs are still zero. And the local bank is not affected since the agents' willingness to pay still equals ρ . In particular, the local bank still lends to the set of agents whose types θ exceed $(\delta\rho\bar{\zeta})^{-1}$. Hence, this step has no effect on the partial surplus.
- (ii.) *The remote bank then gradually lowers its interest rate from ρ to r_0 .* This has three effects. First, it raises the income $\rho - r$ that a remote borrower gets if

her project succeeds. This raises the partial surplus (from which, crucially, the remote bank's payoff is omitted). Second, period-3 income is transferred to local borrowers from the remote bank. (As we are not yet permitting the local bank to securitize, the decline in r cannot affect its securitization profits.) This raises the partial surplus under scheme A and leaves it unchanged under scheme B. Third, the local bank gradually raises its lending threshold $\theta_1 = (\delta r \bar{\zeta})^{-1}$ as r falls. This leaves the local bank's payoff unchanged by the envelope theorem. It does not affect the agents either: those who are dropped by the local bank simply borrow from the remote bank at the prevailing interest rate r . Hence, it does not affect the partial surplus.

- (iii.) *Finally, the local bank is permitted to securitize some or all of its loans.* This has no effect on the agents, who are all still funded at the interest rate r_0 . And it cannot harm the local bank, which can always choose not to securitize. So it cannot lower the partial surplus.

We conclude that securitization cannot lower the partial surplus.

||

Another question pertains to the efficient allocation of funds across agents. Without securitization, the local bank lends to those agents whose expected returns $\rho\theta\bar{\zeta}$ exceed the fixed threshold $1/\delta$ (Theorem 1). Hence, the allocation of loans across agents is efficient: if one agent gets a loan while another does not, the former agent's project must have a higher expected return. While securitization expands lending, the expansion is biased towards agents with higher credit scores. In particular, some agents in area A5 (Figure 1), all of whom are funded, have lower types θ than some agents in area A2, none of whom are funded. Thus, the allocation of loans across agents is now inefficient: while securitization raises welfare, an omniscient planner could reallocate loans across agents so as to obtain a further welfare improvement.

6. EMPIRICAL IMPLICATIONS

Several features of the recent securitization episode in the U.S. are consistent with our model. For example, Keys *et al.* (2012) find that the share of loans with low or no documentation dramatically increased as securitization expanded. This mirrors our prediction that securitization favours screening based on hard information such as credit scores rather than the soft information that may be produced, *e.g.*, from an analysis of loan documentation.

Some other predictions that find empirical support are as follows.

- (1.) *Securitization Stimulates Lending.* As in Shin (2009), securitization leads to expanded lending by connecting liquid investors with loan applicants. In Figure 1, areas A₁, A₄, and A₅ are added. There is considerable evidence that the securitization boom in the 2000s led to expanded lending (Demyanyk and Van Hemert, 2009; Mian and Sufi, 2009; Krainer and Laderman, 2014).
- (2.) *Securitization Favors Remote Lenders, who Securitize More.* The introduction of securitization enables the remote bank to compete for some loan applicants. In addition, the remote bank sells all of its loans while the local bank retains a portion of its loan portfolio. Loutskina and Strahan (2011) find that as securitization rose, the market share of concentrated lenders — those which originate at least 75% of their mortgages in one metropolitan statistical area (MSA) — fell from 20% to 4% from 1992 to 2007. Moreover, concentrated lenders retain a higher proportion of their loans. Finally, when

they expand to new MSA's, these lenders are more likely to sell their remote loans than those made in their core MSA's.

- (3.) *Remote Borrowers have Stronger Observables and Higher Conditional Default Rates.* By Theorem 2, all agents with strong observables can borrow remotely. In contrast, agents with weak observables can borrow only locally, and only if their soft information is strong enough. Agarwal and Hauswald (2015) find that applicants with strong observables tend to apply online for loans, while in-person applicants tend to be those with weaker observables but positive estimates of the bank's soft information about them. Now consider an agent whose credit score $\bar{\theta}$ exceeds the remote bank's lending threshold $\bar{\theta}^*$. She borrows remotely (locally) if her default probability, based on her type θ , is high (low) enough. Thus, remote loans have higher conditional default rates. Indeed, Agarwal and Hauswald (2015) find that online loans default more than observationally equivalent in-person loans, while De Young *et al.* (2008) find that banks that lend remotely have higher default rates. Loutschina and Strahan (2011, p. 1456) find that concentrated lenders (defined above) have lower loan losses despite lending to applicants who are riskier in terms of loan-to-value (LTV) ratios.
- (4.) *Securitized Loans have Higher Conditional Default Rates.* In our model, among agents with credit scores above the remote bank's lending threshold, high (low) types get local (remote) loans, which are partially (wholly) securitized. Thus, securitized loans have higher conditional default rates. Krainer and Laderman (2014) find that controlling for observables, privately securitized loans default at a higher rate than retained loans, while Elul (2015) finds that securitized loans perform worse than observationally similar unsecuritized loans. Rajan *et al.* (2015) find that conditional default rates rose between 1997–2000 and 2001–6 with the rise of securitization; similarly, Demyanyk and Van Hemert (2009) find that conditional and unconditional default rates rose from 2001 to 2007. Our model also predicts a discontinuity at the remote bank's lending threshold: as agents with credit scores slightly above this threshold qualify for remote loans, they have discretely higher securitization and default rates than agents whose scores lie slightly below the threshold. Keys *et al.* (2010) and Keys *et al.* (2012) and find that loans just above the 620 FICO credit score threshold are much more likely to be securitized and to default than loans of borrowers with credit scores just slightly below this threshold.
- (5.) *Securitization Lets Borrowers with Strong Observables Get Cheap Remote Loans.* By Theorem 2, agents with weak observables pay the maximum interest rate to their local bank if they borrow, while agents with strong observables pay a generally lower rate that results from competition between the remote and the local bank. This has two implications. First, the securitization boom in the 2000s should have strengthened the (negative) relation between borrower observables and interest rates. Rajan *et al.* (2015) find that borrower credit scores and LTV ratios explain just 9% of interest rate variation among loans originated in 1997–2000 but 46% of this variation among loans originated in 2006. Second, remote loans should carry lower interest rates. Agarwal and Hauswald (2015) find that internet loans carry lower interest rates than in-person loans, while Degryse and Ongena (2005) and Mistrulli and Casolaro (2008) find that interest rates decrease with the distance between small firms and their lenders.

7. EXTENSIONS

We now consider several variations of the basic model. These are a model with no macroeconomic signal; a model with security design; and a model with multiple local and remote banks.

7.1. *No macroeconomic signal*

A model with no macroeconomic signal is equivalent to the special case of our model in which the conditional expected value of the shock, $E[\zeta|t]$, is independent of the signal t . This implies $\Lambda = \mu = \bar{\zeta}$ by (10) and (12). Substituting $\bar{\zeta}$ for μ in (14), one finds that the remote bank loses money on every type θ to which it lends except the highest type $\theta = (r\bar{\zeta})^{-1}$, on which it breaks even: the remote bank will not lend. Intuitively, there is now symmetric information between the local bank and the investors at the securitization stage. As each bank can reap its full gains from trade with investors, the lending game has common values. Since the uninformed remote bank bids first, it must lose from competing as in the case without securitization (section 3).

