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INFORMATION PRODUCTION, BANKING COMPETITION AND THE MARKET STRUCTURE OF THE BANKING INDUSTRY

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Abstract: This paper analyzes the effects of pre-lending screening on loan market outcome under oligopolistic competition. Better screening decreases loan interest margins and, provided that the average creditworthiness of borrowers is not too low, increases lending volume. We contrast specifically independent screening to common (correlated) filters, and find that the margins are wider and lending volume higher under independent screening. The determinants of the size of the banking industry are also considered. With common filters, more accurate screening increases banks' incentives to enter under common filters, while with independent screening these incentives may be undermined.

Keywords: screening, common (correlated) filters, banking competition, loan pricing, horizontal differentiation, entry

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Tiivistelmä: Tässä tutkimuksessa analysoidaan pankkien luottoasiakkaisiinsa kohdistaman luottokelpoisuusanalyysin (so. yritystutkimuksen) vaikutuksia luottomarkkinoiden toimintaan. Tulokset osoittavat, että tehokkaampi yritystutkimus kaventaa luottojen korkomarginaaleja sekä voi myös johtaa luotonannon kasvuun, mikäli luotonhakijoiden keskimääräinen luottokelpoisuus on riittävän hyvä. Paperissa tarkastellaan erityisesti luottokelpoisuuden selvittämiseen käytettävien testaus- ja analyysimenetelmien tilastollisen luonteen merkitystä. Havaitaan, että luottojen korkomarginaalit ovat leveämpiä ja luottokanta suurempi, jos pankit käyttävät toisistaan riippumattomia luottokelpoisuuden testausmenetelmiä kuin käytettäessä korreloituneita menetelmiä. Tutkimuksessa käsitellään myös pankkitoimialan kokoa ja alalletuloa. Tuloksien mukaan tehokkaampi luottokelpoisuusanalyysi kannustaa alalletuloon sovellettaessa korreloituneita testejä, mutta voi vähentää pankkien alalletulon kannustimia riippumattomien testausteknologioiden tapauksessa.

Avainsanat: yritystutkimus, korreloituneet luottokelpoisuustestit, pankkikilpailu, luottojen hinnoittelu, tuotedifferentiaatio, alalletulo

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1 Introduction

Varying views have recently been put forward regarding banks' role in the pre-lending screening of loan applicants' creditworthiness. Some have argued that such information production is one of the most important functions of banks (Stiglitz and Weiss 1988, Jaffee and Stiglitz 1990, and Wang and Williamson 1998). Others have cast doubt on banks' ability and incentives to perform the task in light of financial market integration, competitive pressures and past banking crises (Chan et al.. 1986, Rajan 1994, Gehrig 1998, and Kanniainen and Stenbacka 2000). Practitioners and regulators alike have in recent times put growing emphasis on loan risk and screening as evidenced by the considerable efforts devoted to developing loan risk modelling techniques and banks' internal credit rating procedures.[1] This paper investigates what bearings, if any, such screening has on banks' lending policy, profits and ultimately market structure in a loan market characterized by oligopolistic competition.

We build our analysis on the observation that screening technologies are changing. Firstly, screening and perceived creditworthiness are becoming more

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[1] See, e.g., the survey of Basle Committee on Banking Supervision (1999) and Jackson et al.'s (1999) summary of a Bank of England conference on credit risk modelling. Altman et al. (1994) and Bardos (1998) discusses some of the techniques used to detect loan risk in practice.

correlated across banks because of rapidly advancing information technology and particularly because of increasing use of electronic databases and other common information sources, such as the Internet. Correlation in the perceived creditworthiness is also increasing because credit scoring models are increasingly standardized and more widespread (Shaffer 1998). Easier access to credit bureaus' databases and other means of information sharing tend to increase the degree of correlation in screening outcomes, too (Pagano and Japelli 1993, Padilla and Pagano 1997, and Gehrig and Stenbacka 2000). We therefore ask if it matters for loan market outcome whether screening is independent or correlated across banks. In particular, does the difference between independent and correlated screening, or common filters as Shaffer (1998) has also called them, have bearings on interest rate margins, lending volume and eventually banks' profits?

Secondly, the current efforts to improve loan risk modelling techniques and banks' internal credit rating procedures should eventually lead to more accurate screening. This view is supported e.g. by the recent study of Petersen and Rajan (2000) documenting that, most likely because of lenders' improved information production ability, firms increasingly rely on more distant lenders and more impersonal methods of communication. We hypothesise that besides influencing lending quality, more accurate screening might at the same time intensify interest rate competition via its effect on the elasticity of demand. This paper examines the potential tradeoff and considers whether and in what way better screening might shape the market structure of the banking industry in the long-run.[2]

In order to analyse the above questions, we follow Williamson (1987), Besanko and Thakor (1992) and Chiappori et al. (1995) and others by adopting a

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[2] Hence our analysis is related to Dell'Ariccia (1998) and Dell'Ariccia et al. (1999), who single out asymmetric information as an important determinant of bank market structure.

spatial model of a banking industry. In the model banks are differentiated because of their location and other attributes of their financial services. We augment the framework by introducing screening and adopt it for two main reasons. On the one hand, it is a straightforward way to assign market power to banks by introducing 'frictions', or participation costs, into loan markets. Such a feature is empirically supported as several studies suggest that banks posses a degree of market power (Fama 1985, Molyneux et al. 1994, and Neven and Röller 1999); that differentiation in particular would be of empirical relevance is argued inter alia in Evans (1997) and Vesala (1998). We reason moreover that it is particularly important in the present context because loan applicants are likely to incur various 'application' costs before their eligibility for a loan is revealed.[3] On the other hand, the spatial model has the property that the interest rate (price) elasticity of loan demand is not infinite. This is important because in contrast to perfectly competitive markets, this environment allows us to uncover the interplay between screening and the interest rate sensitivity of loan applicants, e.g., the degree of competitiveness in bank lending conditional on screening accuracy.

The ex ante screening function of banks and, more generally, their lending standards have lately received not only theoretical (e.g., Broecker 1990, Riordan 1993, Thakor 1996, Gehrig 1998 and Kanniainen and Stenbacka 2000) but also empirical (e.g., Weinberg 1995, Shaffer 1998, and Keeton 1999) attention.[4] The

[3] Besides spatial distance, examples of potential sources of such transaction costs are the required accuracy of project plans, the number of formal and other project specific documents required by banks' loan-officers and the time devoted to creditworthiness tests. The full price a borrower pays for the loan depends on her distance from banks, and the distance may thus vary for various reasons; e.g. Winton's (1999) view is that banks may specialize in different loan sectors in their lending.

[4] De Meza and Webb (1988), Nakamura (1993), Shaffer (1999), and Chiesa (1998) are other examples belonging to this strand of the literature. Gehrig (1998) and Kanniainen and Stenbacka (2000) allow banks to choose their screening ability and provide conditions under which screening investments are reduced by a shift from a monopoly to duopolistic competition. We too have

studies by Broecker (1990) and Riordan (1993) have demonstrated that the larger the number of banks applying independent screening techniques, the greater the chance that an unprofitable project is eventually misclassified as creditworthy. Shaffer (1998) suggests however that the difference between independent and correlated screening can be consequential to this result. The paper points out, and provides numerical examples, that to the extent to which banks utilize common devices, the externalities generated by screening, i.e., the 'winner's curse', can at least in principle be alleviated.[5] This paper extends these observations by contrasting independent screening to common filters in a formal model.

