Competition and Strategic Information Acquisition in Credit Markets

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We investigate the interaction between banks' use of information acquisition as a strategic tool and their role in promoting the efficiency of credit markets when a bank's ability to gather information varies with its distance to the borrower. We show that banks acquire proprietary information both to soften lending competition and to extend their market share. As competition increases, investments in information acquisition fall, leading to lower interest rates but also to less efficient lending decisions. Consistent with the recent wave of bank acquisitions, we also find that merging for informational reasons with a competitor is an optimal response to industry consolidation.

The importance of financial intermediaries in the production of information and, hence, their contribution to improving the functioning of credit markets has long been recognized.[1] Less well understood is the broader role that information plays as part of banks' strategies to compete in a changing industry, which in recent years has seen both the rapid entry of new players[2] as well as dramatic consolidation (Berger *et al.* 1999). We argue that such changes create an incentive for banks to acquire private information to gain market share and maintain profitability. Understanding the interaction between intermediaries' strategic use of information and their function in promoting the efficient allocation of credit has therefore become important from both a practical and a policy perspective. In this article, we

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[1] See, for example, Diamond (1984), Ramakrishnan and Thakor (1984), or Allen (1990).

[2] For instance, the recent deregulation of the banking industry, both in the United States and in Europe, have allowed banks to enter and compete in markets in which they previously had no presence. Similarly, recent technological advances such as automated credit scoring and other improvements in banks' data processing capabilities are often cited as reasons behind the increased competition in credit markets.

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characterize the nature of this interaction and derive implications for the welfare properties of credit markets.

To study these issues, we present a model in which banks enter a loan market and invest resources to collect borrower-specific information. To capture the varying degrees of informational expertise present in modern banking, we take the quality of the information-generation process to be a decreasing function of the distance between bank and borrower. Banks compete for borrowers by deciding whether to screen a loan applicant, whether to offer credit, and on what terms. Lastly, borrowers choose the bank with the best quote.

Our analysis shows that intermediaries' acquisition of proprietary information serves a dual purpose. First, it allows banks to create a threat of adverse selection for their rivals, thus softening price competition.[3] Second, by conducting credit assessments, banks are able to "poach" customers from competitors, thereby extending their market share. However, any attempts to steal competitors' business are tempered by the diminishing ability of intermediaries to generate borrower-specific information as they move away from their area of expertise. This reliance on proprietary intelligence to carve out a captive market highlights an important strategic use of information that, to the best of our knowledge, has not been studied before.

An implication of our model is that both the availability and the pricing of credit should depend on the distance between banks and borrowers. In particular, we find that borrowers located farther away from the bank that has screened them benefit from lower rates but that lending decisions become less efficient as distance increases. The intuition for this finding is that, because banks obtain less precise information for more distant loan applicants, these borrowers will be less informationally captured and, hence, elicit greater competition from other lenders.

Our analysis also sheds light on the likely effect of changes in the competitive structure of credit markets. In our model, increased competition reduces intermediaries' rents and decreases their overall incentives to generate information, thereby affecting both the pricing and the allocation of credit. These effects have two direct consequences. First, intermediaries compete more aggressively because the reduction in private information for each bank implies that their competitors suffer less from adverse-selection problems. Second, however, less information production means that banks are more prone to make errors in their lending decisions as competition intensifies.

From a social-welfare perspective, information acquisition increases the efficiency of credit markets because it helps allocate funds to

[3] See also Sharpe (1990), Rajan (1992), Hauswald and Marquez (2003), or von Thadden (2004) on this point.

creditworthy borrowers. However, our analysis shows that intermediaries devote too many resources to screening activities relative to the social optimum. This overinvestment occurs because all banks attempt to gain market share from their rivals through their investments in information acquisition. Because all banks follow similar strategies, they invest too much in screening without effectively increasing their captive market in equilibrium. These results suggest that policies that constrain banks' ability to invest in information may in fact increase social welfare by reducing the resources spent on these activities.

The strategic role of information acquisition that we identify also has implications for the structure of the banking industry. In particular, we characterize conditions under which banks have an incentive to merge if doing so allows them to coordinate their screening activities across branches. We find that merged banks reduce their informational investments as a result of such coordination. Consistent with empirical evidence, our analysis shows that this reduction enables any independent competitors to capture market share from the merged entity and increase their own profitability. Hence, banks that remain independent benefit from the merger activity of their rivals. Nevertheless, we also find that the independent banks' optimal response to a merger is for them to seek a merger partner as well, thus reducing inefficient overinvestments even further. In this context, our model provides unique insights into the recent wave of mergers in credit markets by showing that merging may be an optimal response to industry consolidation purely as a consequence of banks' information-acquisition strategies. Furthermore, it suggests that, from a policy perspective, mergers may have the socially beneficial effect of curtailing wasteful informational investments.

Casting varying degrees of lending expertise in terms of differentiated information acquisition allows us to analyze the interdependence between banks' information-acquisition strategies and the competitive structure of the industry, an issue that has been largely unexplored. While some of our empirical predictions on loan pricing resemble those from transportation-cost models (see, e.g., Chiappori *et al.* 1995), our approach identifies a unique link between banks' strategies for generating information and the degree of product differentiation that arises endogenously from each bank's investment decisions. Hence, our analysis provides novel explanations for observed empirical regularities and identifies a new channel for strategic interaction in credit markets that traditional models of product differentiation or of banking competition cannot capture.

Recent literature has studied how differential information among intermediaries induces specialization in lending. For instance, Gehrig (1996, 1998) focuses on banks' incentives to produce information. Winton (1999) argues that banks may have an incentive to specialize if diversification were to lower their incentive to monitor borrowers and therefore increase their probability of failure. Closest to our work, Almazan (2002) analyzes a model in which a bank's monitoring expertise is a decreasing function of the distance between borrower and bank. In a similar vein, Chiesa (1998) analyzes the incidence of bank capital on loan screening and portfolio choice. This literature, however, does not consider the role of information acquisition in helping banks to capture market share and, hence, does not endogenize the industry structure.

Similar in spirit to our work, Sharpe (1990) and Rajan (1992) study borrowing under adverse selection and show that relationship building may constrain competition in the refinancing stage. In the context of creditworthiness tests, Broecker (1990) and Riordan (1993) both investigate the potentially negative effects of competition on loan markets under independent loan screening. Dell'Ariccia (2001) shows that private information can serve to constrain entry into the industry. There is also recent work on how banks can limit other lenders' scope of entry by sharing information and encouraging borrower poaching (see, e.g., Bouckaert and Degryse 2005 or Gehrig and Stenbacka 2001). None of these papers, however, endogenize the generation of information, an issue that is central to our work. This article is also related to recent work on how increased credit-market competition changes the incentives to forge banking relationships, such as in Boot and Thakor (2000) or Dinc (2000). By contrast, we analyze how the strategic acquisition of information leads to loan differentiation and drives profitability in lending.

From an empirical perspective, Petersen and Rajan (2002) have highlighted the link between geographical distance and bank-borrower relationships and find that distance seems to be a good, though over time declining, indicator of the strength of a lending relationship. Similarly, Degryse and Ongena (2005) find that loan rates decrease in the distance from lending bank to borrower but increase in the distance of borrower to competitor bank, as predicted by our analysis. Using industry specialization as an alternative way of measuring the distance between borrower and lender, Acharya *et al.* (2004) find strong evidence that a bank's informational effectiveness is lower in newly entered or more competitive sectors. As a result, lending in these sectors leads to lower loan quality which, in light of our results, may be a consequence of the higher threat of adverse selection in such markets.

The article is organized as follows. The next section presents a model of financial intermediation and information acquisition. Section 2 derives the lending equilibrium for a given information acquisition strategy, while Section 3 characterizes the overall credit-market equilibrium. Sections 4 and 5 analyze the welfare properties of the equilibrium and the consequences of merger activity, respectively. Section 6 discusses empirical implications and concludes. Proofs are mostly relegated to the Appendix.

1. A Model of Locationally Differentiated Credit Assessment

Let a continuum of borrowers with mass M be uniformly distributed along a circle with circumference 1. Each potential borrower has an investment project that requires an initial outlay of \$1 and that can be of either high $(\theta = h)$ or low $(\theta = l)$ quality. The projects of high-quality borrowers generate a terminal cash flow $R > 0$ with certainty, whereas those of low-quality borrowers always fail, yielding 0. Final cash flows are observable and contractible, but project type θ is unknown to either borrower or lender.[4] The likelihood of finding a high-quality firm is $q \in (0, 1)$ and this distribution of borrower types is common knowledge. We also assume that borrowers have no private resources and that $qR > 1$, that is, it is *ex ante* efficient to grant a loan.[5]

N banks compete for these borrowers in three stages. First, banks decide whether or not to enter the loan market and how much to invest in a screening technology that generates borrower-specific information. We assume that any entering banks will locate equidistantly around the circle. Given its investment, each bank next decides whether or not to screen a loan applicant. Such credit assessment provides the bank with private information about a borrower's type. Conditional on entry and any borrower-specific information, banks compete in the third stage by simultaneously offering loans at gross interest rates $r \geq 0$ or may decide not to make such offers. Borrowers choose last by accepting a loan from the bank quoting the lowest rate. Figure 1 shows the model's time structure.

Information acquisition requires a costly investment in a screening technology. This investment allows intermediaries to gather

Stage 1	Stage 2	Stage 3
Entry	*Screening*	*Lending Competition*
Banks decide to enter market	Borrowers apply for loans	Banks compete for borrowers
Locate equidistantly	Banks decide to screen	Borrowers choose banks and invest
Screening investment I	Screening results: η	Contracts settled

Figure 1
Time structure of the model

[4] Alternatively, we could assume that there are no self-selection or sorting devices such as collateral available because, for example, the borrower is wealth constrained.