One way to reintroduce a lemons problem is to modify the model so that only the local bank knows the distribution of types θ in its loan portfolio. A simple model with this property is one with a *single* agent whose type θ is known only to the local bank. If the local bank lends, investors know only that the agent's type θ does not lie below the local bank's lending threshold. They do not know the precise value of θ . Hence, the local bank may still retain part of the loan in order to signal that θ is high. As the remote bank does not need to signal, it may still be able to compete with the local bank.

We analyse such a model in our Supplementary Appendix (Frankel and Jin, 2013). Remote lending can still occur. However, unlike our main model, there are now multiple separating equilibria. Intuitively, with a single agent the market does not observe the local bank's lending threshold. Hence, if the local bank deviates (*e.g.* by selling a higher than expected proportion of its loan), the market may conclude that this threshold, and the agent's type, is zero: the loan has no chance of being repaid. Such punishing beliefs can prevent the local bank from securitizing more than an arbitrary proportion (including zero) of its loans. This permits multiple equilibria with different such arbitrary proportions.²⁸

7.2. *Ex post security design*

We now modify the main model of section 2 to permit *ex post* security design, in which each bank can design a general monotone security after the local bank sees its signal.²⁹ Our qualitative results remain intact. However, security design permits the local bank to signal its information more efficiently. This strengthens the local bank's position at the lending stage and thus makes remote lending less likely.

The changes to the model begin in period 2 after the local bank sees its signal t . Rather than choosing a subset of its loans to sell, each bank $i = R, L$ announces a function F_i that specifies the payment $F_i(Y_i) \in [0, Y_i]$ that investors will receive for any given gross return Y_i of bank i 's loan portfolio.³⁰ We restrict to monotone securities, for which both the security payout $F_i(Y_i)$ and the

28. We also show that there is a unique equilibrium that survives the D1 refinement of Banks and Sobel (1987). There is no remote lending in this equilibrium. However, it is hard to justify the strong restrictions on beliefs that D1 imposes. We discuss this issue further in the Supplementary Appendix; see also Fudenberg and Tirole (1991, p. 460).

29. The working paper version of this article (Frankel and Jin, 2011) instead considers *ex ante* security design: each bank designs its security, sees its signal, and decides how many shares of its security to sell. The results are essentially the same in the two cases.

30. We assume that a bank must securitize all of its loans and sell its security in its entirety. This is without loss of generality. Why? Suppose instead that the remote bank securitizes each loan with probability q_R and writes a fixed security F_R on the result, and then sells a proportion \tilde{q}_R of this security to investors. The payout to investors is thus $\tilde{q}_R F_R(q_R Y_R)$. But this is equivalent to securitizing all loans for sure and selling in its entirety a security with payout $\tilde{F}_R(Y_R) = \tilde{q}_R F_R(q_R Y_R)$. Likewise, suppose the local bank securitizes all loans with types θ in $[\theta_1, \theta_2]$ and, given its signal t , writes a security F_L^t on the result and sells a proportion \tilde{q}_L^t of this security. The payout to investors, given t , is thus

portion $Y_i - F_i(Y_i)$ of its portfolio return that bank i keeps are non-decreasing in the portfolio return Y_i .³¹

We make the following technical assumptions. First, the signal density $\Psi'(t) = d\Psi(t)/dt$ is bounded and Lipschitz continuous:

Lipschitz- Ψ . There are constants $k_0, k_1 \in (0, \infty)$ such that for all signals $t, t' \in [0, 1]$, $\Psi'(t) \leq k_0$ and $|\Psi'(t) - \Psi'(t')| \leq k_1 |t - t'|$.

Moreover, the conditional distribution Φ of the shock ζ given the signal t is Lipschitz continuous and has some minimum sensitivity to its arguments:

Lipschitz- Φ . There are constants $k_2, k_3 \in (0, \infty)$ such that for all $\zeta, t \in [0, 1]$,

$$\frac{\partial \Phi(\zeta|t)}{\partial \zeta} \in (k_2, k_3) \text{ and} \tag{17}$$

$$-\frac{\partial \Phi(\zeta|t)}{\partial t} \in [k_2 \zeta(1 - \zeta), k_3]. \tag{18}$$

An intuition for (18) is as follows. A higher signal t is good news about the shock, so $\Phi(\zeta|t)$ is decreasing in t . Thus, the absolute sensitivity of Φ to t is represented by the non-negative quantity $-\frac{\partial \Phi(\zeta|t)}{\partial t}$. As $\Phi(0, t)$ and $\Phi(1, t)$ equal zero and one, respectively, for any t , we cannot require that $\frac{\partial \Phi(\zeta|t)}{\partial t}$ be sensitive to the signal t for all shocks ζ . However, we can require that as ζ moves away from zero (one), this sensitivity rises at least linearly in ζ (respectively, in $1 - \zeta$). The factor $\zeta(1 - \zeta)$ ensures this property as it is approximately equal to ζ in a neighbourhood of $\zeta = 0$ and to $1 - \zeta$ in a neighbourhood of $\zeta = 1$.

We also assume that the partial derivatives of the conditional distribution function Φ are Lipschitz continuous in the signal t :

Lipschitz Partial Derivatives (LPD). There is a $k_4 \in (0, \infty)$ such that for all $\zeta, t', t'' \in [0, 1]$,

$$\max \left\{ \left| \frac{\partial \Phi(\zeta|t')}{\partial \zeta} - \frac{\partial \Phi(\zeta|t'')}{\partial \zeta} \right|, \left| \frac{\partial \Phi(\zeta|t)}{\partial t} \Big|_{t=t'} - \frac{\partial \Phi(\zeta|t)}{\partial t} \Big|_{t=t''} \right\} < k_4 |t' - t''|.$$

Finally, we assume that Φ satisfies the following strengthening of First-Order Stochastic Dominance.

Hazard Rate Ordering (HRO). For all $t' > t''$, $\frac{1 - \Phi(\zeta|t')}{1 - \Phi(\zeta|t'')}$ is increasing in $\zeta \in [0, 1]$.

HRO is weaker than the monotone likelihood ratio property, which is commonly assumed in signaling games (DeMarzo *et al.* 2015).

$\tilde{q}_L^i F_L^i(q_L Y_L)$ where q_L is determined by θ_1 and θ_2 via (4). But this is equivalent to securitizing all loans for sure and, on seeing the signal t , selling (in its entirety) a security with payout $\tilde{F}_L^i(Y_L) = \tilde{q}_L^i F_L^i(q_L Y_L)$.