We find that both the accuracy of screening and the difference between independent and common filters matter for the loan market outcome. Better screening ability decreases banks' loan margins and, provided that the average creditworthiness of borrowers is not too low, increases lending volume. Moreover, under independent screening the presence of a backlog of rejected borrowers in the market reduces the elasticity of the borrowers' post screening loan demand compared to the case of common filters. In addition, the backlog increases the number of borrowers eventually classified as creditworthy. Therefore the margins are wider and lending volume higher under independent screening than under common filters. Improved screening has also bearings on the size of the banking industry. More accurate screening increases the banks' incentives to enter under common filters, while it may undermine them under independent screening.

touched upon the question how competition affects banks' incentives to screen. Our main finding is that intensified competition, stemming either from an increase in the number of competing banks or from a lower degree of differentiation, decreases the banks' screening investments. The details of this analysis can be found from appendix 2.

[5] Shaffer finds that for 20 banks in the market, a correlated screening technology that is only slightly better than random can achieve the same loan loss rate as an i.i.d. screening that is 90 percent accurate.

The rest of the paper proceeds as follows. In section 2, we set up a model of interbank competition with banks engaged in screening. The banks face an adverse selection problem with and without a ‘backlog’ of previously rejected borrowers. The former corresponds to the case of independent screening and the latter to common filters. In section 3, we characterize the equilibrium for a given number of banks in the market and present our main results on the effects of screening on interest rate margins, lending volumes and banks’ profits. The analysis continues in section 4 by introducing an entry stage. Modifications and extensions to the basic model are discussed in section 5, while section 6 concludes.

2 A Model of Interbank Competition with Screening Banks

2.1 Basic Framework

Consider a Salop-type spatial model of a banking industry, set up along the lines of Williamson (1987), Besanko and Thakor (1992) and Chiappori et al. (1995). The economy is universally risk-neutral. There are banks, indexed by i, located on a circle of unit circumference, as well as N potential borrowers uniformly distributed along the circle. Maximal differentiation in location is assumed, and hence the banks are located symmetrically on the circle. The location of a borrower is denoted x. When visiting a bank, a borrower incurs a transportation cost. The cost per unit of length is τ. The cost is not to be interpreted solely in geographical terms but also as a transaction cost that must be paid by all loan applicants if they wish to borrow from a particular bank. The banks cannot determine the location of customers, and therefore no location-based price-discrimination is feasible.

There are two types of loan applicants: A type G applicant is a skillful businessman having access to a project that requires an initial investment of size unity and generates a cash flow $R > 0$ with probability one. A type C applicant is a dishonest charlatan who follows a policy of 'take the money and run'.[6] The charlatan extracts a private benefit, $B > 0$, if granted a loan. In the population of borrowers, the respective fractions of these two types are λ and $(1-\lambda)$.

We assume that borrowers have no initial wealth so that if a project is to be initiated, the borrowers must apply for a loan of size unity. From the perspective of borrowers, the banks are the only source of outside financing in this economy. The banks use standard debt contracts, and r_i denotes the lending rate factor. Banks face a perfectly elastic supply of funds at a gross interest rate equal to ρ.[7]

2.2 Creditworthiness Testing

Banks are aware of the informational problem in the loan market and the non-existence of self-selection devices. They therefore apply creditworthiness tests when considering which projects to finance. As in Broecker (1990), Thakor (1996) and Shaffer (1998, 1999), the screening technology produces a noisy signal which can be either G_s (the entrepreneur is tested to be good, i.e., creditworthy) or C_s (the entrepreneur is tested to be charlatan, i.e., not creditworthy). Though the accuracy of screening could reflect the organisational design of banks and be defined and adjusted separately for different types of borrowers (Kan-

[6] Hence if a charlatan is granted a loan, the bank is sure to loose the entire principal. We motivate this assumption by quoting Stiglitz and Weiss (1988), who write that 'there are always charlatans and cheats willing to use or misuse others' resources for their own benefit or in any case, in ways for which there are low social returns' (p. 13). The assumption simplifies the analysis considerably and is by no means extraordinary in the literature (see, e.g., Chan et al. 1986, Petersen and Rajan 1995, and von Thadden 1995). The model could also be extended, e.g., by assuming that some of the applicants are over-confident entrepreneurs in the spirit of de Meza and Southey (1996) and Manove and Padilla (1999); see section 5 for a discussion.

[7] We acknowledge that a number of important institutional and other features characterizing banking industries, such as competition for deposits, are simply missing from our modeling framework. We have however studied alternative specifications of the basic model. They are discussed in section 5.

niainen and Stenbacka 2000), we for simplicity measure it by a single variable. The technology is uniform across banks and characterized by the following: $Prob(C_s \mid \text{charlatan}) = Prob(G_s \mid \text{good}) = q$, $q \in [1/2, 1)$. If $q = ½$, the testing technology is completely uninformative since the fraction of creditworthy borrowers among the screened ones would be equal to λ.[8] The probabilities that a C-type and G-type borrower pass the test of a representative bank are $(1-q)$ and q, respectively. A specific feature of the technology is that the higher is q, the more accurately a bank can both identify profitable projects and avoid loan risk.

We shall be interested both in independent and correlated screening, i.e., common filters. Under the assumption of independent screening, the probability that a once rejected charlatan (good) applicant will be rejected by another bank she approaches is q $(1-q)$. In the case of common filters, let β_C (β_G) denote the probability that the second bank, which a once rejected charlatan (good applicant) approaches, observes the same signal as the first bank.[9] We can therefore think of β_C (β_G) as a measure of correlation across banks' screening. To see this, consider creditworthiness signals observed for a given charlatan by two neighboring banks (e.g., by i and i+1) and represented by random variables Y_i and Y_{i+1}. They obtain the value one if the applicant is labeled to be a charlatan and zero if he is labeled creditworthy. Using the fact that $E[Y_iY_{i+1}] = E\{E[Y_iY_{i+1}|Y_i]\}$, it can be shown that the covariance of the two signals is $\text{cov}(Y_i, Y_{i+1}) = E[Y_iY_{i+1}] - E[Y_i]E[Y_{i+1}]$ $= q(\beta_C - q)$, where $q \le \beta_C \le 1$. Thus, the covariance is zero if and only if $q = \beta_C$.

[8] This implies that the screening technology is such that its informativeness does not depend on the distribution of borrower types.

[9] In other words, β_C (β_G) is the conditional probability that a second bank rejects a charlatan (good applicant), given that the first one did.

What matters for the purposes of the present analysis is whether or not borrowers that have been denied a loan by one bank find it feasible to apply for a loan at another bank. This is essentially what Shaffer (1998) has called 'applicant attrition'. The backlog of the once rejected applicants plays an active role if they approach another bank for a loan. Such an act is feasible if the expected benefit from applying exceeds the transportation costs of applying, e.g., if the signals of the banks are independent and the costs are low. Should the rejected borrowers however exit due to 'sufficiently' correlated signals and high costs, no backlog would accrue. We shall therefore proceed under the simplifying assumption that the analysis of correlation versus independence properties of screening can be reduced to the investigation of two extreme cases, i.e., to the cases of inactive and active backlogs of the rejected borrowers, respectively. To that end, we make

Assumption A1. *Common filters are perfectly correlated.*

Using the above notation, the assumption of perfect correlation means that $\beta_C = 1$ and $\beta_G = 1$. The assumption implies that in the presence of transportation costs, a borrower that is rejected by the first bank that she approaches exits after the rejection irrespective of her type.[10] Hence it serves the purpose of highlighting the importance and role of screening technology's correlation property in a straightforward fashion.

