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Keskusteluaiheita – Discussion papers

No. 823

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MISUSE AND NON-USE OF INFORMATION ACQUISITION TECHNOLOGIES IN BANKING***

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*** This paper is a substantially revised version of a paper that was earlier circulated under the title: "Vertical Differentiation, Asymmetric Information and Endogenous Bank Screening". We thank Patrick Bolton, Marcus Asplund, Pekka Ilmakunnas, Klaus Kultti, Hannu Salonen, Rune Stenbacka, Juuso Välimäki, Lotta Väänänen and the participants at the seminar of the Finnish Post Graduate Program in Economics for useful comments. Much of this research was initiated when Hyytinen was affiliated with the Bank of Finland and Helsinki School of Economics. The second author would like to thank both the MIT Department of Economics and the NBER for hospitality during this research, and the Academy of Finland and the Yrjö Jahnsson Foundation for financial support. The usual caveat applies..

ISSN 0781-6847 11.10.2002

HYYTINEN, Ari – **TOIVANEN**, Otto, **MISUSE AND NON-USE OF INFORMATION ACQUISITION TECHNOLOGIES IN BANKING.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2002, 14 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; No. 823).

ABSTRACT: In a model of bank lending characterized by asymmetric information, we show that banks may misuse the availability of an interim monitoring technology to soften price competition, even though the borrowers face no moral hazard problem. The interim monitoring technology can also be used to alleviate adverse selection. The equilibria that emerge resemble those in vertical product differentiation models. We also show that a bank may decide not to use a costless and perfect ex-ante screening technology.

JEL: G21, G30, L15

Keywords: adverse selection, banking, ex-ante screening, interim monitoring, vertical differentiation.

HYYTINEN, Ari – **TOIVANEN**, Otto, **MISUSE AND NON-USE OF INFORMATION ACQUISITION TECHNOLOGIES IN BANKING.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2002, 14 s. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847; No. 823).

TIIVISTELMÄ: Tässä paperissa kehitetään luottomarkkinamalli, jonka avulla osoitetaan, että luottolaitokset (pankit) voivat käyttää luotonantoonsa liittyvien moral hazard -riskien vähentämiseksi soveltuvaa "monitorointiteknologiaa" vähentääkseen hintakilpailua olosuhteissa, joissa luottoasiakkaiden käyttäytymiseen liittyvää moral hazard -ongelmaa ei esiinny. Toisaalta havaitaan, että tällaisen teknologian avulla pankki voi myös vähentää sitä kohtaavaa ns. adverse selection -ongelmaa. Mallin tasapainot muistuttavat tasapainoja, joita tyypillisesti nähdään ns. vertikaalisen tuotedifferentiaation malleissa. Osoitamme myös, että pankki saattaa joissain olosuhteissa jättää ottamatta käyttöön teknologian, joka auttaisi sitä selvittämään (potentiaalisten) asiakkaiden luottokelpoisuutta.

1 INTRODUCTION

It has for long been understood that under asymmetric information, the market for loans may function imperfectly and even collapse altogether. Ever since Diamond's (1984) seminal article, it has also been understood that lenders (banks) may have various techniques and technologies to deal with asymmetric information: besides designing contracts that induce self-selection among borrowers (e.g. Bester, 1985), they can resort to ex-ante screening (Broecker, 1990, Thakor, 1996, Hauswald and Marquez 2001), interim monitoring (e.g. Besanko and Kanatas 1993, Holmström and Tirole, 1997), and/or ex-post verification (e.g. Townsend, 1979), depending on the type of asymmetric information and agency problems that prevail. In this paper we add to this literature by showing that banks may misuse monitoring techniques to soften inter-bank competition, and sometimes not use them at all.