31. The former can be justified by assuming that the bank can hide debts. Thus, if F_i were decreasing, bank i could borrow money to inflate Y_i , pay investors the lower payout, and then return the loan. The second assumption follows from free disposal. See DeMarzo *et al.* (2015). The effect of relaxing monotonicity is not known for the case of *ex post* security design. With *ex ante* design, standard debt is no longer optimal if monotonicity is dropped for a class of conditional distribution functions Φ (Nachman and Noe (1994, n. 3)).

By (2) and (3), the realized value Y_i of bank i 's loans may be written $y_i^{\theta_1} \zeta$ where $y_R^{\theta_1} = \int_{\theta=0}^{\theta_1} r\theta dG_{\bar{\theta}}(\theta)$ and

$$y_L^{\theta_1} = \int_{\theta=\theta_1}^1 r\theta dG_{\bar{\theta}}(\theta) \tag{19}$$

are common knowledge at the securitization stage. The realized payout to investors of bank i in period 3 is thus $F_i(y_i^{\theta_1} \zeta)$.

We first consider the remote bank's security design problem. Let F_L^t equal the security designed by the local bank when its signal is t . Let $E[f(\zeta)|F_L^t]$ denote the expectation of a function $f(\zeta)$ given what the local bank's security design F_L^t reveals about the signal t .³² Let $p_R(F_R, F_L^t)$ denote the price $E[F_R(y_R^{\theta_1} \zeta)|F_L^t]$ that investors offer for the remote bank's security F_R when the local bank announces the security F_L^t . The unconditional expected price of the remote bank's security is just $\int_{t=0}^1 p_R(F_R, F_L^t) d\Psi(t)$ which, by the law of iterated expectations, equals the unconditional expected payout $E[F_R(y_R^{\theta_1} \zeta)]$ to investors. From this we subtract the discounted unconditional expected payout to investors $\delta E[F_R(y_R^{\theta_1} \zeta)]$ to obtain the remote bank's unconditional expected securitization profits $\pi_R(F_R) = (1 - \delta)E[F_R(y_R^{\theta_1} \zeta)]$. To maximize this, bank R simply sets $F_R(y_R^{\theta_1} \zeta)$ equal to its maximum value, $y_R^{\theta_1} \zeta$: the bank sells a 100% equity stake in all the loans that it made.

Turning now to the local bank, assume it made some loans: its lending threshold θ_1 is less than one. Given its security F_L^t and signal t , the local bank's expected securitization profits $\pi_L(F_L^t, t)$ equal the price $p_L(F_L^t)$ of its security less the discounted conditional expected payout to investors $\delta E[F_L^t(y_L^{\theta_1} \zeta)|t]$. Define the function

$$f(m, t) = -\frac{1}{1 - \delta} \frac{\frac{\partial E[\min\{m, \zeta\}|t]}{\partial t}}{\Pr(\zeta > m|t)} = \frac{1}{1 - \delta} \frac{\int_{\zeta=0}^m \frac{\partial \Phi(\zeta|t)}{\partial t} d\zeta}{1 - \Phi(m|t)}. \tag{20}$$

Consider the following initial value problem:

Initial Value Problem (IVP). The differential equation $\frac{dm}{dt} = f(m, t)$ with $m: [0, 1] \rightarrow \Re$, together with the initial value $m(0) = 1$.

Proposition 3. *Assume Lipschitz- Ψ , Lipschitz- Φ , LPD, and HRO.*

- (1.) *There exists a unique solution m to IVP, which is strictly positive and decreasing in t .*
- (2.) *There is an equilibrium in which, for each signal t , the local bank issues standard debt with face value $y_L^{\theta_1} m(t)$. This security has the payout $y_L^{\theta_1} \min\{\zeta, m(t)\}$. In this equilibrium, the local bank's unconditional expected securitization profit equals the expected gains from trade $(1 - \delta)y_L^{\theta_1} E[\min\{\zeta, m(t)\}]$ from the issuer's security, where this expectation is taken with respect to both t and ζ .*

Proof See DeMarzo et al. (2015). ||

32. In particular, in a separating equilibrium F_L^t reveals t so $E[f(\zeta)|F_L^t]$ equals $E[f(\zeta)|t]$.

While there may be other signaling equilibria, there are good reasons to focus on this one. First, if the signal t and shock ζ come from discrete distributions, there is a unique equilibrium that satisfies the Intuitive Criterion of Cho and Kreps (1987). Moreover, this unique equilibrium converges to the equilibrium of Proposition 3 as the gaps between signals and shocks shrink to zero.³³ Finally, the Intuitive Criterion has found experimental support in the work of Brands and Holt (1992) and Camerer and Weigelt (1988).

Define

$$\widehat{\Lambda} = E[\min\{\zeta, m(t)\}]. \quad (21)$$

Proposition 4. $\widehat{\Lambda}$ lies in $(0, \bar{\zeta})$.

Proof Appendix. \parallel

The local bank's payoff $\widehat{\Pi}_L(\theta_1, r)$ from choosing the lending threshold θ_1 consists of its discounted expected portfolio return $\delta y_L^{\theta_1} \bar{\zeta}$, plus its expected securitization profits $(1 - \delta)y_L^{\theta_1} \widehat{\Lambda}$ (by part 2 of Proposition 3), less the cost of loaned funds $1 - G_{\bar{\theta}}(\theta_1)$. By equation (19) this payoff is just $\Pi_L(\theta_1 | r, \bar{\theta}, \widehat{\mu})$ where Π_L is defined in (11) and

$$\widehat{\mu} = (1 - \delta)\widehat{\Lambda} + \delta\bar{\zeta}, \quad (22)$$

which lies in $(\widehat{\Lambda}, \bar{\zeta})$ by Proposition 4. By (11), the local bank chooses the lending threshold $[r\widehat{\mu}]^{-1}$ and so the remote bank's payoff in the game is just $\Pi_R(r|\bar{\theta}, \widehat{\mu})$ where Π_R is defined in (14). Thus, our analysis of lending competition in the main model applies unchanged to this version except that μ is replaced by $\widehat{\mu}$ and Λ by $\widehat{\Lambda}$. In light of proposition 3, this implies parts 2 and 3 of the following result. Part 4 states that security design makes securitization more profitable for the local bank: $\widehat{\mu}$ exceeds μ .³⁴ Finally, let

$$\widehat{\theta}^* = \inf\{\bar{\theta} : \Pi_R^*(\bar{\theta}, \widehat{\mu}) \geq 0\} \quad (23)$$

denote the greatest lower bound on the set of credit scores for which the remote bank can profitably lend.³⁵ Part 5 states that security design weakly raises the remote bank's lending threshold: $\widehat{\theta}^* \geq \bar{\theta}^*$. Intuitively, by allowing the local bank to signal more efficiently, security design shrinks the remote bank's advantage at the securitization stage, thus making remote lending less likely. However, remote lending still occurs for credit scores $\bar{\theta}$ in the interval $(\widehat{\theta}^*, 1)$, which is non-empty by part 1.