[5] Although M simply represents a scaling factor guaranteeing that at least two banks are active in equilibrium, we also restrict M and q jointly so that $M(1-q) \in (1, 4/3)$. This assumption ensures that banks will not have an incentive to engage in ruinous competition and will therefore obtain positive profits in equilibrium. A simple scaling of the cost function suffices to relax this assumption.

customer-specific information at a per-borrower cost $c > 0$.[6] Such credit screens yield a signal $\eta \in \{l, h\}$ with quality ϕ that is defined as

$$\phi = \Pr(\eta = h | \theta = h) = \Pr(\eta = l | \theta = l) \tag{1}$$

We assume that the creditworthiness signal's quality ϕ increases in the bank's screening effort or investment I in information-gathering expertise but is decreasing in the borrower's distance x to the bank. Specifically,

$$\phi(x) = \frac{1+I}{2} - x \quad \text{for } x \in \left[0, \frac{I}{2}\right], \tag{2}$$

and 1/2 otherwise. The investment imposes a cost on banks that, for simplicity, we take to be quadratic: $(1/2)I^2$. In addition, banks incur a fixed cost T that reflects the cost of installing and maintaining the resources needed to process information or any possible regulatory cost when entering the credit market. Our specification captures the idea that banks enjoy an informational advantage in the market segments in which they operate, but this expertise is reduced as banks seek to transact with customers located further away. As a result, banks can resort to discriminatory pricing through their interest rate offers as a function of the informational content of their credit screens.

If more than one bank try to screen the same borrower, we assume that the bank with inferior expertise can only gather information about a better-informed bank's borrower-specific knowledge. In particular, if $\phi_i(x) > \phi_j(y)$ for a borrower located at a distance x from bank i and y from bank j, we assume that the information obtained by bank j is a noisy signal on the outcome of bank i's credit assessment. Hence, we can think of the more informed bank as possessing not only all the information of any less-informed bank but also some private information. This assumption captures the notion that all banks ultimately attempt to analyze the same set of data, but that the amount of information obtained depends on each bank's expertise.

In contrast to other treatments of competition with differentiated products (e.g., Salop 1979), we use the concept of bank-borrower distance to model differential screening ability of intermediaries. Bank location can therefore represent expertise in a particular market segment, be it a specific geographic market, a particular industry, or a certain credit product. When banks branch out from their home market by, for instance, opening new branches in previously unserved market locations,

[6] The magnitude of the screening cost c is not relevant for our results, as long as it is not strictly zero. Otherwise, banks would always choose to screen loan applicants even if they could not profit from the information obtained. In analyzing the properties of the equilibrium, we will consider the limiting case where $c \to 0$.

acquiring intermediaries elsewhere, or expanding their customer base beyond a given industry or loan product, they often compete at a disadvantage to existing players in the market. Our setup is consistent with the evidence in Acharya *et al.* (2004) that expanding into new markets or industries leads to higher levels of risk and erodes banks' informational capabilities.

In the context of relationship banking, costly screening can also serve as a metaphor for the time, effort, and resources that it takes to build lending relationships and for the losses that a bank might incur during this period.[7] Hence, we can interpret the screening quality ϕ as the *relative* information advantage of the relationship bank over competitors rather than the *absolute* amount of information a particular lender has.

2. Lending Competition

We first derive the (Perfect Bayesian) equilibrium of the lending game. Starting with the last stage, each bank competes for borrowers with all competitor banks that entered the market. However, a standard feature of this class of models is that the equilibrium can be fully characterized by assuming that each bank competes only with its nearest neighbor on either side (e.g., Engelbrecht-Wiggans *et al.* 1983). Hence, it suffices to study the case of two adjacent banks, one informed and one uninformed, vying for the business of borrowers located between them. We verify in the next section that this approach is indeed appropriate as each borrower will be screened by at most one bank. By symmetry, both banks will be informed about some borrowers and uninformed about others so that we arbitrarily label one intermediary i for informed and the other one u for uninformed.

As has been demonstrated in similar contexts (see, e.g., Broecker 1990 or von Thadden 2004), the interest rate game between two neighboring banks does not have an equilibrium in pure strategies when one bank has superior information. However, we show in the following proposition that a unique equilibrium in mixed strategies over interest-rate offers does exist. Letting $\pi_i(\eta, x)$ denote the expected profit for the informed bank from lending to a borrower located at a distance x with credit assessment η, we have:

Proposition 1. *The bidding game for a given borrower located at a distance x from bank i and $y = (1/N) - x$ from bank u has a unique, mixed-strategy equilibrium, such that*

[7] For instance, James (1987) and Lummer and McConnell (1989) present evidence suggesting that banks have access to private information over the course of the lending relationship.

1. *the uninformed bank breaks even while the informed bank earns positive ex ante (i.e., before the observation of the signal) expected profits given by* $E[\pi_i(\eta, x)] = (1-q)[2\phi(x) - 1]$;
2. *for screening quality* $\phi(x) > \bar{\phi}$, *where* $\bar{\phi} < 1$, *the informed bank denies credit to applicants deemed of low quality* $(\eta = l)$ *while the uninformed bank refrains from offering credit with probability* $1 - \beta(\phi(y)) > 0$; *for* $\phi(x) \leq \bar{\phi}$, *both the informed and the uninformed banks always offer credit to all borrowers.*

Proof. See Appendix.

The lending game has an outcome reminiscent of Bertrand competition. Since the uninformed lender has no private information about the borrower, it is unable to obtain any rents from the loans it grants. An informed bank can use its ability to distinguish good from bad credit risks to adjust its lending strategy accordingly and thus to subject less informed lenders to problems of adverse selection. As a result, an informed lender extracts rents from borrowers deemed to be of high quality by exploiting its informational advantage over competitors.

Proposition 1 also establishes that *ex ante* expected profits for the informed intermediary (before the observation of the signal η) are linear in the informativeness ϕ of the credit assessment and depend on borrower attributes, such as their distribution q. As the pool of borrowers worsens (a decrease in the fraction q of high-quality applicants), an informed bank earns higher profit on those borrowers with good signals. Behind this part of the proposition lies the adverse-selection problem faced by the uninformed bank because screening becomes more important the more low-quality borrowers apply for credit. Note that for sufficiently informative credit screens $(\phi(x) > \bar{\phi})$, the informed bank can rule out lending to borrowers deemed of low quality. However, if the credit screen is relatively uninformative $(\phi(x) < \bar{\phi})$, all borrowers obtain credit, albeit at different interest rates. In this situation, the uninformed bank suffers less from adverse-selection problems and always makes a competing loan offer.

Proposition 2. *Expected interest rates paid by both high- and low-quality borrowers that receive a loan offer increase in the informativeness of the credit assessment* $\phi : \frac{\partial}{\partial \phi} E[r|\theta, \mathit{offer}] > 0$ *for* $\theta \in \{l, h\}$.

The probability that a borrower receives a loan offer from an uninformed bank decreases in the information advantage of the informed bank: $\partial\beta/\partial\phi < 0$.

Proof. See Appendix.

As the quality of the credit assessment increases, the informed bank can more easily filter out bad credit risks. As a result, borrowers become more informationally captured and only receive loan offers at higher interest rates. Since improved screening increases the threat of adverse selection, an uninformed bank will bid less aggressively by offering credit less frequently as well as by raising its interest rate whenever it makes a loan offer. Taken together, these effects imply that expected interest rates paid by borrowers of both high- and low-credit quality increase in the precision of the information obtained by the informed bank.

Corollary 1. *Expected interest rates paid by both high- and low-quality loan applicants that receive a loan offer decrease in the distance x between the informed bank and the borrower:* $\frac{\partial}{\partial x}E[r|\theta, \mathit{offer}] < 0$ *for* $\theta \in \{l, h\}$.

Proof. The result follows from Proposition 2, $\partial\phi/\partial x < 0$, and an application of the chain rule.

Because the quality of information decreases in the distance between the informed bank and the borrower, the expected interest rate on any loan offer must also be decreasing as a function of this distance. Conversely, keeping the distance between banks constant, interest rates are an increasing function of the distance between the uninformed competitor and the borrower. The intuition is simply that the closer a borrower is located to an informed competitor, the greater the adverse selection problem becomes for an uninformed bank. As the distance between the borrower and the informed bank increases, this intermediary's information advantage decreases, and the uninformed bank is able to bid more aggressively. The same effect is at work regarding the probability of a competing offer by an uninformed bank: the greater the distance between the informed bank and the borrower, the smaller the relative informational advantage of the informed bank, and the more likely is an offer by an uninformed lender.

The finding in Degryse and Ongena (2005) that loan rates decrease in the physical distance between a corporate borrower and the lending bank but increase in the distance between the firm and competing banks provides evidence in support of this prediction. Furthermore, by taking $x = x(t),\ x' < 0$, where t represents the length of time a particular firm has interacted with an informed lender, we can also think of bank-borrower distance as capturing, in equilibrium, the duration of a lending relationship. Degryse and Van Cayseele (2000) report that interest rates increase in the duration of lending relationships, which is again consistent with Proposition 2: as banks invest in borrower-specific information acquisition and become more informed over time, they charge higher loan rates to their captive borrowers.[8]

3. Market Equilibrium and Screening Incentives

We now turn to the banks' decision to acquire information and to the industry equilibrium. Because all banks are *ex ante* symmetric, we focus throughout on a symmetric equilibrium in information acquisition, denoting a given intermediary by $n \leq N$. We first verify that, in equilibrium, each loan applicant is screened by at most one bank and characterize the marginal borrower screened by each intermediary. To this end, we define the marginal customer for which bank n has an informational advantage over its neighbor as $\tilde{x}_n \equiv \max\{x : \phi_n(x) \geq \phi_{n+1}(\frac{1}{N} - x)\}$.

Lemma 1. *In equilibrium, borrowers are screened by at most one bank. Intermediaries assess a borrower's creditworthiness up to a maximal distance* $\hat{x}_n = \min\{\frac{1}{2}\frac{(1-q)I-c}{(1-q)},\ \tilde{x}_n\}$.

Proof. See Appendix.

By deriving a bank's choice of the marginal borrower that it screens, Lemma 1 is the foundation for our exploration of strategic information acquisition. The requirement that $\hat{x}_n$ be no greater than $(1/2)[(1-q)I-c]/(1-q)$ follows from the fact that, with insufficient entry, banks enjoy a local monopoly and will only screen borrowers as long as $E[\pi_n(\eta, \hat{x}_n)] \geq c$. In a symmetric equilibrium, all banks invest equally in I, implying that $\hat{x}_n \leq \frac{1}{2N}$. It is therefore clear that a bank would like to screen more borrowers ($\hat{x}_n$ is greater), the smaller the number of active banks and the larger its investment.