[10] A more general model would allow for an intermediate degree of correlation in screening. Such a model has however turned out to be analytically intractable. The reason is that conditional on the degree of correlation, the banks would be in a mixed competition for borrowers: After being rejected once, some of the borrowers would exit while others would stay in the market. The decision would depend, among other things, on the rejected borrower's type and her distance from the nearest bank that has not screened her yet.

2.3 Competitiveness and Timing of Events

In the analysis below, we focus on economies in which the transportation cost, τ, is small enough to guarantee that the entire loan market will initially be covered in equilibrium. We hence examine the case of *full-scale competition* in the terminology of Villas-Boas and Schmidt-Mohr (1999). Further, we assume that the interaction between the banks is local.[11] The last assumption is akin to a local markets assumption and means that the potential market share of a bank consists of the borrowers located between the bank and its immediate neighbors. A borrower located at x between bank i and i+1 can hence approach at most two banks for a loan; if these do not grant it, her borrowing opportunities are exhausted, forcing that particular applicant to exit. This assumption could reflect, e.g., the locality of creditworthiness information and banks monitoring capability (Petersen and Rajan 2000) in the sense that borrowers sufficiently far away from a bank are almost surely not granted a loan. Otherwise the screening accuracy is understood not to depend on the location of borrowers, x.

The timing of events is as follows: *In stage* 1, banks compete for loan customers by announcing simultaneously loan interest rates. *In stage* 2, the borrowers observe the loan interest rates and travel to banks. The borrowers approach banks sequentially. It is assumed in particular i) that the banks reject applicants for whom the signal indicates type C, ii) that, following Shaffer (1998, 1999), the first bank to label an applicant G will make the loan,[12] and iii) that the banks cannot determine whether an applicant has been previously rejected by another bank. The

[11] For instance Stole (1995) has used this assumption when analysing Salop’s model.

[12] In a symmetric equilibrium, no borrower that receives a loan from the first bank she approached would find it advantageous to travel to another bank. The reason is that that would only involve additional transportation costs.

last assumption implies that no discrimination between initial applicants and the subsequent applicants that have been rejected previously is feasible (see, e.g., ‘anonymous lender’ scenario in Shaffer 1998 and Nakamura 1993). This structure implies that for borrowers there *may* be two phases within stage two. First, they decide at which bank to apply for the first time. Second, if denied a loan at that bank, they decide whether to approach a second bank for a loan or to exit.

We study the cases of independent and correlated screening side by side throughout the remainder of the paper. To carefully distinguish between the two cases, we shall use a hat (∧) above the variables that refer to the independent screening case (e.g., q vs. $\hat{q}$).

In the next two sections, we first focus on ‘short-term’ analysis with a given number of banks in the market. We then go on in section 4 to consider a ‘long-term’ perspective by analyzing entry. In the two sections that follow, the accuracy of screening is exogenous and the same for all banks and screening involves no cost.[13]

3 Competition with Screening

Assume that there are n banks that have entered the market and that have located symmetrically on the circle. We begin by deriving loan demand functions in subsection 3.1. The equilibrium is characterised in subsection 3.2.

[13] We have also investigated the model under the assumption that there is a small but positive fixed unit cost per borrower screened. All results hold in that case, too. Moreover, costly screening is considered in appendix 2 where banks’ screening investments are studied.

3.1 Stage Two: Choosing between Banks

We begin this subsection by deriving loan demands with common filters. We do it in detail so as to spell out carefully the sources of applicant attrition in the model.

Loan Demand under Common Filters: Consider the last decision to be made within the stage two of the model, i.e., the situation of once rejected applicants. By assumption, the banks do not know whether an applicant has been previously rejected by another bank or whether she is applying for the loan for the first time. Due to the local markets assumption, there is only one other bank potentially lending to a rejected borrower. It follows that the entire backlog faces a decision between applying for a loan from that bank (and knowing that if granted, the loan interest rate will be the one that was initially quoted) and exiting.

The rejected borrowers, be they *G*- or *C* -types, know that the other potential bank lending them will, by assumption A1, reject them with probability one. Because of the transportation costs, they exit rather than apply. Applicant attrition is hence at work, and no active backlog of rejected borrowers emerges.

We can now proceed to consider the 'first travelling' decision and, in particular, a representative *G*-type borrower located at distance $x \in [0, 1/n]$ from bank *i*. Foresighted borrowers take into account the consequence of correlated screening and anticipate their exit decisions. Bank *i* attracts the borrower if the expected return from applying once is non-negative and if its interest rate offer is more attractive than that of its rival banks. The participation constraint (PC) of the *G*-type borrower reads as:

$$q\pi(r_i) - \tau x \geq 0\,, \tag{1a}$$

where $\pi(r_i) \equiv (R - r_i)$. The first term is the net profit from undertaking the business project multiplied by the probability that a *G*-type borrower is granted a loan.

For the G-type borrower bank i's loan offer is more attractive than that of its rivals if

$$q\pi(r_i) - \tau x \geq q\pi(r) - \tau((1/n) - x), \tag{1b}$$

where it is supposed that $r_j = r$ for $j \neq i$. If (1b) holds as equality, it defines the location of the G-type borrowers who are indifferent between bank i and its neighboring rivals.

Combining (1a) and (1b) reveals that the G-type borrower located at x will travel to bank i if

$$x \leq \min\left\{\frac{q\pi(r_i)}{\tau}, \frac{1}{2n} + \frac{q(\pi(r_i) - \pi(r))}{2\tau}\right\}.$$

The minimum is equal to $(1/(2n) + q(\pi(r_i) - \pi(r))/2\tau)$ if

$$q(\pi(r_i) + \pi(r)) \geq \frac{\tau}{n}. \tag{2}$$

We therefore have that for small enough τ, the PCs of G-types are slack and only the constraint due to competition is relevant in determining the loan demand bank i faces.

For a C-type borrower located at x a similar analysis applies. Her PC reads as

$$(1-q)B - \tau x \geq 0 \tag{3a}$$

and the constraint due to competition as

$$B(1-q) - \tau x \geq B(1-q) - \tau((1/n) - x). \tag{3b}$$

Combining (3a) and (3b) as above results in inequality

$$B \geq \frac{\tau}{2n(1-q)}, \tag{4}$$

which ensures that it is the constraint due to competition that determines the loan demand bank i faces from the charlatans. Since $q < 1$, (4) always holds provided, e.g., that τ is small enough or that the charlatans' private benefit, *B*, is large. Appendix 1 provides conditions under which (2) and (4) hold in equilibrium.

Given the distribution of borrowers on the unit circle, the composition of borrower population and banks' screening ability, the *post screening* loan demand function for the i^{th} bank is

$$L_i = L_{iG} + L_{iC} \tag{5}$$

where

$$L_{iG} = q\left[N\lambda\left(\frac{1}{n} + \frac{q(\pi(r_i) - \pi(r))}{\tau}\right)\right] \text{ and } L_{iC} = (1-q)\left[\frac{N(1-\lambda)}{n}\right].$$

The first term, L_{iG}, consists of the probability of good borrowers correctly passing bank screening times the loan demand of these borrowers, and the second term, L_{iC}, is the probability of charlatans erroneously passing the screening times their loan demand.