Theorem 4. *Assume Lipschitz- Φ , Lipschitz- Ψ , LPD, and HRO. Also assume that, in the security design subgame, the local bank plays the equilibrium described in Proposition 3. Then the following properties hold for generic parameters.*

- (1.) *The remote lending threshold $\widehat{\theta}^*$ lies in $(0, 1)$ and is non-decreasing in the local profitability parameter $\widehat{\mu}$.*

33. These two results appear in DeMarzo *et al.* (2015).

34. As noted in section 1, it does so by letting the local bank signal its private information more efficiently.

35. The function $\Pi_R^*(\bar{\theta}, \widehat{\mu})$, defined in section 4, is the remote bank's payoff $\Pi_R(r|\bar{\theta}, \widehat{\mu})$ at an optimal interest rate r when the local profitability parameter is $\widehat{\mu}$.

- (2.) If $\bar{\theta} < \hat{\theta}^*$, the remote bank does not compete and agents with types θ below $\theta_1 = (\rho\hat{\mu})^{-1}$ do not borrow. Agents with types above θ_1 borrow from the local bank at an interest rate r equal to the gross project return ρ . On seeing its signal t , the local bank issues standard debt with face value $y_L^{\theta_1} m(t)$ where the function m is decreasing in t and is the unique solution to IVP.
- (3.) If $\bar{\theta} > \hat{\theta}^*$, all agents borrow. The remote bank offers an interest rate r in the non-empty interval $\left[(\bar{\theta}\bar{\zeta})^{-1}, \rho \right]$ that maximizes $\Pi_R(r|\bar{\theta}, \hat{\mu})$. If an agent's type θ exceeds $(r\hat{\mu})^{-1}$, she borrows from the local bank; else she borrows from the remote bank. In either case, she pays the interest rate r . The remote bank issues a 100% equity stake in its loans. The local bank's securitization behaviour is as in part 2 of this theorem, except that the local bank's lending threshold θ_1 now equals $(r\hat{\mu})^{-1}$ rather than $(\rho\hat{\mu})^{-1}$.
- (4.) The local profitability parameter $\hat{\mu}$ exceeds the analogous parameter μ in the main model.
- (5.) The remote lending threshold $\hat{\theta}^*$ with security design is at least as high as the remote lending threshold $\bar{\theta}^*$ in the main model.

Proof Appendix. ||

7.3. Multiple local and remote banks

We now modify our main model (section 2) to incorporate multiple local and remote banks. This change transfers rents from banks to borrowers by lowering interest rates. However, it does not alter the set of projects that are financed, either with or without securitization. Moreover, securitization still raises welfare as in our main model.

There is now also a continuum of remote banks $i \in [0, 1]$ and local banks $j \in [0, 1]$. The remote banks first make simultaneous offers. Let r^i be the offer of remote bank i ; if this bank makes no offer, let $r^i = \infty$. We assume that if any remote bank makes an offer, the minimum such offer r exists.³⁶ If no remote bank makes an offer, let $r = \rho$.

The local banks then make simultaneous offers. Let $r_{\theta j}$ be the offer that a type θ agent gets from local bank j ; if no such offer is made, let $r_{\theta j} = \infty$. For each type θ , we assume that the minimum $r_\theta = \min\{r_{\theta j}; j \in [0, 1]\}$ of the local banks' bids exists. If $r_\theta \leq r$ (respectively, $r_\theta > r$), we assume that a type θ agent borrows from the local (remote) bank with the lowest offer; if more than one local (remote) bank made this offer, she flips a coin to choose among them.

We first analyse a base case without securitization: each bank must hold every loan to maturity. If a bank lends, at a gross interest rate r , to a type θ agent, its expected profit is $\delta r \theta \bar{\zeta} - 1$: the discounted interest payment δr times the probability $\theta \bar{\zeta}$ of project success, less the unitary cost of capital. The proof of the following result, which follows that of Theorem 1, is omitted.

Theorem 5. *Without the option of securitization, only the local banks lend. A type θ agent is financed if and only if her project's discounted expected gross return, $\delta \rho \theta \bar{\zeta}$, exceeds the unitary cost of capital. Such an agent pays the interest rate $[\delta \theta \bar{\zeta}]^{-1}$ and receives positive profits, while her lender's profits are zero.*

A comparison with Theorem 1 shows that introducing more banks does not affect the set of projects that are funded. It merely transfers rents from the banks to the agents.

36. For instance, this rules out the following profile of offers: $r^i = 1 + i$ for $i > 0$ and $r^i = \infty$ for $i = 0$.

We now turn to the effects of securitization. We assume the local banks belong to a local cooperative that pools and securitizes their loans.³⁷ After the lending stage, the local cooperative sees the macroeconomic signal t and selects a subset of its loans to securitize, with the goal of maximizing its securitization profits. The cooperative's profits are divided among the local banks in a manner to be described below.

To facilitate comparison with our main model, we restrict attention to equilibria in which each local bank j offers a loan to an agent if and only if the agent's type θ is not less than some threshold $\theta_1^j \in \mathfrak{R}_+$. As the local banks win all ties with the remote banks, the cooperative's portfolio must then consist of all types $\theta \geq \theta_1 = \min_j \theta_1^j$ (which we assume exists and may depend on r).³⁸ If any remote bank competes, each remote bank that bids r receives a representative sample of the agents whose types θ are less than θ_1 , while remote banks that bid higher than r attract no borrowers. Investors observe the measure of loans in each portfolio, and thus can infer the threshold θ_1 .

The securitization stage is equivalent to that of our main model, with the cooperative playing the role of the local bank. Hence, if any remote banks compete, the sum of the expected payoffs of the remote banks that offer the minimum bid r equals the payoff $\Pi_R(r|\bar{\theta}, \mu)$ of the remote bank in our main model (equation (14)). Each remote bank that bids r gets an equal share of this payoff since they all make an equal proportion of remote loans.

As for the cooperative, the proportion of its loan repayments that it sells is $q_L(t) = \left(\frac{E[\zeta|t=0]}{E[\zeta|t]}\right)^{\frac{1}{1-\delta}}$ by part 2 of Proposition 2. The unconditional expected payout to investors that derives from the securitization of a loan to a type θ agent is thus $E[r_\theta \theta E[\zeta|t] q_L(t)]$, which equals $r_\theta \theta \Lambda$ by equation (10). Since the investors are competitive and risk-neutral, the securitization of the marginal borrower $\theta = \theta_1$ raises the cooperative's securitization revenue by $r_{\theta_1} \theta_1 \Lambda$. By gradually lowering the marginal type from one (its upper bound) to zero, one finds that securitizing each type θ increases the cooperative's securitization revenue by $r_\theta \theta \Lambda$. We assume that for each type $\theta \geq \theta_1$, the cooperative pays this marginal revenue to the local bank that lent to agent θ . Later, when project returns are realized, the expected gross return of this loan is $r_\theta \theta \bar{\zeta}$, of which the expected amount $r_\theta \theta \Lambda$ is paid to investors. The remainder (whose expectation is $r_\theta \theta [\bar{\zeta} - \Lambda]$) is paid to bank j , which discounts this payment at the rate δ . In this way, the cooperative passes all revenues on to its member banks. Local bank j 's total expected discounted profit from lending to a type θ agent is thus $r_\theta \theta \Lambda - 1 + \delta r_\theta \theta [\bar{\zeta} - \Lambda]$, which equals $r_\theta \theta \mu - 1$ by (12). The profits of all of the local banks thus sum to $\int_{\theta=\theta_1}^1 (r_\theta \theta \mu - 1) dG_{\bar{\theta}}(\theta)$, which is identical to the local bank's profit function in our main model (equation (11)) except that the interest rate r in that equation is replaced by the interest rate r_θ that here is offered to agent θ .