This lemma also justifies our analysis in the previous section of one informed bank competing against a number of uninformed ones. If more than one bank were to screen a borrower, competition among these banks would drive profits to zero for all but the most informed bank. Because it would never pay to assess a borrower also screened by a better informed rival, $\hat{x}_n$ is the borrower located the furthest away that bank n could profitably screen. For borrowers beyond $\hat{x}_n$, bank n makes loan offers on an uninformed basis. One possible interpretation of such lending is that it represents transactional loans. In this context, Lemma 1 and Proposition 1 imply that every bank offers two types of loans in equilibrium: relationship lending based on the information it has acquired about borrowers in its captive market and transactional lending outside this core segment.

[8] To the extent that informed lending provides insurance against random shocks to profitability, it is also beneficial to borrowers even at the price of being partially locked in to their bank. See Petersen and Rajan (1995) for evidence to this effect.

We note that the probability of a competing uninformed loan offer can serve to measure not only the competitiveness of the market, but also the scope for multiple lending relationships. In our model, all borrowers may obtain competitive loan offers from an uninformed bank, albeit with a probability that is decreasing in the quality of the screening bank's information. Accepting a competing offer from an uninformed lender can therefore be interpreted as the development of a second banking relationship. For instance, Detragiache *et al.* (2000) found that in the United States nearly half of firms with less than 500 employees have only one banking relationship, suggesting that firms may be somewhat captive to their existing lenders, but also that many of them do in fact obtain loans from multiple lenders.

Furthermore, since the screening precision ϕ decreases in distance, the scope for multiple lending relationships increases in the distance from the informed bank to the borrower. Since in equilibrium only one bank will screen any given borrower, this finding is consistent with interpreting the distance between loan applicant and screening bank as the age or size of firms. Under this interpretation, firms located farther away are larger or older, and are therefore more transparent because of the greater amount of publicly available information, so that the information advantage of the screening bank is relatively low.[9] By Proposition 2, borrowers located at roughly the same distance between two neighboring banks should attract more competition as intermediaries vie to establish lending relationships with these borrowers. Evidence on single vs. multiple lending relationships is consistent with this prediction. For instance, Farinha and Santos (2002) report that the likelihood of switching from single to multiple lending relationships increases with a firm's age.

3.1 Informational investments

Given the number of banks N, an intermediary n will choose its informational investment $I_n \in [0, 1]$ so as to maximize profits

$$V_n = 2M \int_0^{\hat{x}_n} \{(1-q)[2\phi(x) - 1] - c\}dx - \left(\frac{I^2}{2} + T\right), \tag{3}$$

where the first term represents the bank's total revenue summed across all borrowers, and the second term is just the total cost of the screening technology. Since we are interested in information acquisition in the face of increasing competition, we will henceforth assume that N is sufficiently large that in equilibrium $\hat{x}_n = \frac{1}{2N}$, that is, the entire market is covered.

[9] It has been argued that more mature firms attract a larger analyst following, generate more coverage in the business press, and tend to have more active institutional shareholders, all of which render them informationally more transparent as evidenced by the recent S&P Transparency and Disclosure scores.

Proposition 3. *For a given number of intermediaries $N \geq 2$ and for $c \to 0$, there exists a unique symmetric equilibrium in information-acquisition strategies with $I_n^* = I^*(N) = \frac{M(1-q)}{N[2-M(1-q)]}$ for all $n \leq N$. This investment falls with more competition (an increase in N) and is greater in markets with a lower average borrower quality (a decrease in q).*

Proof. See Appendix.

In equilibrium, each bank screens all potential borrowers halfway to its nearest competitor (Figure 2) so that its captive market extends up to $\hat{x}_n(I^*) = \frac{1}{2N}$. Subsequently, however, each bank faces competition at the lending stage from its uninformed rivals. Informational investments, by increasing the precision of the credit screen ϕ and therefore the extent of adverse selection, soften competition in the lending market and reduce the probability β that an uninformed bank offers credit (Proposition 2).

Information acquisition also serves a second and distinct strategic purpose, in that intermediaries can try to extend their captive market through their investments in information. Specifically, each bank has an incentive to invest resources in an attempt to poach customers that are

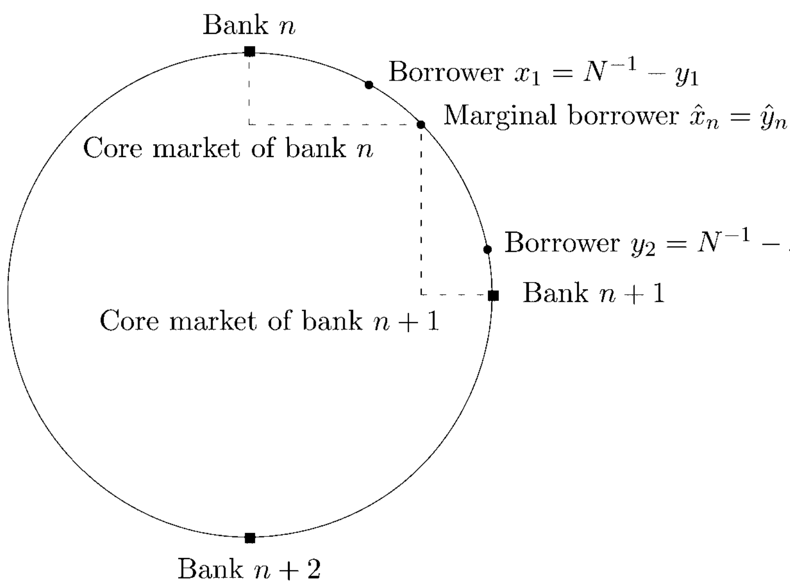

Figure 2
Informed lending markets
In equilibrium, banks n and $n+1$ screen loan applicants up to a distance $\hat{x}_n = \hat{y}_n = \frac{1}{2N}$. Borrowers located between bank n and its marginal borrowers $\hat{x}_n$ comprise its core market.

located closer to a competing bank. Hence, our framework identifies information acquisition as a novel channel for the familiar "business-stealing" effects that have been observed in, for instance, the introduction of new products or advertising (Tirole 1988). By increasing I, each bank hopes to encroach on its rival's captive market, thus increasing its own market share and profit. However, since all banks follow identical strategies in equilibrium, such attempts are not successful and simply lead to overinvestment.[10]

To see the importance of this effect, we compare the results above to a setting in which banks enjoy an informational monopoly. In this case, banks agree not to steal each other's customers, but instead to carve up the market equally and commit *ex ante* to screen only up to the halfway point to the nearest competitor. The maximization problem for each bank would now yield an optimal investment of $I^{\text{mon}} = M(1-q)/N < I^*$. The excess $I^* - I^{\text{mon}} > 0$ represents a pure overinvestment in information acquisition that, although it improves lending efficiency, reduces each bank's profit.

Proposition 3 also establishes intuitive comparative-statics properties of the equilibrium. With more banks, the investment in screening technology for each bank falls because more competition reduces the returns to information acquisition. When borrowers are on average of lower quality (a decrease in q), creditworthiness assessments become more important: as the risk of lending to a low-quality borrower grows, banks invest more in the screening technology, which helps them to avoid inefficient lending decisions. At the same time, from Proposition 1 we know that their profits rise as the average quality q of borrowers decreases.

3.2 Information production and competitive loan pricing

We now analyze the effect of competition on the expected interest rates paid by borrowers. As a direct consequence of Proposition 3, the equilibrium informativeness of credit screens $\phi^* = \phi(I^*)$ decreases in the number of active banks: $\frac{\partial \phi^*}{\partial N} = \frac{\partial \phi}{\partial I}\frac{\partial I^*}{\partial N} < 0$. At the same time, the likelihood of a competing bid from an uninformed bank increases as the informed banks' informational advantage shrinks: $\frac{\partial \beta}{\partial N} = \frac{\partial \beta}{\partial \phi}\frac{\partial \phi^*}{\partial N} > 0$. Combining the preceding observations with Proposition 2 yields the following:

Proposition 4. *Expected interest rates paid by both high- and low-quality borrowers that receive a loan offer decrease in the number of active banks:* $\frac{\partial}{\partial N}E[r|\theta,\ \mathit{offer}] < 0$ *for* $\theta \in \{l, h\}$.

[10] This strategic use of information acquisition is very different from the softening of *ex ante* competition for borrowers resulting from the disclosure of proprietary intelligence as in Bouckaert and Degryse (2005) or Gehrig and Stenbacka (2001). Such disclosure also weakens borrowers' informational capture, whereas in our model an increase in proprietary information serves to preserve the intermediaries' *ex post* potential for rent extraction.

Proof. By Proposition 2, $\frac{\partial}{\partial \phi} E[r|\theta,\text{ offer}] > 0$ so that the result follows from $\partial \phi^* / \partial N < 0$ and the chain rule.

Since entry reduces informational investments, an uninformed bank can compete more aggressively for a given loan applicant because it faces a diminished threat of adverse selection. As a result, interest rates paid by both high- and low-quality borrowers decline as the number of banks increases. This finding contrasts with predictions of models that take information acquisition as exogenous. In Broecker (1990), for instance, the inference problem for each bank worsens even as the aggregate amount of information increases with the number of competitors, leading banks to bid less aggressively and interest rates to rise.

Similarly, we can investigate the effect of competition on the aggregate amount of information produced, which can be expressed as $\Phi(N) = 2N \int_0^{1/(2N)} \phi_n^*(x, N)\, dx$. Simple differentiation shows that aggregate information production decreases as the number of banks increases. Hence, we would expect average interest rates paid by both good and bad credit risks to decline as the number of banks increases.

The preceding results suggest that increased competition is beneficial as it leads to lower interest rates paid on average. However, the more aggressive loan pricing results from a reduced incentive to invest in screening. While interest rates decline, banks also make less efficient lending decisions.[11]

3.3 Free-Entry Equilibrium

We next establish the existence of a free-entry equilibrium and characterize the effect of changes in technological or regulatory barriers to entry into credit markets.

Proposition 5. *There exists a free-entry equilibrium with $N^e > 0$ active intermediaries and corresponding informational investment $I^*(N^e) > 0$. A reduction in the fixed cost T increases N^e, thus leading to a decrease in the equilibrium investment I^*.*

Proof. See Appendix.

A lowering of entry barriers, as represented by a reduction in the fixed cost T, leads to the entry of new lenders, to more competition for borrowers, and, consequently, to lower returns to informed intermediation.

[11] Broecker (1990) illustrates similar lending inefficiencies in the context of independent but symmetric noisy creditworthiness tests and finds that adverse-selection problems worsen as the number of banks rises. In our model, the deterioration of overall credit quality stems from banks' reduced incentive to screen. Shaffer (1998) provides evidence that is consistent with both models: as the number of banks in a market grows, each bank's provision for loan losses increases.