Loan Demand under Independent Screening: As previously, we begin by considering the once rejected applicants. They confront a decision problem between exiting and applying for a loan from the bank that has not screened them yet. Since the maximum distance between two banks is 1/*n*, the entire population of the good but once rejected borrowers apply subsequently irrespective of their location if

$$\hat{q}\pi(\hat{r}_i) - \tau / n \geq 0. \tag{6a}$$

Similarly, all the once rejected charlatans apply subsequently irrespective of their location if

$$(1-\hat{q})B - \tau / n \geq 0. \tag{6b}$$

We proceed under the assumption that (6a) and (6b) hold. The restrictions that this assumption imposes on the parameters of the model are discussed in appendix 1.

The decision to apply after one rejection is anticipated and shows up in the initial, 'first round' travelling decision. In other words, foresighted borrowers recognize the possibility of being rejected by the first bank that they approach and the subsequent additional travelling decision.[14] Therefore, the *G*-type borrower located at *x* prefers bank *i* to the rival if

$$\hat{q}\pi(\hat{r}_i)+(1-\hat{q})\left[\hat{q}\pi(\hat{r})-\tau((1/n)-x)\right]-\tau x$$
$$\geq \tag{7a}$$
$$\hat{q}\pi(\hat{r})+(1-\hat{q})\left[\hat{q}\pi(\hat{r}_i)-\tau x\right]-\tau((1/n)-x),$$

where it is supposed that $\hat{r}_j=\hat{r}$ for $j\neq i$. Notice that by (6a) and (6b), the terms in the square brackets are positive. Analogously, the *C*-type borrower located at *x* prefers bank *i* to its rivals if

$$(1-\hat{q})B+\hat{q}\left[((1-\hat{q})B-\tau((1/n)-x)\right]-\tau x$$
$$\geq \tag{7b}$$
$$(1-\hat{q})B+\hat{q}\left[((1-\hat{q})B-\tau x)\right]-\tau((1/n)-x).$$

Define $\hat{s}_{iG}=1/n+(1/\tau)\hat{q}\left(\pi(\hat{r}_i)-\pi(\hat{r})\right)$ as bank *i*'s market share of the good borrowers applying for the first time. It follows that the *post screening* loan demand function for the i^{th} bank is

$$\hat{L}_i=\hat{L}_{iG}+\hat{L}_{iC} \tag{8}$$

where

$$\hat{L}_{iG}=\hat{q}\left[N\lambda\left(\hat{s}_{iG}+(1-\hat{q})((2/n-\hat{s}_{iG}))\right)\right];\text{ and}$$

$$\hat{L}_{iC}=(1-\hat{q})\left[N(1-\lambda)\left(1/n+\hat{q}/n\right)\right].$$

[14] Appendix 1 shows that 'first round' PCs similar to (1a) and (3a) are redundant if inequality (6a) and (6b) hold.

In the square brackets of $\hat{L}_{iG}$ we have the initial loan demand of good borrowers, $\hat{s}_{iG}$, plus the backlog demand, $(1-\hat{q})(2/n-\hat{s}_{iG})$, with $\hat{q}$ in the front of the square bracket being the probability of a good applicant passing the test of bank *i*. The term $\hat{L}_{iC}$ has a similar interpretation.

3.2 Stage One: Interbank Competition

In this section we characterize the (symmetric) Nash equilibrium of the loan interest rate game. Given $r_j = r$ for $j \neq i$, the i^{th} bank solves the following problem in the case of common filters:

$$\max_{\{r_i\}} \Pi_i = (r_i L_{iG} - \rho L_i) \qquad \text{with } L_i = L_{iG} + L_{iC} .$$

For the independent screening case, the maximization problem is equivalent to the one just given except that L_i and L_{iG} are replaced by $\hat{L}_i = \hat{L}_{iG} + \hat{L}_{iC}$ and $\hat{L}_{iG}$, respectively.

It is easy to verify that the objective function is in both cases concave. A maximum is therefore characterized by the first-order condition:

$$\frac{\partial \Pi_i}{\partial r_i} = L_{iG} + \frac{\partial L_{iG}}{\partial r_i}\left(r_i - \rho\right) = 0 \tag{9}$$

and analogously for the case of independent screening.

Drawing on the first-order condition it is straightforward to compute the following unique equilibrium for the case of common filters and independent screening, respectively:[15]

[15] The conditions under which the proposed equilibria are consistent with the initial assumption of full-scale competition and, in the case of independent screening, with the initially assumed behavior of the once rejected borrowers, i.e. (6a) and (6b), are given in appendix 1.

$$r = \rho + \frac{\tau}{nq} \tag{10a}$$

$$\hat{r} = \rho + \frac{\tau(2-\hat{q})}{n\hat{q}^2} \tag{10b}$$

Though quite a wide range of comparative static exercises could be performed, we now focus fully on the ramifications of banks' screening ability and of the difference between independent screening and common filters, on the pricing of loans, lending volume and banks' profits. To that end, we first remark that if $q = \hat{q}$, independent screening is intrinsically as accurate as the use of common filters. Since such a situation is considered quite frequently in what follows, we simply use notation '$q = \hat{q}$' when referring to the condition.

Let us now compute banks' interest rate margins. In the case of common filters and independent screening they are $\Delta r \equiv r - \rho = \tau / nq$ and $\Delta\hat{r} \equiv \hat{r} - \rho = \tau(2-\hat{q}) / n\hat{q}^2$, respectively. The interest rate margins immediately bring forth the following:

Proposition 1. *The interest rate margin is inversely related to the accuracy of screening, i.e.,* $d\Delta r / dq < 0$ *and* $d\Delta\hat{r} / d\hat{q} < 0$. *Moreover, if* $q = \hat{q}$, *the interest rate margin is higher under independent screening than under common filters, i.e.,* $\Delta\hat{r} - \Delta r > 0$.

There are two effects that arrive on the scene in proposition 1. Firstly, there is a loan denial effect that has to do with the interest rate elasticity of loan demand: The more likely it is that a *G*-type borrower is granted a loan, the more sensitive is the demand to changes in the loan interest rates. This implies that the interest rate margins are decreasing in the screening ability. In the case of independent screening, there is an additional effect that leads to the higher interest rate margin. The good borrowers rejected by bank *i*'s neighboring rivals and subsequently accepted by bank *i* have the impact of increasing the amount of the good borrowers financed by the i^{th} bank for a given loan interest rate. In other words, the presence of the backlog of the rejected borrowers reduces the interest rate sensitivity of the creditworthy borrowers' *post screening* loan demand. This effect hence supports a higher interest margin under independent screening than under common filters.[16]

In a way, the above establishes a link to the model of informative advertising and price competition with differentiated products by Grossman and Shapiro (1984). In that model firms rely on independent advertising technologies and more effective advertising increases the elasticity of demand. Such an effect can be seen to parallel the one stemming from improved screening here.

Notice finally that the interest rate margin is independent of the type distribution and thus the average creditworthiness of borrowers, i.e., λ.[17] This could result in banks making non-positive equilibrium profits when they play the proposed equilibrium strategies; we compute below the conditions ensuring that the profits are non-negative. We also show in a later section that this has an expected impact on entry by limiting the size of the banking industry.

Since in the symmetric equilibrium, $L = (N/n)[q\lambda + (1-q)(1-\lambda)]$ and $\hat{L} = (N/n)[\hat{q}(2-\hat{q})\lambda + (1-\hat{q}^2)(1-\lambda)]$, the following can be shown to hold:

Proposition 2. *Provided that the average creditworthiness in the population of borrowers is relatively high, the lending volume is directly related to the accuracy*

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[16] The prediction goes well with the recent finding of Strahan (1999). He documents that borrowers that are harder for outside lenders to value (implying less correlated screening) pays more for their loans.