In equilibrium, the local banks bid the interest rate r_θ of any type $\theta \geq \theta_1$ down to the point where their expected profit $r_\theta \theta \mu - 1$ from lending to this type is zero. Hence, all local banks offer the interest rate $r_\theta = (\theta \mu)^{-1}$ to type θ as long as this rate does not exceed the agent's willingness to pay r . Otherwise, they do not compete for agent θ . The lending threshold θ_1 must therefore satisfy $(\theta_1 \mu)^{-1} = r$ or, equivalently, $\theta_1 = (r \mu)^{-1}$: the local banks have the same lending threshold as in our main model (equation (13)). And as noted, each remote bank that bids $r \leq \rho$ receives profits that are proportional to $\Pi_R(r|\bar{\theta}, \mu)$ as in the main model. Hence, for generic parameters,

37. By assigning the issuance decision to a cooperative, we sidestep the technical issues that arise in signalling games when multiple senders see the same signal (see Bagwell and Ramey, 1991). As the local banks are small, fixed costs of issuance would create an incentive to issue their loans through a cooperative. As information among them is symmetric, bargaining costs would be minimal. However, an explicit model of the bargaining process that would lead to such an agreement is outside the scope of this article.

38. If θ_1 is not less than one, the local cooperative's portfolio is empty.

if there is any r for which $\Pi_R(r|\bar{\theta}, \mu)$ is positive — if $\Pi_R^*(\bar{\theta}, \mu) > 0$ — the remote banks all bid the lowest such r ; else they do not compete.

This implies the following modification of Theorem 2. The threshold $\bar{\theta}^*$ is defined in (15) and is identical to that of the main model. Hence, part 1 of this result follows from part 1 of Theorem 2.

- Theorem 6.** (1.) *The threshold $\bar{\theta}^*$ lies in $(0, 1)$ and is non-decreasing in the local profitability parameter μ . It is identical to the remote bank's lending threshold $\bar{\theta}^*$ in the main model.*
- (2.) *If $\bar{\theta} < \bar{\theta}^*$, the remote banks do not compete and agents with types θ below $(\rho\mu)^{-1}$ do not borrow. Agents with types above $(\rho\mu)^{-1}$ borrow from a local bank at the interest rate $(\theta\mu)^{-1}$. On seeing its signal t , the local cooperative securitizes all local loans to types $\theta \in [(\rho\mu)^{-1}, \theta_2]$, where its securitization threshold θ_2 is determined implicitly by (4) using $\theta_1 = (\rho\mu)^{-1}$ and $q_L = \left(\frac{E[\xi|t=0]}{E[\xi|t]}.$*
- (3.) *If $\bar{\theta} > \bar{\theta}^*$, all agents borrow. The remote banks offer the lowest interest rate r in the non-empty interval $[(\bar{\theta}\bar{\xi})^{-1}, \rho]$ for which $\Pi_R(r|\bar{\theta}, \mu)$, defined in (14), is non-negative. If an agent's type θ exceeds $(r\mu)^{-1}$, she borrows from a local bank at the interest rate $(\theta\mu)^{-1}$; else she borrows from a remote bank at the interest rate r . The remote banks securitize all of their loans. On seeing its signal t , the local cooperative securitizes all local loans to types $\theta \in [(r\mu)^{-1}, \theta_2]$, where its securitization threshold θ_2 is determined implicitly by (4) using $\theta_1 = (r\mu)^{-1}$ and $q_L = \left(\frac{E[\xi|t=0]}{E[\xi|t]}\right)^{\frac{1}{1-\delta}}$.*

A comparison of Theorems 1 and 2 with Theorems 5 and 6 shows that whether or not banks can securitize, the introduction of multiple remote and local banks merely lowers the interest rates paid by borrowers. It does not alter the effects of securitization on the set of projects that are financed or securitized.

8. CONCLUDING COMMENTS

We treat securitization as an exogenous innovation that encourages remote lending. If instead securitization were initially possible and an exogenous barrier to remote lending were then lifted, our model would also predict a simultaneous increase in both remote lending and securitization.³⁹ In practice, legal barriers to interstate banking fell gradually starting in Maine in 1978 and ending with the federal government's passage of the Interstate Banking and Branching Efficiency Act of 1994, which abolished all remaining restrictions (Loutskina and Strahan, 2011, pp. 1451–1452). Since securitization was invented earlier, these barriers may have fallen partly in response to pressure from large banks who were eager to increase their securitization profits. Alternatively, their fall may have been due to an exogenous change in regulatory philosophy. This might be an interesting topic for future empirical research.

Our model follows the literature in assuming that banks securitize because they are less patient than investors. However, if banks are risk-averse, they might instead securitize in order to reduce their exposure to local macroeconomic shocks.⁴⁰ This benefit would likely be smaller for the local bank for two reasons: asymmetric information prevents it from selling its entire portfolio,

39. Since we assume banks lack private information about their remote loans and have a lower discount factor than investors, banks securitize all of their remote loans. Since — in our model — they securitize only some of their local loans, removing a barrier to remote lending would raise the proportion of loans that are securitized.

40. This assumes that investors are either less risk averse or better able to construct diversified portfolios.

and the price of its security varies with its signal which creates risk. Hence, securitization should still favour remote lending. It should also favour applicants whose project outcomes are more correlated with local macroeconomic shocks, such as real estate developers: a risk averse bank would be especially hesitant to lend to such applicants if it could not securitize. This is an interesting question for future research.

Finally, securitization in our model worsens screening by allowing the entry of uninformed remote lenders. Another theory is moral hazard: securitization weakens a lender's incentive to screen when doing so is costly (Rajan *et al.*, 2010).⁴¹ The relative importance of these two theories is an interesting open question.