Each bank optimally reacts to such entry by reducing its investment in information.

It is straightforward to show that the free-entry equilibrium number of banks is a function of both the cost of acquiring information and the severity of informational asymmetries, as measured by the fraction of bad credit risks $1 - q$. The effect of the distribution of borrowers is subtle because it also affects the investment in information. As we showed in Proposition 1, an increase in the fraction of low-quality borrowers has a positive effect on bank profits for a given screening technology. Hence, the market can support a greater number of banks when the distribution of borrowers is skewed toward bad credit risks, so that the free-entry number of banks N^e is increasing in the fraction of low-quality borrowers.

3.4 Changes in screening technology

There has been much debate concerning the likely impact of changes in banks' ability to gather and process information on their capacity to establish and maintain relationships with borrowers. In recent work, Petersen and Rajan (2002) argue that increased access to information has eroded some of the geographic boundaries that have previously defined banking markets. This erosion has allowed banks to serve not only borrowers located farther away, but also those that they could not previously identify as high-quality applicants. Similarly, Emmons and Greenbaum (1998) suggest that improved information-processing ability may lead banks to offer credit to previously unserved or underserved customers, thus expanding the market. As Wilhelm (2001) observes, technological progress has allowed banks to leverage human capital to a point where far fewer loan officers are required for the management of portfolios of unchanged size. Hence, one would expect a corresponding decrease in the cost of screening or, equivalently, an increase in its informativeness.

Although the complete analysis of advances in information technology is beyond the scope of this article, we can offer some perspective on the preceding observations within the context of our model. Suppose one starts from a situation where regulatory barriers to entry or costs of initial access to the information technology, captured by T, are high. In this equilibrium, there are some borrowers who are never screened by any bank. These pure transactional market segments exist because entry has not yet pushed banks to encroach on each other's markets (i.e., $\hat{x}_n < \frac{1}{2N}$). In this case, lowering the per-borrower cost of screening c, which can be interpreted as an improvement in banks' credit assessment abilities and access to information, causes each bank's core market to expand ($\hat{x}_n$ increases). Improving the informativeness of the signal ϕ through, for instance, better information processing capabilities or a lower cost of investment would have a similar effect.[12] As a result of the improved ability to acquire information, banks should find it beneficial to screen and serve borrowers that were previously underserved.

4. The Social Value of Information

An important question that we now address is the extent to which credit markets are likely to achieve a socially desirable outcome in terms of information production and the allocation of credit.

4.1 Availability of credit and lending efficiency

We first consider how the ability of borrowers to obtain credit in our framework depends on the structure of the market. Efficient allocation of credit requires that high-quality applicants be able to obtain loans, whereas low-quality ones should be denied credit. Let O_θ denote the probability that a borrower of type $\theta \in \{l, h\}$ obtains credit. For a high-quality borrower, the credit screen will yield a positive signal with probability ϕ, which also represents the probability that such an applicant obtains a loan offer from the screening bank. If the informed bank (wrongly) denies credit, a high-quality borrower might still receive a loan with probability β from an uninformed bank. Hence, the probability of receiving a loan offer for a high-quality borrower is $O_h = \phi + (1 - \phi)\beta$, where, for notational simplicity, we suppress the dependence of ϕ and β on distance.

A similar expression holds for a low-quality borrower, who receives a loan offer with probability $O_l = (1 - \phi) + \phi\beta$. An increase in the quality of information ϕ can be said to enhance lending efficiency if O_h increases and O_l decreases.

Lemma 2. *Let $\phi \geq \overline{\phi}$. The probability O_h that a high-quality applicant receives a loan offer is decreasing in screening quality ϕ for $\phi < \hat{\phi}$ and increasing for $\phi > \hat{\phi}$, where $\overline{\phi} < \hat{\phi} < 1$. The probability O_l that a low-quality applicant receives a loan offer is decreasing in ϕ.*

Proof. See Appendix.

The probability O_h that a high-quality borrower obtains credit increases in the quality of information as long as this quality is beyond a certain threshold $\hat{\phi}$. For values of ϕ below this threshold the consequences of adverse selection for the uninformed bank outweigh the more efficient lending decisions by the informed bank: the likelihood of

[12] For an analysis of the impact of innovations in information technology on the competitiveness of financial markets, see Hauswald and Marquez (2003).

obtaining an offer from an uninformed lender decreases more rapidly than the increase in the probability of getting an offer from an informed lender. Hence, the probability of a loan offer strictly decreases for $\overline{\phi} \leq \phi < \hat{\phi}$ and is constant for $\phi < \overline{\phi}$. When ϕ is sufficiently high, however, the probability that a high-quality applicant obtains credit unambiguously increases because the likelihood that the informed bank correctly identifies the borrower increases toward one as the credit assessment becomes perfectly informative (as $\phi \rightarrow 1$).

For bad credit risks, the probability of obtaining a loan O_l unambiguously decreases in ϕ for two reasons. First, an informed bank is able to identify the borrower more accurately. Second, an uninformed lender faces a more severe adverse-selection threat and is therefore less likely to extend a loan offer. Hence, informational investments always decrease type II errors in credit offers, but their effect on type I errors depends on the quality of information, which, ultimately, is a function of the number of active banks.

For the following results, consider a given borrower located at a fixed distance x from the screening bank.

Corollary 2. *The probability O_h that a high-quality applicant receives a loan offer decreases in the number of active banks N for $N < \hat{N}$ and is (weakly) increasing for $N > \hat{N}$, where $\hat{N}$ is such that $\phi^*(\hat{N}) = \hat{\phi}$. The probability O_l that a low-quality applicant obtains credit is (weakly) increasing in N.*

Proof. The corollary follows from Lemma 2, $\partial\phi^*/\partial N < 0$, and an application of the chain rule.

With many active intermediaries, returns to screening are low, banks invest little in information production (Proposition 3), and the equilibrium informativeness of screening ϕ^* can fall below the threshold $\hat{\phi}$. In this situation, high-quality loan applicants would benefit from even more competition because they would be denied credit less frequently.[13] Conversely, when screening is very profitable because only a small number of banks compete, the equilibrium quality of the screens $\phi^*(N)$ exceeds the threshold $\hat{\phi}$ and more competition reduces the probability of obtaining a loan for good credit risks. For low-quality borrowers, by contrast, competition unambiguously increases their chance of obtaining credit, since it leads to less efficient lending decisions and thus a greater probability of a type II error.

Given that the efficiency of lending decisions decreases for low-quality applicants but that the effect is ambiguous for high-quality ones, we next

[13] The qualification that the probability O_h is only weakly increasing in N reflects the fact that for sufficiently large N, ϕ^* may be below $\overline{\phi}$, in which case changes in N have no effect on O_h. A similar comment applies to O_l.

study the incidence of competition on the social benefit of extending credit. This benefit is simply the difference between the expected surplus from lending to high-quality borrowers and the expected loss from inefficient lending to low-quality borrowers. Again, suppressing the dependence on borrower location x, the net surplus of any lending decision is given by

$$w(\phi) = qO_h(R-1) - (1-q)O_l.$$

Proposition 6. *The expected social benefit of lending, w, increases in N for* $N > \tilde{N}$ *and decreases otherwise for some* $\tilde{N} < \infty$.

Proof. See Appendix.

Proposition 6 shows that more competition is only beneficial when there are already many active banks. In this case, banks generate so little information in equilibrium that a further reduction in ϕ, which occurs when the number of banks increases, actually increases the probability that a high-quality borrower obtains credit. This effect more than offsets the reduction in the screening out of bad credit risks. With less competition, however, an increase in the number of active banks decreases the expected surplus from lending because it reduces banks' informational investments: with screening quality ϕ sufficiently high, an increase in N reduces ϕ, leading to worse lending decisions.

The preceding results hold for a given borrower x. However, in light of our earlier observations on overall information production Φ, Proposition 6 suggests that these same results should also hold on aggregate. In other words, entry in our model diminishes the efficiency of overall credit allocation for less competitive markets (low N), whereas it enhances efficiency for more competitive markets (high N).

4.2 Information production and social welfare

The preceding results illustrate the social benefit of competition through its impact on the generation of information in our model. However, it remains to be seen whether, absent external interference, credit-market competition is likely to achieve a socially desirable outcome. To this end, we compare the free-entry equilibrium investment to that chosen by a social planner who does not interfere in the competitive structure of the market and therefore does not distort banks' incentives to lend.[14] Summing the equilibrium lending surplus over all borrowers served by all N intermediaries, we obtain the social welfare function as

[14] Our approach is similar to Mankiw and Whinston (1986).

$$W = N\left\{2M\int_{0}^{\frac{1}{2N}} w(\phi^*;x)dx - \left[\frac{1}{2}(I^*)^2 + T\right]\right\} \tag{4}$$

We can decompose the preceding welfare expression into equilibrium per-bank expected profits $V^* = V_n(I^*)$ plus the expected surplus from lending in the absence of any private information. The latter is given, on a per-bank basis, by $B = 2M\int_0^{1/(2N)} \beta(x)(qR-1)\, dx$, which is simply the *ex ante* average surplus from granting a loan weighted by the probability that an uninformed bank makes a loan offer, summed over all its borrowers. Summing across all banks, we then have

$$W = N(V^* + B) \tag{5}$$

This expression for the aggregate lending surplus shows that any welfare effects must stem from banks' decisions to invest in information acquisition and their use of that information in lending. Pricing decisions, such as interest rates offered, represent a pure transfer between banks and borrowers and have no aggregate welfare implications.[15]

Proposition 7. *Under free entry, banks overinvest in information acquisition relative to the social optimum.*

Proof. See Appendix.

The preceding proposition verifies our earlier assertion that, to extend the reach of their captive market, banks invest excessively in information acquisition. Although such investments do, in fact, enhance the informational transparency of credit markets and lead to better lending decisions, they are wasteful from a social perspective because their benefits are outweighed by the increase in costs.

From a policy perspective, our analysis suggests that limiting banks' informational investments may in fact be desirable. One possibility could be to grant banks exclusive screening rights in their captive markets so that they cut back on wasteful investment by spending $I^{\text{mon}} < I^*$.[16] Similar approaches have been suggested to address information-induced externalities in the context of competition among market makers by, for instance, Dennert (1993). Our results also suggest other remedies, such

[15] This general feature of models in which prices are non-distortionary allows us to isolate the welfare effects stemming purely from information production.