Interim monitoring that allows banks to control the moral hazard (project choice) problem of their borrowers has lately attracted considerable attention. However, no earlier study has to our best knowledge considered the possibility that banks could utilize the familiar interim monitoring technologies for purposes other than controlling moral hazard in circumstances where this original motivation is absent. In the first part of this paper we show that if borrowers are heterogeneous both in the level of private benefits that their projects yield and in their probability of success (but face no project choice), banks can and will decide on the level of interim monitoring strategically so as to differentiate themselves.[1] Such behavior we label "mis-use". We show that in equilibrium, endogenous "vertical product differentiation" between two banks may arise: the banks may choose different levels of interim monitoring to soften price competition in interest rates (quite like firms choose maximally different product quality in the seminal model of Shaked and Sutton 1982).

What we also find is that the bank investing in interim monitoring faces a less severe adverse selection problem than the bank not investing in it. Interim monitoring - a technology commonly perceived to deal with moral hazard - can thus be used as a means to alleviate adverse election. The intuition is that borrowers with a higher success probability "self-select" into a bank with tighter interim monitoring to have access to a lower interest rate. At the same time, the bank's rival attracts the borrowers with a lower success probability. Thus, "advantageous selection" happens at the level of an individual bank as a consequence of the bank's endogenous choice of interim monitoring technology (for an analysis of advantageous selection in insurance markets, see de Meza and Webb 2001).[2]

In the second part of the paper we address endogenous ex-ante screening and interim monitoring simultaneously. To this end, we add to the model a costless choice of an ex-ante screening technology that would allow the bank to perfectly learn the success probability of the borrowers. We show that it is possible that one of the banks may in

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1 The potentially special role of 'non-neutral' forms of differentiation in loan markets has earlier been recognised informally by Villas-Boas and Schmidt-Mohr (1999).

2 This result is, of course, closely related to the well-known "pool worsening" effect of Stiglitz and Weiss (1981) in which the average quality of loan borrowers decreases as a response to an increase in the interest rate. This pool worsening does not happen in our model at the aggregate level, but only for the bank with less effective interim monitoring technology that charges a higher interest rate than its rival.

equilibrium forego this option.[3] This choice we call "non-use": our analysis shows that it may occur simultaneously with mis-use.

The remainder of the paper is organized as follows: in the next section, we present the model. In section 3, we derive our results for interim monitoring. In section 4 we add to the model the choice of a costless and perfect ex-ante screening technology. Section 5 offers short concluding comments.

2 THE MODEL

We study a simple setting: there are two profit-maximizing banks i, i = 1, 2. Risk-neutral loan borrowers (entrepreneurs) that are protected by limited liability apply for funds for a project. The size of the project is normalized to unity and equal to the size of the loan because we assume that the borrowers have no initial wealth. Each implemented project either succeeds, yielding revenue X, or fails, yielding nothing.

The two banks are the only source of outside finance in the economy. We assume that the banks make use of standard debt contracts and cannot design contracts that would induce self-selection among borrowers. A borrower's debt service obligation to bank i is denoted r_i. The banks face a perfectly elastic supply of funds at a gross interest rate $\rho \geq 1$.

Borrowers are heterogeneous in their creditworthiness, and in the level of their potential private benefit τ. Proportion γ of borrowers is "good" and succeeds with probability p. The remaining borrowers succeed with probability κp, where $\kappa < 1$. The private benefit of borrowers τ is distributed uniformly and with density $1/\overline{\tau}$ on the interval $\left[0, \overline{\tau}\right]$. The private benefit is not conditional on success or failure (following e.g. in Holmström and Tirole, 1997) and independent of the creditworthiness of borrowers. The difference to the usual interim monitoring set-up is thus that entrepreneurs face no project choice.[4]

For concreteness, we assume that banks' choice of the interim monitoring technology, s_i, can be represented as the fraction of the potential private benefit that a borrower loses because of the monitoring. We assume that $s_i \in \left[\underline{s}, \overline{s}\right]$, where $\underline{s} \geq 0$ and $\overline{s} \leq 1$. Finally, we assume for simplicity that monitoring is costless; this assumption could easily be relaxed.