APPENDIX: PROOFS

Proof of Theorem 2. The remote bank's profit per borrower from offering the interest rate r is $\phi_R(r|\bar{\theta}, \mu) = r\bar{\zeta}E_{\bar{\theta}}[\theta|\theta \leq (r\mu)^{-1}] - 1$: its total profits $\Pi_R(r|\bar{\theta}, \mu)$ divided by its measure of borrowers $G_{\bar{\theta}}((r\mu)^{-1})$. It is increasing in the mean type $E_{\bar{\theta}}[\theta|\theta \leq (r\mu)^{-1}]$ of the remote bank's borrowers which, in turn, is increasing in the credit score $\bar{\theta}$ by ICE and non-increasing in the local profitability parameter μ (for fixed r). Now suppose the remote bank is willing to lend at $(\bar{\theta}', \mu')$ at the interest rate r' : $\phi_R(r'|\bar{\theta}', \mu')$ is non-negative. Then for any higher credit score $\bar{\theta}''$, $\phi_R(r'|\bar{\theta}'', \mu')$ must be positive: at the same interest rate r' , the remote bank strictly prefers to lend at $(\bar{\theta}'', \mu')$. So the remote bank lends if and only if the credit score exceeds the threshold $\bar{\theta}_{\mu}^* = \inf S_{\mu}$ where S_{μ} is the set of all credit scores $\bar{\theta}$ such that, for some interest rate r , $\phi_R(r|\bar{\theta}, \mu)$ — and thus $\Pi_R(r|\bar{\theta}, \mu)$ — is non-negative.⁴² The other claims in parts 2 and 3 follow from Proposition 2. As for part 1, $\bar{\theta}^*$ is non-decreasing in μ since, for any local profitability parameters $\mu'' > \mu'$, $S_{\mu''} \subseteq S_{\mu'}$:⁴³ $\bar{\theta}_{\mu''}^*$ cannot exceed $\bar{\theta}_{\mu'}^*$. And by ICE, as the credit score $\bar{\theta}$ converges to zero, the remote bank's profit per borrower $\phi_R(r|\bar{\theta}, \mu)$ converges to -1 : the threshold $\bar{\theta}^*$ is positive. For r to be optimal for bank R , bank L 's lending threshold $(r\mu)^{-1}$ cannot exceed one. Moreover, $\mu < \bar{\zeta}$ as shown just after equation (12). Hence, by ICE, $\lim_{\bar{\theta} \uparrow 1} E_{\bar{\theta}}[\theta|\theta \leq (r\mu)^{-1}] = (r\mu)^{-1} > (r\bar{\zeta})^{-1}$, so $\lim_{\bar{\theta} \uparrow 1} \phi_R(r|\bar{\theta}, \mu) > 0$: the threshold $\bar{\theta}^*$ is less than one. \parallel

Proof of Theorem 3, continued. The first part of this proof appears in section 5. It remains only to show rigorously that securitization cannot lower the partial surplus when the remote bank lends. Let ω equal either one or $1/\delta$, depending on whether the chosen scheme is A or B, respectively. Let $U(r, z) = \int_{\theta=z}^1 (\rho - r)\theta\bar{\zeta}dG_{\bar{\theta}}(\theta)$ denote the collective payoff of the agents when the interest rate is r and types $\theta \geq z$ are financed. Let $\tilde{\Pi}_L(r, \sigma) = \int_{\theta=(r\sigma)^{-1}}^1 (r\sigma\theta - 1)dG_{\bar{\theta}}(\theta)$ denote the local bank's payoff where r is the interest rate and the parameter σ equals $\delta\bar{\zeta}$ without securitization and μ with securitization. Without securitization, the agents get zero, so the partial surplus $PS_{\omega}^{\text{nosec}}$ is $\omega\tilde{\Pi}_L(\rho, \delta\bar{\zeta})$. With securitization, the partial surplus PS_{ω}^{sec} is $U(r_0, 0) + \omega\tilde{\Pi}_L(r_0, \mu)$ where r_0 is the interest rate offered by the remote bank. We decompose the change in the partial surplus that results from securitization as $PS_{\omega}^{\text{sec}} - PS_{\omega}^{\text{nosec}} = A + B + C$ where

$$A = U(\rho, 0) - U(\rho, (\delta\rho\bar{\zeta})^{-1}) = 0$$

is the effect of the remote bank's extending loans to all agents at the interest rate ρ ,

$$\begin{aligned} B &= - \int_{r=r_0}^{\rho} \frac{\partial}{\partial r} (U(r, 0) + \omega\tilde{\Pi}_L(r, \delta\bar{\zeta})) dr \\ &= \int_{r=r_0}^{\rho} \left[\int_{\theta=0}^1 \theta\bar{\zeta}dG_{\bar{\theta}}(\theta) - \omega \int_{\theta=(r\delta\bar{\zeta})^{-1}}^1 \delta\theta\bar{\zeta}dG_{\bar{\theta}}(\theta) \right] dr \\ &= \int_{r=r_0}^{\rho} \left[\int_{\theta=0}^{(r\delta\bar{\zeta})^{-1}} \theta\bar{\zeta}dG_{\bar{\theta}}(\theta) + (1 - \delta\omega) \int_{\theta=(r\delta\bar{\zeta})^{-1}}^1 \delta\theta\bar{\zeta}dG_{\bar{\theta}}(\theta) \right] dr \geq 0 \end{aligned}$$

41. Some policy responses are analysed in Bubb and Kaufman (2014) and Hartman-Glaser *et al.* (2012).

42. Let $\bar{\theta} > \bar{\theta}^*$. By definition of $\bar{\theta}^*$, there is a $\bar{\theta}'$ in $(\bar{\theta}^*, \bar{\theta})$ and a r' , such that $\phi_R(r'|\bar{\theta}', \mu) \geq 0$. But then $\phi_R(r'|\bar{\theta}, \mu) > 0$: the remote bank lends at $\bar{\theta}$. Alternatively, suppose that $\bar{\theta} < \bar{\theta}^*$. By definition of $\bar{\theta}^*$, $\phi_R(r'|\bar{\theta}, \mu) < 0$ for all $r' \leq \rho$: the remote bank does not lend at $\bar{\theta}$.

43. If $\bar{\theta} \in S_{\mu''}$, then $\phi_R(r|\bar{\theta}, \mu'') \geq 0$ for some r . But then $\phi_R(r|\bar{\theta}, \mu') \geq 0$ for the same r : $\bar{\theta} \in S_{\mu'}$.

is the effect of gradually lowering the interest rate from ρ to r_0 , and

$$C = \omega \int_{\sigma=\delta\bar{\zeta}}^{\mu} \frac{\partial}{\partial\sigma} \tilde{\Pi}_L(r_0, \sigma) d\sigma = \omega \int_{\sigma=\delta\bar{\zeta}}^{\mu} \left[\int_{\theta=(r_0\sigma)^{-1}}^1 r_0\theta dG_{\bar{\theta}}(\theta) \right] d\sigma \geq 0$$

is the effect of giving the local bank access to the securitization market. Hence $PS_{\omega}^{Sec} \geq PS_{\omega}^{nosec}$ as claimed. \parallel