[16] Indeed, there is evidence that regulators in Europe encouraged the formation of banks that exclusively lent to certain industries and protected these *de facto* screening monopolies in the 19th century. A more modern example can be found in the case of the "Austrian Controlbank for Industry and Commerce," set up at the beginning of the 20th century to, among other things, monitor and enforce such arrangements.

as the lowering of regulatory barriers to entry, with further entry reducing the overall level of investment in screening capabilities. Alternatively, regulators might attempt to directly influence banks' investment activities through, for instance, taxes or the dissemination of screening technology and other risk-management innovations. Indeed, the new regulatory standards commonly referred to as Basel II mandate that regulators establish a set of industry best practices. Such dissemination could adversely affect banks' incentives to invest in screening technology (Hauswald and Marquez 2004) and further reduce the level of overinvestment.

5. Credit-Market Consolidation

Some of the most visible recent changes in the banking industry can be traced to an unprecedented wave of consolidation over the last decade. While many different motives for bank mergers have been suggested in the literature (see, e.g., the survey by Berger *et al.*, 1999) the important link between intermediaries' incentives to merge and their information-acquisition and lending strategies has not been explored.

To study the effects of bank mergers, we slightly specialize our model and consider a market with $N = 4$ active banks indexed (clock-wise) by $n = 1, \ldots, 4$.[17] Suppose that banks 1 and 2 combine their operations, but that banks 3 and 4 remain independent. As a consequence, the merged bank, which we call bank m, is able to coordinate screening activities between branches 1 and 2. Such coordination allows each branch to commit to screening only half of the loan applicants, that is, up to a distance $\frac{1}{2N}$, thus avoiding the business-stealing effect identified earlier. For borrowers located between one of its branches and a stand-alone bank, the merged entity engages in competitive information acquisition as before, screening up to the marginal customer $\hat{x}_m$, which is defined in complete analogy to $\hat{x}_n$ in Lemma 1. Since we wish to isolate the effect of information on banks' incentives to merge, we abstract from any scale economies and assume that the merged bank must incur the cost of investment at each of its branches so that its overall cost is $(1/2)(I_m^2 + I_m^2) = I_m^2$. Scale effects would not alter our conclusions but simply make mergers even more profitable.

The stand-alone (*sa*) banks 3 and 4 choose their informational investments as before but take into account that the competition they now face on either side is asymmetric. Specifically, each independent bank competes against a branch of the merged entity capturing a market share of $(1/N) - \hat{x}_m$. At the same time, they also compete against each other, capturing a market share $\hat{x}_{sa}$ that again corresponds to $\hat{x}_n$ in Lemma 1.

[17] Our results generalize to an arbitrary number of intermediaries as long as mergers occur between adjacent banks.

Let I_m^* and V_m^* denote the optimal investment and equilibrium profit of the merged bank at each of its branches, respectively, and I_{sa}^* and V_{sa}^* those of each independent one-branch bank.

Proposition 8. *After merging, bank m invests less at each branch than in the competitive case ($I_m^* < I^*$), whereas the stand-alone competitors invest more ($I_{sa}^* > I^*$) and capture market share from the merged bank $\left(\frac{1}{N} - \hat{x}_m > \frac{1}{2N}\right)$, but not from each other $\left(\hat{x}_{sa} = \frac{1}{2N}\right)$.*

For high average borrower quality q, per-branch profits of the merged bank increase relative to the competitive case ($V_m^* > V^*$). The stand-alone banks are always more profitable ($V_{sa}^* > V^*$).

Proof. See Appendix.

Figure 3 depicts the consequences of a merger between banks 1 and 2. By coordinating screening activities across its branches, the merged bank is able to reduce the inefficiency in its choice of investment because its incentive to compete for market share falls. As a result, it invests less in information acquisition than in the fully competitive case ($I_m^* < I^*$). The optimal strategy of the stand-alone banks, however, is to increase their informational investments to extend their captive markets and, as a consequence, to gain market share at the expense of the merged entity $\left(\hat{x}_m < \frac{1}{2N}\right)$. Both results are consistent with recent empirical evidence, such as that in Berger *et al.* (2005) who find that smaller banks are better able to collect and process "soft" information than larger banks.

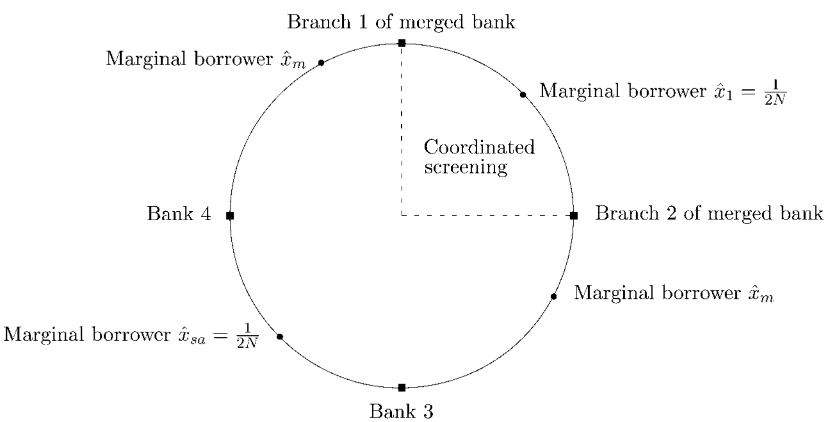

Figure 3
Bank mergers and market share
The graph illustrates how a merger between banks 1 and 2 (to produce bank m) leads to a loss of market share for the merged bank since bank m screens borrowers only up to $\hat{x}_m < \frac{1}{2N}$ when competing with one of the standalone banks. $\hat{x}_{sa} = \frac{1}{2N}$ represents the marginal borrower for the stand-alone banks when competing against each other.

Furthermore, Berger *et al*. (1998) report that newly merged banks tend to reduce small business lending but that this reduction is often more than offset by the competitive reactions of other banks.

Since the merged banks invest less and therefore obtain less precise information on average from their credit screens, Proposition 2 implies that expected interest rates paid by borrowers in their captive market fall. Conversely, the informativeness of credit screens by the independent banks rises, so that borrowers in their markets pay higher interest rates. Such effects have indeed been cited in the context of bank consolidation as intermediaries have often defended their mergers by alleging potential benefits for customers arising from cost cutting and better coordination of activities. In fact, Berger *et al*. (2001) found that, in the wake of industry consolidation, larger banks offer lower rates to small-business borrowers despite the well-documented finding that they also reduce the supply of credit to these borrowers. In our model, such benefits arise from more competitive loan pricing following the reduction in informational investments. As a consequence, the likelihood of competing loan offers increases, albeit at the cost of making less efficient lending decisions.

Proposition 8 also shows that the merging banks benefit from consolidation when the average quality of borrowers (q) is high because, in this case, the overinvestment in screening resources is particularly wasteful. Perhaps more surprisingly, we find that the independent banks benefit from the merger as well, since their optimal response is to increase their own investment and capture larger market shares. This rise in profitability of the stand-alone banks mirrors the findings of Deneckere and Davidson (1985) that mergers also benefit competitors in situations where firms compete in prices and produce differentiated products. In our model, however, the benefit stems from changes in each bank's investment behavior and their incidence on the intensity of competition.

We next characterize the stand-alone banks' optimal response to their competitors' consolidation.

Corollary 3. *Suppose that banks 1 and 2 have merged, and consider a merger between banks 3 and 4, leaving two "superbanks" (sb). The per-branch profits of the merged superbanks,* V_{sb}, *are higher than those of the stand-alone banks (3 and 4):* $V^*_{sb} > V^*_{sa} > V^*$.

Proof. See Appendix.

As Deneckere and Davidson (1985) show, independent firms left out of a merger are often able to free-ride on price increases by the merged firms and therefore may not wish to respond by merging themselves. However, Corollary 3 establishes that per-branch profits of the independent banks increase even further if they combine operations once other banks have already merged. This finding stems from the fact that, in our model, the merger serves as a commitment device to reduce the level of overinvestment in information acquisition and therefore to compete less vigorously in the poaching of borrowers from the other merged bank. Hence, when the industry consolidates into two superbanks with two branches each, both the previously independent banks and the already merged entity reduce their respective informational investments to levels below those of the independent, competitive case. As a result, the profits of both remaining banks increase.

Our results provide a new perspective on the occurrence of merger waves in the banking industry observed by, among others, Greenspan (1998). In light of Proposition 7, the reduction in informational investments is welfare enhancing. Hence, encouraging mergers might be an additional policy response to the overinvestment in informational resources identified earlier. As the informativeness of credit screens fall, expected interest rates paid by borrowers also decrease. It is worthwhile to point out that this dynamic is a pure consequence of strategic information acquisition since, for comparability with the full competition case, we assume throughout that banks continue to compete against each other at the lending stage.

We have assumed so far that if a merger takes place it occurs between adjacent competitors. As an alternative, banks could open multiple nonadjacent branches or combine forces with competitors that are not their neighbors. To examine the consequences of such branch proliferation, suppose that bank 1 were to merge with bank 3 (Figure 3) so that it has two branches at opposite ends of the circle. In this case, each branch of the merged entity faces competition from independent banks on either side. Hence, the merged bank cannot reduce its investment in information acquisition for fear of losing some of its captive market through poaching by its neighbors. In this case, we are back in the fully competitive setting of Section 3 because there is no benefit to the merged bank in coordinating screening across nonadjacent branches.

Finally, it is also clear that a merger of two banks that reduces the location of the merged entity down to just one branch would not be profitable. In analogy to models of product differentiation, the bank's positioning at two separate locations allows it to retain at least part of its previous information monopoly, even as it reduces inefficient investment. Consolidating the two branches down to just one would lead to a loss of strategic flexibility that makes it more difficult for the bank to protect its core market. Similar issues have been studied in the literature on "flexible manufacturing" by, for instance, Eaton and Schmitt (1994).

6. Discussion

In this article, we show how banks exploit informational asymmetries concerning borrower quality to soften price competition and to carve out and extend captive markets. This strategic role of information acquisition induces banks to overinvest in informational resources, enhancing lending efficiency but also leading to socially excessive information production. By analyzing the resulting incentives for industry consolidation, we also shed some light on the recent debate concerning the nature and future evolution of banking.