[17] The relative amount of *C*-type borrowers is not a determinant of the equilibrium loan rates here, as neither the expected profit per a loan granted to *C*-types nor their demand behavior is affected by changes in the loan interest rates. Thus, even though better screening improves the average borrower quality in the bank's loan book, the improvement is not driving the margins.

of screening, i.e., if $\lambda > \frac{1}{2}$*, then* $dL/dq > 0$ *and if* $\lambda > \hat{q}$*, then* $d\hat{L}/\hat{q} > 0$*. Otherwise, the reverse obtains. Moreover, if* $q = \hat{q}$*, the lending volume is higher under independent screening than under common filters, i.e.,* $L < \hat{L}$*.*

The first result here is intuitive: as screening becomes more accurate, it depends on the average quality of borrowers whether the banks wish to expand or contract their lending. Notice in particular that $\lambda > \hat{q}$ cannot be ruled out since for the screening to be informative, it is only required that $\hat{q} > \frac{1}{2}$. As to the second result, the lending volume is higher under independent screening because some of the borrowers rejected by a bank receive financing from the other bank they approach, reflecting the well-known winners' curse effect.

We now turn to the effects of screening on banks' profits. In the symmetric equilibrium characterized above, the expected profits of a representative bank are in the case of common filters and independent screening as follows:

$$\Pi = \frac{\lambda N \tau}{n^2} - (1-q)\frac{(1-\lambda)N}{n}\rho \tag{11a}$$

$$\hat{\Pi} = \frac{\lambda N \tau}{n^2}\left(\frac{(2-\hat{q})^2}{\hat{q}}\right) - (1-\hat{q}^2)\frac{(1-\lambda)N}{n}\rho \tag{11b}$$

By (11a), $\Pi > 0 \Leftrightarrow \lambda > \dot{\lambda} \equiv \left(1 + \tau/(n\rho(1-q))\right)^{-1}$. Assuming moreover that $q = \hat{q}$, a comparison of (11a) and (11b) yields the following for a fixed number of banks in the market:

$$\hat{\Pi} > \Pi \Leftrightarrow \lambda > \ddot{\lambda} \equiv \left\{1 + \left(\tau/(n\rho)\right)\left((q^2 - 5q + 4)/(q^2(1-q))\right)\right\}^{-1}. \tag{12}$$

Through comparison we find that $\dot{\lambda} < \ddot{\lambda} < 1$. We thus have

Proposition 3. *Assume that* $q = \hat{q}$*. Provided that the average creditworthiness in the population of borrowers is relatively high, the banks' profits are non-negative* *and higher under independent screening than under common filters, i.e., provided that* $\lambda > \ddot{\lambda}$, $\hat{\Pi} > \Pi > 0$.

The intuition is clear-cut. By proposition 1 the banks earn higher returns per a loan granted to the creditworthy borrowers under independent screening than under common filters. Thus, common filters result in the banks having identical information sets, leading to more intense competition. The higher returns are however traded off against a pool-worsening effect that exists under independent screening since the average quality of borrowers in the backlog of the once rejected borrowers is lower than in the population of borrowers. The pool-worsening effect is of minor importance if λ is high, and it is not present at all in the case of common filters since the once rejected backlog exits. Hence the result follows.

We conclude this section by noting that the symmetric information profits in a symmetric equilibrium would be $\lambda N\tau / n^2$, as the banks would lend to the good borrowers only. It is easy to verify that under independent screening the profits are higher than under symmetric information whenever the average creditworthiness in the population of borrowers is relatively high. In such a case, the main effect of screening is to increase interest margins and the borrowers' quality is of second-order importance. With common filters no such tradeoff emerges since the profits per a good borrower are independent of screening in equilibrium.

That banks' expected profits are a function of their screening abilities suggests that the size of banking industry depends on them. To see how, we next consider entry.

4 Entry (endogenous *n*)

In this section, banks' entry incentives are analyzed by introducing *stage zero* during which the banks enter simultaneously and locate symmetrically on the circle. To focus on the effects of the banks' screening ability, we shall ignore (as is typical; see for instance Williamson 1987, Besanko and Thakor 1992, and Dell'Ariccia 1998) both the integer problems regarding the feasible number of banks in the market as well as the banks' location choices when considering the entry. Though fixed costs of financial intermediation can have significant consequences on the industry equilibrium (Williamson 1987), it is assumed that no such costs exist here. We assume that entry continues until expected profits are driven to zero.

Using (11a) and (11b) yields

$$n^* = \frac{\lambda\tau}{(1-q)(1-\lambda)\rho} \tag{13a}$$

$$\hat{n}^* = \frac{\lambda\tau(2-\hat{q})^2}{(1-\hat{q}^2)\hat{q}(1-\lambda)\rho} \tag{13b}$$

The following proposition is immediate:

Proposition 4. *The equilibrium number of banks is finite under free entry.*

This result is thus akin to a confirmation of Dell'Ariccia's (1998) finding that, contrary to the traditional models of horizontal differentiation with zero fixed entry costs, a loan market characterized by asymmetric information can sustain only a limited number of competing banks (see also Dell'Ariccia et al. 1999). Asymmetric information and particularly the charlatans, whose presence is not reflected in the interest rate margin, hence result in a barrier to entry in the banking industry. This can be verified by considering the limiting case of λ approaching unity; the zero-profit equilibrium would then be characterized by a continuum of banks locating at all sites on the circle.

Proposition 4 provides a basis for two additional results. Firstly, differentiating (13a) and (13b) with respect the screening accuracy and resorting to a simple numerical analysis yields

Corollary 1. *Under free-entry, the number of banks is directly related to the accuracy of common filters, i.e.,* $dn^* / dq > 0$. *It is inversely related to the accuracy of independent screening provided that the accuracy is relatively low, i.e.,* $d\hat{n}^* / d\hat{q} < 0$ *if* $q \in [\frac{1}{2}, \hat{q}_T)$ *with* $\hat{q}_T \cong 0.717$*; otherwise the reverse obtains.*

In the common filter case the explanation of the result is that while more accurate screening lowers the interest rate margin, the associated improvement in the average creditworthiness in banks' loan portfolios uniformly dominates this adverse profit effect. With relatively inaccurate independent screening, the opposite may hold. The reason is the pool-worsening effect that is present under independent screens; more accurate screening decreases the average quality of borrowers in the backlog applying for a second time. Hence, any improvement in banks' screening is to some extent offset by this effect, implying that an increase in the loan quality due to improved screening may not be sufficient to offset the profit loss that the tighter interest margin trigger.[18]

Secondly, imposing $q = \hat{q}$ and comparing (13a) and (13b) results in

[18] Note specifically that the conditions for the existence of equilibrium derived in appendix 1 do not rule out the possibility that better screening reduces the number of banks. As long as screening is not perfect, all the results hold provided, for instance, that the revenue that the project generates, *R*, and the charlatans' private benefit, *B*, are large enough.