The timing is as follows: in the first stage, banks simultaneously decide on their monitoring technology; and in the second, they compete by simultaneously making interest rate (price) offers. Finally, borrowers choose by applying for and accepting a loan from the bank yielding the highest expected utility.

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3 There exists a literature that studies the effects of such screening when it is exogenous (e.g. Broecker, 1990). Endogenous ex-ante screening investments have also been studied (e.g. Chan, Greenbaum and Thakor, 1986, Hauswald and Marquez 2001).

4 Notice that the private benefit τ is non-monetary; the individual rationality constraint of a borrower is therefore $r_i \leq X$.

3 EQUILIBRIUM ANALYSIS

A. Interest Rate Competition

We denote in this subsection the bank that has a less efficient technology - meaning that the borrower receives a larger proportion of the potential private benefit - bank 1. Occasionally, we will below call bank 1 also the "non-monitoring" bank, as with endogenous monitoring choices, the bank investing less in the monitoring will actually choose not to monitor at all (meaning that $s_1 = \underline{s}$).

To compute the equilibrium, a necessary first step is to derive the demand functions. A borrower with potential private benefit $\tilde{\tau}_h \in [0, \overline{\tau}]$ and success probability $h \in \{p, \kappa p\}$ is indifferent between the loan offers of banks 1 and 2 if

$$h(X - r_1) + (\overline{s} - s_1)\tilde{\tau}_h = h(X - r_2) + (\overline{s} - s_2)\tilde{\tau}_h \Leftrightarrow \tilde{\tau}_h = \frac{h(r_1 - r_2)}{\Delta s}, \tag{1}$$

where $\Delta s \equiv s_2 - s_1 > 0$.[5] From (1) we can immediately see that borrowers of type h with $\tau \in [\tilde{\tau}_h, \overline{\tau}]$ choose bank 1 and that bank 2 that has a better monitoring technology has to charge a lower interest rate than bank 1. It is also clear from (1) that borrowers with a lower success probability are more inclined towards choosing the non-monitoring bank 1, i.e., $\tilde{\tau}_p > \tilde{\tau}_{\kappa p}$. Bank 1 faces the following total demand:

$$D_1 = \left[\gamma(\overline{\tau} - \tilde{\tau}_p) + (1-\gamma)(\overline{\tau} - \tilde{\tau}_{\kappa p})\right]\frac{1}{\overline{\tau}} \tag{2a}$$

Bank 2's demand is given by

$$D_2 = \left[\gamma\tilde{\tau}_p + (1-\gamma)\tilde{\tau}_{\kappa p}\right]\frac{1}{\overline{\tau}} \tag{2b}$$

Expected profits are then given for the non-monitoring bank 1 by $\pi_1(r_1, r_2) = (1/\overline{\tau})\left[\gamma(\overline{\tau} - \tilde{\tau}_p)(pr_1 - \rho) + (1-\gamma)(\overline{\tau} - \tilde{\tau}_{\kappa p})(\kappa p r_1 - \rho)\right]$ and for the monitoring bank 2 by $\pi_2(r_1, r_2) = (1/\overline{\tau})\left[\gamma\tilde{\tau}_p(pr_2 - \rho) + (1-\gamma)\tilde{\tau}_{\kappa p}(\kappa p r_2 - \rho)\right]$. Differentiating these globally concave profit functions, and solving the first-order conditions, we obtain the Nash equilibrium loan interest rates:

$$\hat{r}_1 = \frac{\overline{p}}{\overline{\overline{p}}}(\rho + \tfrac{2}{3}\overline{\tau}\Delta s) > \hat{r}_2 = \frac{\overline{p}}{\overline{\overline{p}}}(\rho + \tfrac{1}{3}\overline{\tau}\Delta s) \tag{3}$$

where $\overline{p} \equiv \gamma p + (1-\gamma)(\kappa p)$ and $\overline{\overline{p}} \equiv \gamma p^2 + (1-\gamma)(\kappa p)^2$. For these to be equilibrium interest rates, both banks have to make nonnegative profits. For a moment, assume this to be the case.