Our analysis delivers several empirical predictions. We find that expected interest rates decrease in bank-borrower distance, which is consistent with recent empirical findings regarding loan pricing in function of both physical distance between lenders and borrowers (Degryse and Ongena 2005) and the duration of lending relationships (Degryse and Van Cayseele 2000). We also find that more competition implies lower expected interest rates and reduced investment in information acquisition. This reduction in informational investments, in turn, leads to less efficient credit allocation and a deterioration in aggregate loan quality.

In addition, our framework is useful for studying the likely effects of bank mergers, an important issue given the recent wave of consolidation in the industry. We find that the merger of competing banks may be beneficial for those intermediaries that remain independent, since their increased investment in information production allows them to gain market share at the expense of the merging banks. Berger *et al.* (2005) report that lending relationships are significantly shorter when firms borrow from larger banks, which corresponds to a smaller captive market for the merged bank in our model. We also find, however, that independent banks' optimal response to industry consolidation is for them to find merger partners as well. Our results therefore suggest a new explanation for merger waves in the banking industry based solely on the strategic use of information acquisition.

Incorporating location-specific asymmetric information into a model of spatial competition in banking provides unique insights not readily available from standard location-based models. Traditionally, such models have focused on transportation costs and uniform loan pricing (see Freixas and Rochet, 1997, for a survey). It is straightforward to show that a transportation-cost model of lending with discriminatory pricing but without asymmetric information yields very similar empirical predictions on interest rates as a function of distance and the number of active banks as those in our setting.[18] Hence, one could view such a model as a reduced-form representation of our framework rooted in informational asymmetries. However, the degree of differentiation arises endogenously in our setting. Consequently, our model can be used to analyze the link between banks' investments in building market share through information production and subsequent pricing and credit allocation decisions.

[18] For a model that incorporates asymmetric information and a role for borrower screening (but with uniform pricing), see Villas-Boas and Schmidt-Mohr (1999).

These issues cannot easily be studied in models of bank competition in which differentiation is exogenously imposed through, for instance, transportation costs. Our model also allows us to distinguish between information-based (e.g., "relationship") and uninformed (e.g., "transactional") lending and to extract empirical predictions simultaneously for both loan types in a unified framework.

Our analysis extends to other information-sensitive industries such as private equity, in particular venture-capital or buy-out firms. In this context, we could think of the screening quality ϕ as representing the relative informational advantage certain firms have over competitors in evaluating entrepreneurs in specific industries or particular technological areas. For private-equity firms, informational investments would consist both of the effort spent on identifying suitable funding opportunities as well as human-capital investments, such as the hiring of additional partners to garner specific expertise. Indeed, Ljungqvist and Richardson (2003) present empirical evidence that is consistent with a model of imperfect competition among private-equity firms based on unique skills of their general partners in screening and monitoring investments.

In light of our results, the strong specialization that we observe in private equity comes as no surprise. If one interprets our screening investment ("effort") variable I as core expertise, it simply means that many small players establish a particular niche of expertise in which they have higher success in identifying promising business opportunities. In addition, the requisite human-capital investment discourages less informed competitors from competing for screened projects within the captive market of the VC. We could slightly extend our framework by including a slope coefficient in our screening-precision specification that captures how fast screening expertise decreases outside the core market. We would argue that such a slope coefficient is likely to be quite high in private-equity markets, yielding a correspondingly lower degree of competition. Bengtsson *et al.* (2002) provide empirical evidence that VCs screen less when competition for deal flow is intense, which, in our model, corresponds to an erosion of their market niche. However, a full analysis of the competitive dynamics of private-equity markets is beyond the scope of this work.

Appendix

Proof of Proposition 1. To fix notation, we derive the success (repayment) probability of a potential borrower located at a distance x conditional on the screening signal $\eta \in \{l, h\}$, which, by Bayes' rule, follows for terminal value ξ as

$$p(h;x) \equiv \Pr(\xi = R|\eta = h) = \frac{\phi(x)q}{\phi(x)q + (1-\phi(x))(1-q)} \in [q,1]$$

$$p(l;x) \equiv \Pr(\xi = R|\eta = l) = \frac{(1-\phi(x))q}{\phi(x)(1-q) + (1-\phi(x))q} \in [0,q]$$

We also define $r_q = 1/q$ and $r_l(x) = 1/p(l;x)$ as the break-even interest rates for a borrower of average quality and for one with a negative signal, respectively. Finally, let $r_i(\eta)$ and r_u denote interest-rate offers by the informed and uninformed bank, respectively.

The construction of the mixing distributions follows a sequence of standard arguments summarized here (for details see Hauswald and Marquez 2000). Let $F_i(r,\eta;x)$ represent the informed bank's bidding distribution over loan-rate offers r for a borrower with signal η located at a distance x and, similarly, let $F_u(r;N^{-1}-x)$ represent the uninformed bank's bidding distribution for the same borrower. Define $\bar{x}$ as the value of x such that $p(l;x)R=1$. We first consider a borrower located at a distance $x<\bar{x}$ from the informed bank so that $p(l;x)R<1$. For such a borrower, the informed bank never bids if $\eta=l$, so that $F_i(r,l;x)=0$ for all r. By standard arguments (e.g., Engelbrecht-Wiggans *et al.* 1983), both $F_i(r,h;x)$ and $F_u(r;x)$ can be shown to be continuous, strictly increasing, and atomless on a common support $[\underline{r},\bar{r})$. The expected profit for each bank from offering an interest rate r can therefore be stated as

$$\pi_i(r,\eta;x) \equiv \left[1-F_u(r;N^{-1}-x)\right][p(\eta;x)r-1] \tag{6}$$

$$\pi_u\left(r;N^{-1}-x\right) \equiv \Pr(\eta=h)[1-F_i(r,h;x)][p(h;x)r-1]+\Pr(\eta=l)[p(l;x)r-1] \tag{7}$$

Standard arguments also establish that, since a less informed bidder cannot profit from a sealed-bid auction against a better informed competitor, the uninformed bank must break even in equilibrium, implying that $\pi_u(r;(1/N)-x)=0$ for all r and x. To calculate the lower bound of the support, note that, at $\underline{r}$, the uninformed bank wins almost surely and therefore makes a profit of $\underline{r}q-1=0$, implying that $\underline{r}=r_q=1/q$. Clearly, neither the informed nor the uninformed bank will ever offer a rate higher than R, the project's pay-off in the successful state. Hence, we can conclude that the common support is $[r_q,R)$.

We now turn to the case of borrowers located at a distance $x\geq\bar{x}$ from the informed bank and consider $[\underline{r}_i^l,\bar{r}_i^l)$, the support of $F_i(r,l;x)$ for $x\geq\bar{x}$. Clearly $\underline{r}_i^l\geq r_l(x)=1/p(l;x)$. A repeated application of undercutting arguments establishes that the informed bank offers to lend at $r_i(l)=r_l(x)=1/p(l;x)$ almost surely for $\eta=l$ so that $\underline{r}_i^l=\bar{r}_i^l=1/p(l;x)$. The remainder of the proof follows the case for $x<\bar{x}$ with minor modifications to imply a common support for the case of $\eta=h$ of $[r_q,r_l(x))$, so that the upper bound now depends on the borrower's location. Hence, we conclude that for any x, the common support is $[r_q,r_l(x)\wedge R)$.

Since the mixing distributions are strictly increasing, equilibrium profit for each bank must be the same for every interest rate offered in the support of its mixing distribution, that is, profits must be constant on $[r_q,r_l(x)\wedge R)$. For $\pi_i(r,h;x)=\bar{\pi}$ and $\pi_u(r;x)=0$, Equations (6) and (7) imply the following system of equations defining the loan-rate distributions:

$$\left[1-F_u(r;N^{-1}-x)\right][p(h;x)r-1]=\bar{\pi} \tag{8}$$

$$\Pr(\eta=h)[1-F_i(r,h;x)][p(h;x)r-1]+\Pr(\eta=l)[p(l;x)r-1]=0 \tag{9}$$

Evaluating the first equation at the lower bound of the support, $\underline{r}=1/q$, we note that since $F_u(\underline{r};y)=0$, the constant must be $\bar{\pi}=p(h;x)(1/q)-1$. Substituting the definition of $\Pr(\eta=h)=\phi(x)q+[1-\phi(x)](1-q)=[q-p(l;x)]/[p(h;x)-p(l;x)]$ into Equation (9) and solving the preceding system for F_u and F_i yields

$$F_i(r,h;x)=\frac{p(h;x)-p(l;x)}{q-p(l;x)}\frac{qr-1}{p(h;x)r-1} \tag{10}$$

$$F_u\left(r; N^{-1} - x\right) = \frac{p(h;x)}{q} \frac{qr - 1}{p(h;x)r - 1} = \phi F_i(r,h;x) \tag{11}$$

Since both banks randomize over the full support of the distribution functions they cannot profitably deviate from their mixed strategies. Hence, the preceding distributions represent the unique equilibrium of the bidding game for a given borrower. Note that $\beta(\phi(y)) = F_u(R; N^{-1} - x) = [p(h;x)/q][qR - 1]/[p(h;x)R - 1] = \phi(x)F_i(R,h;x) < 1$ for $y = (1/N) - x$, so that the uninformed bank refrains from bidding for borrowers with probability $1 - \beta(\phi(y)) > 0$ whenever $x < \bar{x}$.