Corollary 2. *Assume that* $q = \hat{q}$. *Provided that the accuracy of screening is relatively low, the number of banks is higher under independent screening than under common filters, i.e., if* $q \in [\frac{1}{2}, \frac{4}{5})$, *then* $\hat{n}^* - n^* > 0$. *Otherwise, the reverse obtains.*

The finding is a parallel to proposition 3 and further highlights the difference between independent screening and common filters. With relatively inaccurate screening, the banks' profits from the good borrowers can be so high with independent screening relative to those with common filters that incentives to enter are higher despite the presence of the pool-worsening effect. To see why, notice that for $q = \hat{q}$, it holds that $\Delta\hat{r} - \Delta r > 0$ (from proposition 1) and that difference $\Delta\hat{r} - \Delta r$ is inversely related to the accuracy of screening. The latter holds since $|d\Delta\hat{r} / dq| > |d\Delta r / dq|$ whenever $q = \hat{q}$. Thus, with relatively inaccurate screening, the difference in the effects of common filters and independent screening on the interest rate margin is large. In such a case, the screening is however close to being 'uninformative', implying that the pool-worsening effect that emerges under independent screening is relatively unimportant. It ensues that for uninformative screens, the number of banks is higher under independent screening than under common filters.

In the next section we consider certain extensions to the basic model and certain properties and assumptions of the above analysis that are open to discussion and criticism.

5 Modifications and Extensions

A potential criticism to the basic model is that the liability side of banks' balance sheets is not given proper attention. We have however studied an asymmetric market structure with a local market for deposits. In that version of the model, the banks compete directly with their immediate neighbors in the loan market, but are local monopolists on the liability side. Depositors furthest away from the banks hold fiat money.[19] As the lending volume changes with the accuracy of screening, so does the banks' need for deposits. All the results that we have presented hold under the assumption that the depositors' transportation costs are not 'too high', implying that the supply of deposits is elastic, much as in the basic model.

Had we instead assumed that banks compete directly against each other on the deposit side, too, the results of the paper would remain unchanged under the additional assumption that the banks can at the same time raise or invest unlimited funds in interbank markets, or at the central bank, at a given rate. This would basically be the market environment of the liability side in the model analyzed by Chiappori et al. (1995). The results of Gottardi and Yanelle (1997) indicate, however, that if the additional assumption were not made, there would be a continuum of Nash equilibrium strategies due to the nature of simultaneous 'two-sided' banking competition.

The assumption that there are charlatans whose demand is not responsive to changes in the interest rate is a strong one. The model could however be extended, e.g., by assuming that some of the applicants are over-confident entrepreneurs in the spirit of de Meza and Southey (1996) and Manove and Padilla (1999). Building on rather convincing empirical evidence from psychology and behavioural economics, these papers argue that entrepreneurial optimism may well characterize bank lending and project financing. An important point here is that the motivation of an optimistic entrepreneur to apply for a loan differs from that of a charlatan. The optimistic entrepreneur may apply for a loan because she does not know her type but rather overestimates her likelihood of success. In an augmented

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[19] The asymmetric market structure is thus as in Williamson (1987).

model that allows for such entrepreneurial optimism, the results are similar to those presented earlier in this paper. They additionally show that the loan interest rates would in equilibrium be increasing in the amount of optimists in the market, as the banks would find it advantageous to increase the interest rate so as to discourage the optimistic, price-sensitive but unprofitable borrowers from applying. We have also found that the higher interest rates would strengthen the banks' incentives to invest in screening.

Another key assumption in the present analysis has been that the borrowers have no initial wealth or credit history. Had they own funds which could be pledged as collateral (or used as equity), various self-selection and signaling devices would have a role to play. This might fundamentally affect the screening incentives of banks. For instance, Manove et al. (1998) have recently shown that if collateral protects lenders effectively from loan risks, secured lending maybe inappropriately emphasized over creditworthiness testing. Another way in which collateral might affect the present analysis is studied in Villas-Boas and Schmidt-Mohr (1999). They consider borrower screening via incentive compatible loan contracts. Credit history and reputational considerations would alter the banks' loan pricing schemes, too; they provide, among other things, an alternative basis for price discrimination to that of ex ante screening. An analysis of these interesting issues and particularly their interaction with pre-lending screening in general and in an imperfectly competitive environment in particular are, however, outside the scope of the present analysis.

Finally, Shaffer (1998) has acknowledged that it is somewhat restrictive to assume that the outcome of a bank's creditworthiness testing is a binary signal. Even though a loan decision is a decision between lending and not lending and therefore quite compatible with the binary signal, credit scoring models typically classify would-be borrowers in a richer fashion. This feature is to some extent captured in the analysis of Nakamura (1993), who considers the acceptance threshold for a continuous density function of signals. He does not, however, allow for endogenous determination of interest rates nor does he consider the loan market structure in the way we have done here.[20]

6 Conclusions

The present paper builds on the view that screening technologies are changing. One the one hand, the degree of correlation across bank-level creditworthiness testing has increased, or is likely to increase, due to increasing use of standardized credit scoring models and new common information sources, such as the Internet, electronic databases and credit registers. On the other hand, considerable efforts have recently been devoted to developing better screening technologies. Our particular emphasis has therefore been on the effects of the difference between independent screening and common filters and improved screening on banks' lending policy and market structure.

Both the difference between independent and common filters and the accuracy of screening have been found to matter for the loan market outcome. The difference determines whether the backlog of previously rejected borrowers in the market is active (the independent screening case) or not (the common filter case). We have found that the loan interest margins are wider and lending volume higher under independent screening than under common filters. Better screening de-

[20] An additional criticism stemming from Nakamura's analysis is that banks could distinguish between the first time applicants and applicants that have been denied a loan by other banks. That situation could arise, e.g., in small local banks' lending with identifiable customer bases. However, to the extent to which borrowers themselves have no incentives to reveal such facts and communication between bankers is hampered, e.g., by moral hazard, our assumption ought not to be at odds with most lending markets.

creases the margins and, provided that the average creditworthiness of borrowers is not too low, increases lending volume. Under free entry, improved screening has an effect on the size of the banking industry, too. More accurate screening increases the banks' incentives to enter under common filters but may undermine them under independent screening.

Exchanging information on market conditions tends to increase the degree of correlation in firms' perceptions on them. The above results might for this reason have bearings on the literature on information sharing among oligopolists in general (see, e.g., Raith 1996 for an overview) and among banks in particular (e.g., Pagano and Japelli 1993 and Gehrig and Stenbacka 2000). Broadly interpreted, the results here suggest that a higher degree of correlation in the firms' perceptions on customer attributes should lead to less fragmented markets and therefore to increased competition. However, no such effect seems to emerge for instance in Gehrig and Stenbacka (2000), who find that information sharing in future tends to reduce informational rents and thereby current competitiveness. Future research could contrast the mechanisms behind these two seemingly opposite results.

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Appendix 1.

The conditions under which the proposed equilibria of the basic model are consistent with the behavior of the once rejected borrowers and with the initial assumption of full-scale competition are given in this appendix.

Common Filters Case: Note, firstly, that by Assumption A1 common filters are perfectly correlated. Small but positive transportation costs are therefore sufficient to ensure that irrespectively of their type, the once rejected borrowers exit.

Secondly, consider the following pair of inequalities:

$$R > \rho + \frac{3\tau}{2nq} = \rho\left(1 + \frac{3(1-q)(1-\lambda)}{2q\lambda}\right) \tag{1.1}$$

$$B > \frac{\tau}{2n(1-q)} = \rho\,\frac{(1-\lambda)}{2\lambda} \tag{1.2}$$

Inequality (1.1) and (1.2) ensure that all the borrowers prefer in equilibrium some bank's loan offer to exiting altogether. Notice that (1.1) is obtained from the main text's expression (2) and (1.2) from (4). The last terms in (1.1.) and (1.2) are obtained using the number of banks under free entry. The two conditions are satisfied provided, for instance, that the project's revenue, *R*, and the charlatans' private benefit, *B*, are large.