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5 Interim monitoring turns out to be formally almost equivalent to assuming vertical differentiation as in e.g. Shaked and Sutton (1982).

We can use (3) to compute the equilibrium interest difference, $\Delta\hat{r} \equiv \hat{r}_1 - \hat{r}_2$, between the two banks.[6] The difference is $(⅓)\overline{\tau}\Delta s\overline{p} / \overline{\overline{p}} > 0$.[7] The equilibrium interest difference can be interpreted as *a monitoring discount* in the monitoring bank's loan interest rate. We obtain:

Proposition 1. *In equilibrium,*

(a) the monitoring discount, $\Delta\hat{r}$, is directly related to the difference in monitoring quality but inversely related to the average creditworthiness of borrowers in the market (formally, $d\Delta\hat{r} / d\Delta s > 0$ and $d\Delta\hat{r} / d\gamma \leq 0$); and

(b) loan interest rates are directly related to the difference in monitoring quality and the cost of banks' funds but inversely related to the average creditworthiness of borrowers in the market (formally, $d\hat{r}_i / d\Delta s > 0$, $d\hat{r}_i / d\rho > 0$ and $d\hat{r}_i / d\gamma \leq 0$ for i = 1, 2).

Many of the results presented in proposition 1 are self-explanatory. However, the negative effect of the average creditworthiness of borrowers on the monitoring discount may require some further clarification. It emerges because the elasticity of demand increases as the average creditworthiness of borrowers increases. As a result of this, competition is fiercer between the banks for a given difference in monitoring, and the non-monitoring bank's incentive to increase its interest rate relative to that of the monitoring bank is lowered.

Let us now consider the average success probability in bank *i*'s loan portfolio, denoted $A_i(p)$. We can think of $A_i(p)$ as being a measure of the extent of the adverse selection problem that bank *i* faces. To compute $A_i(p)$, we first use the equilibrium interest rate difference to obtain the equilibrium demands. They allow us to compute $A_i(p)$ for *i* = 1, 2:

$$A_1(p) = \frac{\frac{2}{3}\overline{p}}{1 - \frac{1}{3}(\overline{p}^2 / \overline{\overline{p}})} \tag{4a}$$

$$A_2(p) = \frac{\frac{1}{3}\overline{p}}{\frac{1}{3}(\overline{p}^2 / \overline{\overline{p}})} \tag{4b}$$

It is easy to verify that for $A_2(p) > A_1(p)$ to hold it is sufficient that $\kappa < 1$, proving the following result:

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6 One could imagine that it might be profitable for bank 1 to charge the same interest rate as bank 2 and to thereby get all borrowers, improving its borrowers' average quality. However, it can be shown that such a deviation is never profitable.

7 The initial assumption of having an interior optimum holds in the proposed equilibrium, i.e., $X > \hat{r}_1 > \hat{r}_2$ and $\overline{\tau}\Delta s / p > \hat{r}_1 - \hat{r}_2$, provided that X is 'large' and that $1/p > \frac{1}{3}(\overline{p} / \overline{\overline{p}})$. For the latter condition to hold for all γ, it is necessary and sufficient that $\kappa > 1/3$.

Proposition 2. *The non-monitoring bank faces a more severe adverse selection problem than the monitoring bank.*

The economic intuition behind this proposition is simple: The less creditworthy borrowers care less than the more creditworthy borrowers about their debt service obligation since they have a lower success probability and put therefore less weight on the repayment than the more creditworthy borrowers. In other words, the more creditworthy borrowers "self-select" into a bank with tighter interim monitoring. At the same time, the bank's rival attracts the less creditworthy borrowers. Thus, "advantageous selection" happens at the level of individual banks (for an analysis of advantageous selection in insurance markets, see de Meza and Webb 2001).