Proof of Proposition 4. Since Ψ has no atoms, $\Psi(t) \leq k_0 t$ by Lipschitz- Ψ . Let $t_0 = (2k_0)^{-1}$, so $\Psi(t_0) \leq 1/2$, whence $t_0 \in (0, 1)$. Let $m_0 = m(t_0)$, which lies in $(0, 1)$ by part 1 of Proposition 3. By Lipschitz- Φ ,

$$\begin{aligned} \bar{\zeta} - \widehat{\Lambda} &= \int_{t=0}^1 \int_{\zeta=0}^1 \max\{0, \zeta - m(t)\} d\Phi(\zeta|t) d\Psi(t) \\ &\geq \int_{t=t_0}^1 \left(\int_{\zeta=\frac{1+m_0}{2}}^1 (\zeta - m_0) d\Phi(\zeta|t) \right) d\Psi(t) \geq \frac{k_2}{2} \left(\frac{1-m_0}{2} \right)^2 > 0, \end{aligned}$$

so $\widehat{\Lambda} < \bar{\zeta}$. Similarly,

$$\begin{aligned} \widehat{\Lambda} &= \int_{t=0}^1 \int_{\zeta=0}^1 \min\{\zeta, m(t)\} d\Phi(\zeta|t) d\Psi(t) \\ &\geq \int_{t=0}^{t_0} \int_{\zeta=m_0}^1 m_0 d\Phi(\zeta|t) d\Psi(t) \geq k_2 m_0 (1 - m_0) \Psi(t_0) \end{aligned}$$

which is positive since, by assumption, $\Psi(t_0) > 0$. \parallel

Proof of Theorem 4: The proof of part 1 is just the proof of part 1 of Theorem 2, with $(\mu, \bar{\theta}^*)$ replaced by $(\widehat{\mu}, \widehat{\theta}^*)$. Parts 2 and 3 are proved in the text. As for part 4, by (12) and (22) it suffices to show that $\widehat{\Lambda} > \Lambda$. Define $v(m(t), t) = E[\min\{\zeta, m(t)\}|t]$, so $\widehat{\Lambda} = E[v(m(t), t)]$ by the law of iterative expectations. By (10), it suffices to show that when $t \geq 0$, $v(m(t), t)^{1-\delta} E[\zeta|t]^\delta \geq E[\zeta|t=0]$.⁴⁴ The case $t=0$ holds since $m(0) = 1 > \zeta$. As for $t > 0$, $E[\zeta|t=0]$ is independent of t and $m(t)$ is decreasing in t . Hence, it suffices to show that when $m(t) < 1$,

$$0 < \frac{\frac{d}{dt}(v(m(t), t)^{1-\delta} E[\zeta|t]^\delta)}{v(m(t), t)^{1-\delta} E[\zeta|t]^\delta} = (1-\delta) \frac{\frac{d}{dt} v(m(t), t)}{v(m(t), t)} + \delta \frac{\frac{d}{dt} E[\zeta|t]}{E[\zeta|t]}. \tag{A.1}$$

By (20) and IVP, $\frac{dm(t)}{dt} = -\frac{1}{1-\delta} \frac{v_2(m(t), t)}{v_1(m(t), t)}$, so $\frac{d}{dt}[v(m(t), t)] = -\frac{\delta}{1-\delta} v_2(m(t), t)$, whence (A.1) can be rewritten as

$$0 < \frac{\frac{d}{dt} E[\zeta|t]}{E[\zeta|t]} - \frac{v_2(m(t), t)}{v(m(t), t)}. \tag{A.2}$$

Let $c \in [0, 1]$. Integrating by parts, $v(c, t) = c - \int_{\zeta=0}^c \Phi(\zeta|t) d\zeta$, so (A.2) must hold if, for $c < 1$,

$$0 < \frac{d^2}{dt dc} \ln \left(\int_{\zeta=0}^c [1 - \Phi(\zeta|t)] d\zeta \right) = \frac{d}{dt} \left[\frac{1 - \Phi(c|t)}{\int_{\zeta=0}^c [1 - \Phi(\zeta|t)] d\zeta} \right]. \tag{A.3}$$

By HRO, for all $\zeta' > \zeta''$, $\frac{1-\Phi(\zeta''|t)}{1-\Phi(\zeta'|t)}$ is decreasing in t . Integrating over $\zeta'' < \zeta'$, $\frac{\int_{\zeta=0}^{\zeta'} [1-\Phi(\zeta|t)] d\zeta}{1-\Phi(\zeta'|t)}$ is decreasing in t , which implies (A.3): $\widehat{\Lambda}$ exceeds Λ . Part 5 follows from part 1 of Theorem 2 since the definition of $\widehat{\theta}^*$ (equation (23)) is identical to that of $\bar{\theta}^*$ (equation (15)) except that μ is replaced by the higher $\widehat{\mu}$. \parallel

Acknowledgments. We thank Dimitri Vayanos (the editor) and three anonymous referees, as well as seminar participants at Copenhagen, Hebrew U., IDC-Herzliya, Lund, U. Minnesota, Stanford GSB, Tel Aviv, Warwick, the 2012 Workshop on Consumer Credit and Payments at FRB-Philadelphia, the 2013 AFA annual meeting, and the 2015 Econometric Society World Congress.

Supplementary Data

Supplementary data are available at *Review of Economic Studies* online.

44. The notation “ $f_0(t) \geq f_1(t)$ when $t \geq 0$ ” means that $f_0(t)$ exceeds (equals) $f_1(t)$ when t exceeds (equals) zero.