To derive the expression for expected profits of the informed bank, we again evaluate the expression for its *ex ante* profits at the lower bound of the support:

$$E[\pi_i(\eta, x)] = \Pr_x(\eta = h)\pi_i(\underline{r}, h; x) + [1 - \Pr_x(\eta = h)]\pi_i(\underline{r}, l; x)$$

Since $\pi_i(\underline{r}, l; x) = 0$ and $\pi_i(\underline{r}, h; x) = \bar{\pi} = p(h;x)(1/q) - 1$, the preceding expression reduces to $E[\pi_i(\eta, x)] = (1 - q)[2\phi(x) - 1]$, which is well defined for $\phi(x) \geq 1/2$. ■

Proof of Proposition 2. Pick any borrower x and let $\hat{r} = \min\{r_i, r_u\}$ be the expected interest rate paid if the borrower is deemed of high quality ($\eta = h$) and obtains offers from both the informed and uninformed banks. Let $F(r)$ be the distribution function of $\hat{r}$, which is given by $F(r) = F_i(r,h) + F_u(r) - F_i(r,h)F_u(r)$, where we suppress the dependence on x for notational clarity. By Equation (11), we know that $F_u(r) = \phi F_i(r,h)$, which can be used to show that $F = F_i[1 + \phi(1 - F_i)]$. We then obtain the following expressions for expected interest rates for each borrower type $\theta \in \{l, h\}$ given that an offer is made:

$$\begin{aligned}
E[r|\theta = h, \text{offer}] &= \Pr(\eta = h|\theta = h)E[\hat{r}|\eta = h, \text{offer}] + \Pr(\eta = l|\theta = h)E[r_u|\text{offer}] \\
&= \frac{1}{\phi + (1-\phi)\beta}\int_{\underline{r}}^{R} [1 - \phi F_i(r,h)]^2 dr + \underline{r}\ \frac{1}{\phi + (1-\phi)\beta} \\
E[r|\theta = l, \text{offer}] &= \Pr(\eta = h|\theta = l)E[\hat{r}|\eta = h, \text{offer}] + \Pr(\eta = l|\theta = l)E[r_u|\text{offer}] \\
&= \int_{\underline{r}}^{R} \frac{[1 - \phi F_i(r,h)][1 - (1-\phi)F_i(r,h)]}{(1-\phi) + \phi\beta} dr + \underline{r}\ \frac{1}{(1-\phi) + \phi\beta}
\end{aligned}$$

where $\underline{r} = 1/q$. For ease of notation, we henceforth drop all references to conditioning on offers.

For high-quality borrowers that receive a loan offer, differentiating $E[r|\theta = h]$, which is bounded from above, with respect to ϕ yields

$$\frac{\partial}{\partial\phi}E[r|\theta = h] = \frac{(1-q)}{[(1-\phi) + \phi\beta]^2} \frac{4\phi qR(1-q)(1-\phi) - 2\phi^2(qR - 1) + qR[qR - 1 - (1-q)]}{q[\phi q(R-1) - (1-\phi)(1-q)]^2}$$

The sign of this expression depends on the sign of $g(\phi) = 4\phi qR(1-q)(1-\phi) - 2\phi^2 (qR - 1) + qR[qR - 1 - (1-q)]$. But $\partial g(\phi)/\partial\phi = 4\phi(2q^2R - 3qR + 1) + 4Rq(1-q) > 0$ for $R \geq 1/q(2-q)$ which always holds by $qR > 1$. Since $g(1/2) = (1/2)(2qR - 1)(qR - 1) > 0$, we get that $g(\phi) > 0$ for $\phi \in \left[\frac{1}{2}, 1\right]$, so that indeed $\partial E[r|\theta = h]/\partial\phi > 0$, as claimed.

For low-quality borrowers, let the probability that such a loan applicant obtains funding be given by $O_l = (1-\phi) + \phi\beta$. The expression under the integral sign then becomes

$[1-\phi F_i(r,h)][1-(1-\phi)F_i(r,h)]/O_l$. It is straightforward to verify that $\partial O_l/\partial\phi = -(1-\beta)+\phi\frac{\partial\beta}{\partial\phi}<0$ since $\beta<1$ and $\frac{\partial\beta}{\partial\phi}=\frac{\partial F_u(R)}{\partial\phi}=-(1-q)(qR-1)/(\phi qR-2\phi q-1+q+\phi)^2<0$, which also establishes the second part of the proposition. For the numerator, we obtain

$$\frac{\partial}{\partial\phi}\{[1-\phi F_i(r,h)][1-(1-\phi)F_i(r,h)]\} = 2(qr-1)q\frac{(2\phi-1)(1-q)(r-1)}{(\phi q(r-1)-(1-\phi)(1-q))^3}>0$$

by $\phi\in[1/2,1]$ and $r\geq 1/q>1$ so that $\frac{\partial}{\partial\phi}\{[1-\phi F_i(r,h)][1-(1-\phi)F_i(r,h)]/O_l\}>0$. Finally, we observe that $\frac{\partial}{\partial\phi}(1/O_l)=-\frac{(\partial O_l/\partial\phi)}{O_l^2}>0$. Since $E[r|\theta=l]$ is bounded from above, we can conclude that the expected interest rate for a low-quality applicant also increases in ϕ:

$$\frac{\partial E[r|\theta=l]}{\partial\phi}=\int_{\underline{r}}^{R}\frac{\partial}{\partial\phi}\left\{\frac{[1-\phi F_i(r,h)][1-(1-\phi)F_i(r,h)]}{O_l}\right\}dr-\frac{\frac{\partial O_l}{\partial\phi}}{O_l^2}\frac{1}{q}>0.$$

The preceding results hold for the case of credit screens that are sufficiently informative for the informed bank to deny credit to applicants deemed of low quality, that is, for $\phi>\bar{\phi}$, where $\bar{\phi}$ is defined by $p(l,\bar{\phi})R=1$. For borrowers with uninformative credit screens ($\phi<\bar{\phi}$), the informed bank always offers credit and the uninformed bank always bids ($\beta=1$) so that our results go through. ■

Proof of Lemma 1. We first show that for $c>0$, borrowers are screened by at most one bank. Suppose that two banks, i and j, screen a borrower located at a distance x from i and y from j. By assumption, if $\phi_i(x)>\phi_j(y)$, bank i's signal is a sufficient statistic for bank j's. By the results in Engelbrecht-Wiggans *et al.* (1983), profits in the subsequent competition stage would be zero for bank j (see the proof of Proposition 1): although it is informed, its information is a subset of bank i's information set, and so the usual zero-profit result holds. For $c>0$, bank j cannot recoup its cost of screening and, anticipating that bank i will screen, will not screen itself. Letting c now go to 0 implies that bank i will always screen.

Since, for any bank n, *ex ante* expected profits are given by $E[\pi_n(\eta,x)]=(1-q)[2\phi(x)-1]$, $E[\pi_n(\eta,\hat{x}_n)]=c$ now defines $\hat{x}_n$, which can be obtained from $(1-q)(I-2\hat{x}_n)=c$ as

$$\hat{x}_n=\frac{1}{2}\frac{(1-q)I-c}{(1-q)},$$

as long as $(1/2)[(1-q)I-c]/(1-q)\leq\widetilde{x}_n$. Otherwise, screening intervals would overlap, contradicting the preceding result. Hence, it must be that

$$\hat{x}_n=\min\left\{\frac{1}{2}\frac{(1-q)I-c}{(1-q)},\widetilde{x}_n\right\}.$$ ■

Proof of Proposition 3. By Lemma 1, a bank $i\leq N$ screens up to the point where its information is equal to that of any competitor j in terms of signal quality $\phi_i(x)=(1+I_i)/2-x$. Solving $\phi_i(x)\geq\phi_j\left(\frac{1}{N}-x\right), j=i\pm 1$, we find a bank's captive market segment as $0\leq x\leq(I_i-I_j)/4+1/(2N)=\hat{x}_i$. Differentiating equation (3) with respect to I_i and using the preceding expression for $\hat{x}_i$ yields the following first-order condition:

$$\frac{\partial V_i}{\partial I_i} = 2M \int_0^{\hat{x}_i} (1-q)2\frac{\partial \phi(x)}{\partial I_i} dx + 2M[(1-q)(2\phi(\hat{x}_i) - 1) - c]\frac{\partial \hat{x}_i}{\partial I_i} - I_i = 0$$

Imposing symmetry ($I_i = I_j = I$), letting c be small ($c \to 0$), and rearranging the FOC, we obtain the following equilibrium condition

$$\frac{M(1-q)}{N} + \frac{M(1-q)}{2}\left(I - \frac{1}{N}\right) - I = 0$$

that yields the optimal investment $I^* = \frac{M(1-q)}{N[2-M(1-q)]}$. It is easily verified that, for $\frac{M(1-q)}{[2-M(1-q)]} \leq N$, $I^* \leq 1$, so that in equilibrium, $\phi^*(x) = (1+I^*)/2 - x$ is well defined: $\phi^*(\frac{1}{2N}) > 1/2$. Since $\partial I^*/\partial N = \frac{-M(1-q)}{N^2[2-M(1-q)]}$<0 and $\partial I^*/\partial(1-q) > 0$, the comparative statics result are immediate. ■

Proof of Proposition 5. For $c \to 0$, bank profits evaluated at the optimal investment I^* are $V^* = V_n(I^*) = \{M(1-q)[M(1-q)-1][4-3M(1-q)]/[2N^2(M(1-q)-2)^2]\} - T$, so that $V_n(I^*) = 0$ yields the free-entry equilibrium number of banks N^e (up to integer constraints). Note that N^e is well defined if $M(1-q) \in \left(1, \frac{4}{3}\right)$. An application of the Implicit Function Theorem to $V_n^*(N^e) = 0$ now yields $\partial N^e/\partial T < 0$ since V^* is also monotonically decreasing in T. Hence, by Proposition 3, $\partial I^*/\partial T = (\partial I^*/\partial N)(\partial N^e/\partial T) > 0$. ■

Proof of Lemma 2. Given ϕ, the probability that a high-quality applicant obtains a loan offer is $O_h = \phi + (1-\phi)\beta$, so that

$$\frac{\partial O_h}{\partial \phi} = 1 - \beta + (1-\phi)\frac{\partial \beta}{\partial \phi} = (1-q)\frac{q\left[R\left(2\phi^2 - 1\right) - 1\right] + 2(\phi-1)^2 + 4q\phi(1-\phi)}{[\phi q(R-1) - (1-\phi)(1-q)]^2}$$

Note that $\partial O_h/\partial\phi|_{\phi=1/2} = -2(qR-1)(1-q)/[q(R-1)-(1-q)]^2 < 0$ and $\partial O_h/\partial\phi|_{\phi=1} = (1-q)/q(R-1) > 0$ by the assumption that $qR - 1 > 0$. Furthermore, $\partial O_h/\partial\phi|_{\phi=\hat{\phi}} = 0$ for $\hat{\phi} = \left[2(1-q) + \sqrt{2q(R-1)(qR-1)}\,\right]/(2[q(R-2)+1])$ from $q[R(2\phi^2 - 1) - 1] + 2(\phi-1)^2 + 4q\phi(1-\phi) = 0$. Hence, $\partial O_h/\partial\phi < 0$ for $\phi < \hat{\phi}$, and $\partial O_h/\partial\phi > 0$ otherwise. For $\phi < \bar{\phi}$, $O_h = 1$ by the same argument as in the proof of Proposition 2, so that $\partial O_h/\partial\phi|_{\phi<\bar{\phi}} = 0$.