Independent Screening Case: Consider first the good borrowers. For a fixed number of banks, inequality

$$\begin{aligned} &\hat{q}\pi(\hat{r}_i) + (1-\hat{q})\left[\hat{q}\pi(\hat{r}) - \tau((1/n) - x)\right] - \tau x \geq 0 \\ &\Leftrightarrow \\ &x \leq \frac{\pi(\hat{r}_i) + (1-\hat{q})\pi(\hat{r})}{\tau} - \frac{(1-\hat{q})}{\hat{q}n} \end{aligned} \tag{1.3}$$

is a ‘first round’ PC ensuring that a good borrower located at x prefers initially, i.e., before she has approached any bank, applying for a loan to not funding her project.

Inequality (7a) in the main text is the condition determining whether the good borrower prefers bank i to its rivals. After rearranging it reads as

$$x \leq \frac{1}{2n} + \frac{\hat{q}}{2\tau}(\pi(r_i) - \pi(r)). \tag{1.4}$$

Combining (1.3) and (1.4) shows that the latter is binding in the equilibrium with n banks in the market provided that

$$R > \rho + \frac{\tau}{n}\left(\frac{4-\hat{q}}{2\hat{q}^2}\right). \tag{1.5}$$

The assumption that the backlog of the rejected borrowers stays in the market for the ‘second round’, i.e., apply for a loan after the first rejection, rather than exit, requires that in equilibrium

$$R > \rho + \frac{\tau}{n}\left(\frac{2}{\hat{q}^2}\right) = \rho\left(1 + \frac{2(1-\lambda)(1-\hat{q}^2)}{\lambda\hat{q}(2-\hat{q})^2}\right) \tag{1.6}$$

Condition (1.6) is based on (6a) from the main text when evaluated, firstly, in equilibrium for a given number of banks in the market and, secondly, under free entry. Since the right hand side of (1.6) is larger than that of (1.5), condition (1.6) is sufficient to ensure that the proposed equilibrium is consistent with our initial assumption of full-scale competition and regarding the behaviour of the good borrowers. The condition holds provided for instance that the project’s revenue, R, is high.

A similar analysis for the charlatans reveals that condition (6b) in the main text is sufficient to ensure that the proposed equilibrium is consistent with the initial assumption of full scale competition and that the entire backlog of once rejected charlatans apply for a second time for loans. It is reproduced here as:

$$B > \frac{\tau}{(1-\hat{q})n} = \rho\left(\frac{(1-\lambda)\hat{q}(1+\hat{q})}{(2-\hat{q})^2}\right), \tag{1.7}$$

where the last equality follows from the free entry condition. Condition (1.7) holds provided for instance that the charlatans' private benefit, *B*, is large.

Appendix 2.

In this appendix we consider banks' screening investments by developing a model of endogenous screening accuracy. Gehrig (1998) and Kanniainen and Stenbacka (2000) have recently compared a monopoly bank's screening investments to those of duopoly banks and showed that by and large, the monopoly bank invests more in screening. We ask how more intense competition stemming from reduced differentiation between banks or increased number of competitors beyond a duopoly influences the banks' screening investments. Other extensions are discussed in section 5 of the main text.

In order to endogenize banks' screening abilities and to focus on the determinants of the banks' screening investments we ignore entry; there are n banks located symmetrically on the circle in what follows.

It is assumed that the accuracy of screening can be adjusted by investing more resources. Perfect screening is however infeasible since it would require infinite resources (see, e.g., Gehrig 1998 and Kanniainen and Stenbacka 2000 for a similar assumption). The total cost of adjusting the accuracy is given by an increasing and convex cost function $C(q)$ with $q_i \in [½, 1)$ for all i. The following specifies the cost function:

Assumption. *The screening cost function satisfies* $C'(q) > 0$ and $C''(q) > 0$ *with the boundary conditions:*

i) $C(\tfrac{1}{2}) = 0$ and $C'(\tfrac{1}{2}) = 0$

ii) $\lim_{q \to 1} C(q) = \infty$ and $\lim_{q \to 1} C'(q) = \infty$.

Banks' screening decisions are assumed to be unobservable to the loan applicants.[1] An interpretation of this feature of the model is in terms of banks' commitment ability; the suggested set-up corresponds to the case in which the banks are able, or forced, to commit to their pricing decisions, say for reputational reasons, but not to their screening levels.[2]

As the probability of passing bank screening is not observable to the loan applicants, they will form rational expectations on banks' privately optimal loan policy decisions, i.e., infer the decisions as being the ones that prevail in Nash equilibrium. The rational beliefs on the values of q_i ($\hat{q}_i$) are denoted $E[q_i]$ ($E[\hat{q}_i]$).[3]

As before, in examining the loan pricing and screening choices of the i^{th} bank, it is assumed that $r_j = r$ ($\hat{r}_j = \hat{r}$) and $q_j = q$ ($\hat{q}_j = \hat{q}$) for $j \neq i$. The timing of events is that in stage one banks choose their screening investments simultaneously with loan interest rates. In stage two, borrowers travel to banks.

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[1] We have also analyzed a version of the model with observable screening investments. In that model, the banks would in general invest more resources in screening than with unobservable screening levels. The reason is that a more accurate screening would, other things equal, boost the demand of the good borrowers but discourage that of the charlatans. This situation would be more in line with the view of Kanniainen and Stenbacka (2000), who suggest that a bank's screening ability reflects its prior commitment to an organisational design.

[2] An additional motivation for the unobservability of screening decisions is the relatively complex and varying nature of modern risk evaluation procedures as well as the opaque internal structures of larger banking firms. Should that be the case, loan applicants could only conjecture what a bank's screening intensity might be instead of being able to detect it before applying. In contrast, interest rates on loans are frequently publicly quoted and therefore observed by all market participants.

[3] Note that a charlatan may not apply at all if she believes that the probability that she is detected is high enough. We proceed under the assumption that this constraint does not bind and then derive conditions under which this indeed is so in equilibrium.

Stage Two: Choosing between banks

The derivation of the loan demand functions parallels that of the case of exogenous screening and can be found in appendix 2. The *post screening* loan demand functions for the i^{th} bank in the case of common filters read as:

$$L_{iG} = q_i\left[N\lambda\left(\frac{1}{n}+\frac{1}{\tau}(E(q_i)\pi(r_i)-E(q)\pi(r))\right)\right] \tag{2.1a}$$

$$L_{iC} = (1-q_i)\left[N(1-\lambda)\left(\frac{1}{n}+\frac{1}{\tau}(E(q)-E(q_i))B\right)\right] \tag{2.1b}$$

Note that the demand functions do not directly depend on the rivals' screening ability, q. They do, however, reflect the borrowers' views on the banks' screening ability, i.e., $E(q)$ and $E(q_i)$.