REFERENCES

- AGARWAL, S. and HAUSWALD, R. (2015), "The Choice Between Arms-Length and Inside Debt" (Mimeo).
- AXELSON, U. (2007), "Security Design with Investor Private Information", *Journal of Finance*, **62**, 2587–2632.
- BAGWELL, K. and RAMEY, G. (1991), "Oligopoly Limit Pricing", *RAND Journal of Economics*, **22**, 155–172.
- BANKS, J. S. and SOBEL, J. (1987), "Equilibrium Selection in Signalling Games", *Econometrica*, **55**, 647–661.
- BIAIS, B. and MARIOTTI, T. (2005), "Strategic Liquidity Supply and Security Design", *Review of Economic Studies*, **72**, 615–649.
- BRANDTS, J. and HOLT, C. A. (1992), "An Experimental Test of Equilibrium Dominance in Signaling Games", *American Economic Review*, **82**, 1350–1365.
- BUBB, R. and KAUFMAN, A. (2014), "Securitization and Moral Hazard: Evidence from Credit Score Cutoff Rules", *Journal of Monetary Economics*, **63**, 1–18.
- CAMERER, C. and WEIGELT, K. (1988), "Experimental Tests of a Sequential Equilibrium Reputation Model", *Econometrica*, **56**, 1–36.
- CASE, K. E., SHILLER, R. J. and THOMPSON, A. K. (2012), "What Have They Been Thinking? Homebuyer Behavior in Hot and Cold Markets", *Brookings Papers on Economic Activity*, Fall 2012, 265–298.
- CHENG, I.-H., RAINA, S. and XIONG, W. (2014), "Wall Street and the Housing Bubble", *American Economic Review*, **104**, 2797–3829.
- CHO, I.-K. and KREPS, D. (1987), "Signaling Games and Stable Equilibria", *Quarterly Journal of Economics*, **102**, 179–221.
- DANG, T. V., GORTON, G. and HOLMSTRÖM, B. (2013), "Ignorance, Debt, and Financial Crises" (Mimeo, Yale University).
- DEGRYSE, H. and ONGENA, S. (2005), "Distance, Lending Relationships, and Competition", *Journal of Finance*, **60**, 231–266.
- DELL'ARICCIA, G., FRIEDMAN, E. and MARQUEZ, R. (1999), "Adverse Selection as a Barrier to Entry in the Banking Industry", *RAND Journal of Economics*, **30**, 515–534.
- DELL'ARICCIA, G. and MARQUEZ, R. (2004), "Information and Bank Credit Allocation", *Journal of Financial Economics*, **72**, 185–214.
- DEMARZO, P. and DUFFIE, D. (1999), "A Liquidity-Based Model of Security Design", *Econometrica*, **67**, 65–99.
- DEMARZO, P., FRANKEL, D. M. and JIN, Y. (2015), "Portfolio Liquidation and Security Design with Private Information" (Mimeo), available at SSRN: <http://ssrn.com/abstract=2591218> (last accessed on April 9, 2015).
- DEMYANYK, Y. and VAN HEMERT, O. (2009), "Understanding the Subprime Mortgage Crisis", *Review of Financial Studies*, **24**, 1848–1880.
- DE YOUNG, R., GLENNON, D. and NIGRO, P. (2008), "Borrower–Lender Distance, Credit Scoring, and Loan Performance: Evidence from Informational-Opaque Small Business Borrowers", *Journal of Financial Intermediation*, **17**, 113–143.
- ELUL, R. (2015), "Securitization and Mortgage Default", *Journal of Financial Services Research* (forthcoming).
- FINANCIAL CRISIS INQUIRY COMMISSION. (2011), "The Financial Crisis Inquiry Report (Official Government Edition)", U.S.G.P.O.
- FOOTE, C. L., GERARDI, K. S. and WILLEN, P. S. (2012), "Why Did So Many People Make So Many *Ex Post* Bad Decisions? The Causes of the Foreclosure Crisis", in Blinder, A. S., Lo, A. W., and Solow R. M. (eds.), *Rethinking the Financial Crisis* (Russell Sage and Century Foundations), pp. 136–186.
- FRANKEL, D. M. and JIN, Y. (2011), "Securitization and Lending Competition", Iowa State University (Working Paper No. 11025).
- FRANKEL, D. M. and JIN, Y. (2013), "Securitization and Lending Competition: Online Appendix" (Mimeo).
- FUDENBERG, D. and TIROLE, J. (1991), *Game Theory*. (Cambridge, MA: MIT).
- GORTON, G. B. and HAUBRICH, J. G. (1990), "The Loan Sales Market", *Research in Financial Services*, **2**, 85–135.
- HARTMAN-GLASER, B., PISKORSKI, T. and TCHISTYI, A. (2012), "Optimal Securitization with Moral Hazard", *Journal of Financial Economics*, **104**, 186–202.
- HAUSWALD, R. and MARQUEZ, R. (2006), "Competition and Strategic Information Acquisition in Credit Markets", *Review of Financial Studies*, **19**, 967–1000.
- HILL, C. A. (1996), "Securitization: A Low-Cost Sweetener for Lemons", *Washington University Law Quarterly*, **74**, 1061–1120.
- JAFFEE, D. M. and ROSEN, K. T. (1990), "Mortgage Securitization Trends", *Journal of Housing Research*, **1**, 117–137.
- KEYS, B. J., MUKHERJEE, T., SERU, A. and VIG, V. (2010), "Did securitization Lead to Lax Screening? Evidence from Subprime Loans", *Quarterly Journal of Economics*, **125**, 307–362.
- KEYS, B. J., SERU, A. and VIG, V. (2012), "Lender Screening and the role of Securitization: Evidence from Prime and Subprime Mortgage Markets", *Review of Financial Studies*, **25**, 2071–2108.
- KEYS, B. J., PISKORSKI, T., SERU, A. and VIG, V. (2012), "Mortgage Financing in the Housing Boom and Bust", in Glaeser, E. L. and T. Sinai (eds.), *Housing and the Financial Crisis* (Chicago: University of Chicago Press), pp. 143–204.
- KRAINER, J. and LADERMAN, E. (2014), "Mortgage Loan Securitization and Relative Loan Performance", *Journal of Financial Services Research*, **45**, 39–66.

- LELAND, H. E. and PYLE, D. H. (1977), "Informational Asymmetries, Financial Structure, and Financial Intermediation", *Journal of Finance*, **32**, 371–387.
- LOUTSKINA, E. and STRAHAN, P. E. (2011), "Informed and Uninformed Investment in Housing: The Downside of Diversification", *Review of Financial Studies*, **24**, 1447–1480.
- MA, Y. (2014), "Bank CEO Optimism and the Financial Crisis" (Mimeo, Harvard University).
- MIAN, A. and SUFI, A. (2009), "The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis", *Quarterly Journal of Economics*, **124**, 1449–1496.
- MISTRULLI, P. E. and CASOLARO, L. (2008), "Distance, Lending Technologies and Interest Rates" (Mimeo, Bank of Italy).
- MYERS, S. and MAJLUF, N. (1984), "Corporate Financing and Investment When Firms Have Information Shareholders Do Not Have", *Journal of Financial Economics*, **13**, 187–221.
- NACHMAN, D. and NOE, T. (1994), "Optimal Design of Securities Under Asymmetric Information", *Review of Financial Studies*, **7**, 1–44.
- PETERSEN, M. A. and RAJAN, R. G. (2002), "Does Distance Still Matter? The Information Revolution in Small Business Lending", *Journal of Finance*, **57**, 2533–2570.
- RAJAN, R. G. (1992), "Insiders and Outsiders: The Choice between Informed and Arm's-Length Debt", *Journal of Finance*, **47**, 1367–1400.
- RAJAN, U., SERU, A. and VIG, V. (2010), "Statistical Default Models and Incentives", *American Economic Review (Papers and Proceedings)* **100**, 506–510.
- RAJAN, U., SERU, A. and VIG, V. (2015), "The Failure of Models That Predict Failure: Distance, Incentives and Defaults", *Journal of Financial Economics*, **115**, 237–260.
- SHAKED, M. and SHANTHIKUMAR, J. G. (2007), *Stochastic Orders* (New York: Springer).
- SHARPE, S. (1990), "Asymmetric Information, Bank Lending and Implicit Contracts: A Stylized Model of Customer Relationships", *Journal of Finance*, **55**, 1069–1087.
- SHIN, H. S. (2009), "Securitization and Financial Stability", *Economic Journal*, **119**, 309–332.
- von THADDEN, E.-L. (2004), "Asymmetric Information, Bank Lending and Implicit Contracts: the Winner's Curse", *Finance Research Letters*, **1**, 11–23.
- WANG, Y. (2009), "Cracks in the Foundation: A Transactional Study of Non-Agency Residential Mortgage-Backed Securities" (Mimeo, Harvard Law School).