The probability of a low-quality applicant being granted credit is $O_l = (1-\phi) + \phi\beta$ so that $\frac{\partial O_l}{\partial \phi} = -(1-\beta) + \phi\frac{\partial \beta}{\partial \phi} < 0$ except for uninformative credit screens $\phi < \bar{\phi}$, for which we have $O_l = 1$ and therefore $\partial O_l/\partial\phi|_{\phi<\bar{\phi}} = 0$. ■

Proof of Proposition 6. For the expected benefit of lending $w(\phi)$ we have

$$\frac{\partial^2 w}{\partial \phi^2} = 2\frac{(1-q)[q(R-1)+1-q](qR-1)^2}{[\phi q(R-1) - (1-\phi)(1-q)]^3} > 0,$$

since $\phi q(R-1) - (1-\phi)(1-q) > 0$ for $\phi > 1/2$, and $qR - 1 > 0$. We can also show that for $\phi \downarrow 1/2$, $\partial w/\partial\phi < 0$, and for $\phi \uparrow 1$, $\partial w/\partial\phi > 0$. Hence, w has a minimum at $\tilde{\phi} = (1/2)[2(1-q) + \sqrt{2}(qR-1)]/[q(R-1)+1-q]$ (from $\partial w/\partial\phi = 0$), so that it first decreases in ϕ and then increases as $\phi \to 1$. Since $\partial\phi^*/\partial N < 0$, an application of the chain rule establishes the proposition. ■

Proof of Proposition 7. From our social-welfare objective function $W = N(V^* + B)$, socially optimal informational investments have to satisfy the following first-order condition for given N:

$$\frac{\partial W}{\partial I} = N\left(\frac{\partial V^*}{\partial I} + \frac{\partial B}{\partial I}\right) = 0$$

where

$$\frac{\partial B}{\partial I} = -2M\frac{(1-q)(qR-1)^2}{\{N(qR-1)+(IN-1)[q(R-1)+(1-q)]\}[qR-1+qI(R-1)+I(1-q)]}.$$

Evaluating the above first-order condition at the free-entry investment $I^e = \frac{M(1-q)}{N(2-M(1-q))}$, we find that $\partial B/\partial I|_{I_n^e} < 0$ since $I^e N - 1 = M(1-q)/[2-M(1-q)-1] = [2M(1-q)-2]/[2-M(1-q)] > 0$ by our assumption that $M(1-q) \in (1, 4/3)$. Similarly, we have that $\partial V^*/\partial I|_{I^e} = 0$ by the first-order condition for banks' profit-maximizing investments (see proof of Proposition 3). Hence, we obtain $\frac{\partial W}{\partial I}|_{I^e} = N\frac{\partial B}{\partial I}|_{I^e} < 0$ so that in the free-entry equilibrium banks invest more in I than is socially optimal. ■

Proof of Proposition 8. The merged entity chooses investment I_m per branch by maximizing

$$V_m = M\int_0^{\hat{x}_m}[(1-q)(2\phi(x)-1)-c]dx + M\int_0^{\frac{1}{2N}}[(1-q)(2\phi(x)-1)-c]dx - \left(\frac{1}{2}I_m^2 + T\right)$$

while the stand-alone banks maximize

$$V_{sa} = M\int_0^{\frac{1}{4}-\hat{x}_m}[(1-q)(2\phi(x)-1)-c]dx + M\int_0^{\hat{x}_{sa}}[(1-q)(2\phi(x)-1)-c]dx - \left(\frac{1}{2}I_{sa}^2 + T\right)$$

with respect to I_{sa}. The banks' respective market shares follow from $\phi_m\left(\frac{1}{2N} - \hat{x}_m\right) = (1+I_m)/2 - \frac{1}{2N} - \hat{x}_m \le (1+I_{sa})/2 - \hat{x}_m = \phi_i(\hat{x}_m)$, so that $\hat{x}_m = (1/4)(I_i N - I_m N + 2)/N$ and, as before (see the proof of Proposition 3), $\hat{x}_{sa} = (I_i - I_j)/4 + \frac{1}{2N}, i \neq j,\ i = 3, 4$.

Differentiating the preceding profit expressions with respect to $I_m, I_{3,sa}$, and $I_{4,sa}$ and imposing symmetry for the independent banks we obtain, after letting the screening cost c go to zero,

$$\begin{aligned}
\frac{\partial V_m}{\partial I_m} = 0 &= \frac{M(1-q)}{2N} + \frac{M(1-q)}{4}\frac{2 - I_{sa}N + I_m N}{N} \\
&\quad + \frac{M(1-q)}{4}\left(I_m - \frac{2}{N} + \frac{I_{sa}N - I_m N + 2}{2N}\right) - I_m \\
\frac{\partial V_{sa}}{\partial I_{sa}} = 0 &= \frac{M(1-q)}{4}\frac{2 - I_m N + I_{sa}N}{N} + \frac{M(1-q)}{4}\left(I_{sa} - \frac{1}{2}\frac{I_{sa}N - I_m N + 2}{N}\right) \\
&\quad + \frac{M(1-q)}{2N} + \frac{M(1-q)}{4}\left(I_{sa} - \frac{1}{N}\right) - I_{sa}
\end{aligned}$$

Solving the two equations yields

$$I_m^* = \frac{M(1-q)(24-17M(1-q))}{\left[7M^2(1-q)^2-32M(1-q)+32\right]N}$$

$$I_{sa}^* = \frac{M(1-q)[16-9M(1-q)]}{N\{M(1-q)[7M(1-q)-32]+32\}}$$

Comparing investment levels per branch, we find that $I_m^* < I^* = M(1-q)/\{N[2-M(1-q)]\} < I_{sa}^*$, where the first inequality follows from $I_m^* - I^* = 2M(1-q)\{M(1-q)[5M(1-q)-13]+8\}/N[7M^2(1-q)^2-32M(1-q)+32][2-M(1-q)]$, which is negative for $M(1-q) \in (1, 8/5)$, and the second one from $I_{sa}^* - I^* = 2(1-q)^2M^2[(1-q)M-1]/\{[7(1-q)^2M^2-32(1-q)M+32]N[2-(1-q)M]\} > 0$ since $7(1-q)^2M^2-32(1-q)M+32 > 0$. Substituting the optimal investments back in to find equilibrium market shares, we finally get that $\frac{1}{2N} - \hat{x}_m = 2M(1-q)[M(1-q)-1/\{N[7M^2(1-q)^2-32M(1-q)+32]\} > 0$ since $M(1-q) > 1$ and that $\hat{x}_{sa} = \hat{x}_i = \frac{1}{2N}$ by $I_{sa}^* = I_{3,sa}^* = I_{4,sa}^*$.

Neglecting the screening cost c, equilibrium profits per branch are

$$V_m^* = \frac{1}{2}M(1-q)[1-M(1-q)]\frac{199(1-q)^3M^3-1080(1-q)^2M^2+1856(1-q)M-1024}{\left[7(1-q)^2M^2-32(1-q)M+32\right]^2N^2} - T$$

$$V_{sa}^* = \frac{1}{2}M(1-q)[1-M(1-q)]\frac{247(1-q)^3M^3-1192(1-q)^2M^2+1920(1-q)M-1024}{\left[7(1-q)^2M^2-32(1-q)M+32\right]^2N^2} - T$$

We can now compare these two profit expressions to obtain

$$V_{sa}^* - V_m^* = \frac{8M^2(1-q)^2[4-3M(1-q)][M(1-q)-1]^2}{\left[7M^2(1-q)^2-32M(1-q)+32\right]^2N^2} > 0$$

since $M(1-q) \in (1, 4/3)$. Similarly, recalling that V^* denotes the equilibrium profits per bank in the nonmerger case, we have

$$V_{sa}^* - V^* = \frac{2M^2(1-q)^2[8-5M(1-q)][5M^2(1-q)^2+16-19M(1-q)][M(1-q)-1]^2}{[7M^2(1-q)^2-32M(1-q)+32]^2N^2[M(1-q)-2]^2} > 0.$$

Finally, for $M(1-q) \in \left(1, \frac{7}{6}\right)$

$$V_m^* - V^* = \frac{-2M^2(1-q)^2[13M^3(1-q)^3-71M^2(1-q)^2+120M(1-q)-64][M(1-q)-1]^2}{[7M^2(1-q)^2-32M(1-q)+32]^2N^2[M(1-q)-2]^2} > 0$$

so that, for high average-borrower quality q, banks have an incentive to merge. ■

Proof of Corollary 3. If banks 3 and 4 merge, per-branch profits of the superbanks *sb* become, for $\hat{x}_m = (1/4)(I_mN - I_nN + 2)/N, m \neq n$,

$$V_{sb} = M\int_0^{\hat{x}_m}\{(1-q)[2\phi(x)-1]-c\}dx + M\int_0^{\frac{1}{2N}}\{(1-q)[2\phi(x)-1]-c\}dx - \left(\frac{1}{2}I_{sb}^2 + T\right)$$

Repeating the analysis in the proof of Proposition 8, we find that both superbanks invest $I_{sb}^* = 3M(1-q)/\{N[4-M(1-q)]\}$ at each branch, which is lower than I_m^* and I_{sa}^*. Since

$$V_{sb}^* - V^* = \frac{-2[M(1-q)-1]^2 M^2(1-q)^2[M(1-q)-3]}{N^2[M(1-q)-2]^2[4-M(1-q)]^2} > 0$$

by our usual restriction that $M(1-q) \in (1, 4/3)$, we note that banks always have an incentive to simultaneously merge in pairs. Finally,

$$V_{sb}^* - V_{sa}^* = \frac{-8[M(1-q)-1]^2 M^2(1-q)^2\left[6M^3(1-q)^3 - 41M^2(1-q)^2 + 88M(1-q) - 64\right]}{\left[7M^2(1-q)^2 - 32M(1-q) + 32\right]^2 N^2[4-M(1-q)]^2} > 0$$

if $6M^3(1-q)^3 - 41M^2(1-q)^2 + 88M(1-q) - 64 < 0$, which is satisfied for $M(1-q) \in (1, 4/3)$. Hence, the best response to a merger is for the stand-alone banks to merge as well. ■

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