In the case of independent screening, we have

$$\hat{L}_{iG} = \hat{q}_i\left[N\lambda(\hat{s}_{iG}+(1-\hat{q})(2/n-\hat{s}_{iG}))\right] \tag{2.1c}$$

$$\hat{L}_{iC} = (1-\hat{q}_i)\left[N(1-\lambda)(\hat{s}_{iC}+\hat{q}(2/n-\hat{s}_{iC}))\right] \tag{2.1d}$$

where we have used:

$$\hat{s}_{iG} = 2\left(\left(\frac{E(\hat{q}_i)}{E(\hat{q}_i)+E(\hat{q})}\right)\frac{1}{n}+\left(\frac{E(\hat{q}_i)E(\hat{q})}{E(\hat{q}_i)+E(\hat{q})}\right)\frac{(\pi(\hat{r}_i)-\pi(\hat{r}))}{\tau}\right) \text{ and;}$$

$$\hat{s}_{iC} = 2\left(\frac{1-E(\hat{q}_i)}{(2-E(\hat{q}_i)-E(\hat{q}))}\right)\frac{1}{n}.$$

In contrast to the case of common filters, the demand functions of the i^{th} bank now depend on the rivals' screening ability, q. In addition, they reflect the borrowers' views on the banks' screening abilities. With the demands within reach, we can turn into interbank competition.

Stage One: Interbank Competition in Loan Interest Rates and Screening Investments

In the case of common filters, the i^{th} bank solves:

$$\max_{\{r_i,q_i\}} \Pi_i = (r_i L_{iG} - \rho L_i - C(q_i))$$

where $L_i = L_{iG} + L_{iC}$. An interior solution in the case of common filters is characterized by the following first-order conditions

$$\frac{\partial \Pi_i}{\partial r_i} = L_{iG} + \frac{\partial L_{iG}}{\partial r_i}(r_i - \rho) = 0 \tag{2.2a}$$

$$\frac{\partial \Pi_i}{\partial q_i} = \frac{\partial L_{iG}}{\partial q_i} r_i - \frac{\partial L_i}{\partial q_i}\rho - C'(q_i) = 0 \tag{2.2b}$$

In a Nash symmetric equilibrium with rational beliefs on the part of borrowers, it holds that $q_i = q = E[q_i] = E[q]$ and $r_i = r$. After some algebra, we find that for the common filter case equation (2.2a) and (2.2b) enable us to write down the following:

$$r = \rho + \frac{\tau}{nq} \tag{2.3a}$$

$$\frac{\lambda N \tau}{n^2 q} + \frac{(1-\lambda)N}{n}\rho - C'(q) = 0 \tag{2.3b}$$

In the case of independent screening, the maximization problem would be equivalent to the above one except that L_i is replaced by $\hat{L}_i = \hat{L}_{iG} + \hat{L}_{iC}$. From the maximization problem, we would get the first-order conditions analogous to (2.2a) and (2.2b). Imposing then $\hat{q}_i = \hat{q} = E[\hat{q}_i] = E[\hat{q}]$ and $\hat{r}_i = \hat{r}$ into the first-order conditions gives:

$$\hat{r} = \rho + \frac{\tau(2-\hat{q})}{n\hat{q}^2} \tag{2.4a}$$

$$\frac{\lambda N \tau (2-\hat{q})^2}{n^2 \hat{q}^2} + \frac{(1-\lambda)(1+\hat{q})N}{n}\rho - C'(\hat{q}) = 0 \tag{2.4b}$$

The sufficient second-order conditions are shown in appendix 1 to be satisfied at the proposed equilibria provided that the cost function is convex enough. There we also show that corner solutions can be ruled out. Finally, the conditions under which the proposed equilibria are consistent with the assumed behavior of the once rejected borrowers and with the initial assumption of full-scale competition are the same as those presented in appendix 1 for fixed *n*.

The determinants of screening investments are characterized next:[4]

Proposition. *In a symmetric Nash equilibrium the following holds:*

(a) *If the cost of adjusting screening accuracy does not depend on the correlation properties of the screening technology, i.e.,* $C(q) = C(\hat{q})$ *for* $q = \hat{q},\ \forall\ q, \hat{q} \in \left[\tfrac{1}{2}, 1\right)$, *banks invest less in screening under common filters than under independent screening;*

(b) *Using common filters banks screen borrowers less intensively, the more there are banks in the market* ($dq/dn < 0$)*, the lower are transportation costs* ($dq/d\tau > 0$) *and the higher are the costs of financing* ($dq/d\rho < 0$)*. The same qualitative properties hold with independent screening provided that the cost function is sufficiently convex, i.e.,* $C''(\hat{q}) > N(1-\lambda)/n$.

Proof (Sketch). To prove part (a), assume that the cost of adjusting screening accuracy does not depend on the correlation properties of screening, i.e., $C(q) = C(\hat{q})$ when $q = \hat{q},\ \forall\ q, \hat{q} \in \left[\tfrac{1}{2}, 1\right)$. Consider q such that it implicitly solves (2.3b). Substituting that value into (2.4b) and then subtracting the former from the latter gives the desired result since the cost function is convex. Applying implicit function theorem to (2.3b) and (2.4b) proves part (b). **QED.**

[4] A remaining comparative statics exercise would be to consider the effects of improved average creditworthiness on screening investments. Provided that loan market competition is intense enough, i.e., provided that either τ is small or n is large, it can be verified that improved creditworthiness leads to smaller screening investments. The reason is that higher λ reduces the need to avoid charlatans but makes it easier to cover the costs of screening, as a larger fraction of loans are creditworthy for a given screening level. The former effect dominates the more competitive the banks are, as it then is less profitable to lend to the good.

There are two effects that come into play in part (a), both of which are due to the presence of the active backlog of rejected borrowers: First, independent screening supports higher loan interest rates and thereby higher revenues from each identified *G*-type applicant. Second, the backlog worsens the average quality of applicants that a representative bank finances at the quoted loan interest rate. These effects tend to encourage screening investments.

As to part (b), intensified competition, which can here stem either from an increase in the number of competing banks or from a lower degree of differentiation, decreases the banks' screening investments. A decrease in the transportation costs implies that the banks become less differentiated and that it therefore is less profitable to be able to identify a good borrower; the loss that a bank incurs from granting loans to charlatans is, however, not affected. As a result of this, incentives to invest in screening are undermined. An increase in the number of banks reduces screening investments for two reasons. Firstly, the profits obtained from the loans granted to the good borrowers decrease, as the banks' markets shares and interest margins decrease. Secondly, the more there are banks in the market, the smaller a bank's market share of the charlatans and hence the total loss that it incurs from not being able to sort them out. For a given screening level, the costs of screening are independent from the number of banks. The costs are therefore traded off against diminished benefits when n increases, which leads lower screening investments.

The above result points towards the problematic consequences of increased competition in loan markets. Kanniainen and Stenbacka (2000) find that when compared to a duopolistic market structure, a monopoly bank monitors good projects more effectively. The same holds for bad projects provided that the parametrically given lending rate competition between the duopolists is not too intense.[5] Gehrig (1998) too compares a monopoly bank to duopoly banks and demonstrates that banks' information production intensities are monotonically increasing (decreasing) in industry rents when the value from attracting creditworthy borrowers exceeds (falls short of) the value of sorting out unprofitable applicants. The screening investments are here also shown to be inversely related to the level of competition. We augment the previous studies by showing that the source of increasing competitiveness can be entry beyond a duopoly or a decrease in the degree of differentiation between the banks' financial services. Despite the emphasis recently put on the abolishment of regulatory entry barriers, the potential empirical importance of the latter impetus for competition should not be overlooked. Increased information flows, advances in information technology, financial innovations, more standardized loan application processes ('commodity-type' bank loans) and the like are among the current forces that modify the borrowers' perceptions on how differentiated banks' financial products are.

[5] Their finding is therefore in line with Chan et al. (1986) who show that the incentives of a monopolist bank to invest in a screening technology increases with the durability of information and parametrically given loan interest rates.