This result is, of course, closely related to the well-known "pool worsening" effect of Stiglitz and Weiss (1981) in which the average quality of loan borrowers decreases as a response to an increase in the interest rate. This pool worsening does not happen in our model at the aggregate level, but only for the bank with less effective interim monitoring technology that charges a higher interest rate than its rival. Thus, even though the private benefit is independent of the creditworthiness of borrowers, borrowers' relative preference for different banks systematically correlates with their creditworthiness and is therefore not 'neutral'. Proposition 2 shows that because of this non-neutrality, a bank can use interim monitoring - a technology normally thought to address moral hazard problems - to alleviate the adverse selection problem it faces.

To conclude our analysis of the second stage of the game, let us derive a condition that ensures that both banks make nonnegative profits. It is easy to show that expected profits of banks are given by

$$\pi^B \equiv \hat{\pi}_2(\hat{r}_1, \hat{r}_2) = \frac{1}{9}\frac{\overline{p}^2}{\overline{\overline{p}}}\overline{\tau}\Delta s \tag{5b}$$

for the monitoring bank 2 and

$$\pi^C \equiv \hat{\pi}_1(\hat{r}_1, \hat{r}_2) = \frac{4}{9}\frac{\overline{p}^2}{\overline{\overline{p}}}\overline{\tau}\Delta s - \frac{(1-\gamma)\gamma}{\overline{\overline{p}}}(p(1-\kappa))^2 \rho \tag{5a}$$

for the non-monitoring bank 1.

From equations (5a) and (5b) it can be seen that it is only the non-monitoring bank whose individual rationality constraint may be violated (even when interim monitoring is costless). However, as the heterogeneity (i.e. $\overline{\tau}$) of borrowers increases, the non-monitoring bank's profits grow at a faster rate than those of the monitoring bank. We can therefore show that if $\hat{\tau} > \overline{\tau} > \breve{\tau}$, where $\hat{\tau} \equiv 3\gamma(1-\gamma)(p(1-\kappa))^2 \rho / \overline{p}^2 \Delta s$ and $\breve{\tau} \equiv \frac{4}{9}\gamma(1-\gamma)(p(1-\kappa))^2 \rho / \overline{p}^2 \Delta s$), the non-monitoring bank's profits are lower than those of the monitoring bank but non-negative.

B. Choice of Monitoring Technology

To analyze the choice of monitoring technologies, we need to calculate the expected profits that result from the second stage interest competition. If banks choose the same monitoring technology, they face Bertrand competition in homogenous products. In such circumstances they will make zero expected profits. If they choose different monitoring technologies such that bank 1 is the non-monitoring bank, equations (5a) and (5b) give the expected profits. Finally, reversing the roles of the two banks would give the expected profits for the remaining case in which bank 1 is the monitoring bank and bank 2 the non-monitoring bank.

We are now ready to endogenize a bank's decision to invest in interim monitoring: In the first stage of the game there are two ex-ante symmetric banks that have access to the monitoring technology and that simultaneously decide whether to use or not to use it. It is clear from equations (5a) and (5b) that both banks prefer differentiation in interim monitoring if and only if $\overline{\tau} > \breve{\tau}$. Further, the banks obviously prefer maximal differentiation. We therefore assume that banks can only choose discrete interim monitoring $s_i \in \{\underline{s}, \overline{s}\}$. This simplification allows us to write down the normal form for the first stage of the game. It is shown in Table 1.

Table 1. Interim Monitoring Decisions

Bank 2 / **Bank 1**	$(s_2 = \underline{s})$	$(s_2 = \overline{s})$
$(s_1 = \underline{s})$	0,0	π^C, π^B
$(s_1 = \overline{s})$	π^B, π^C	0,0

Note: The definitions of these reduced form profit expressions are given in equations (5a) and (5b).

A straightforward analysis of the table yields the following proposition, our "misuse" result:

Proposition 3. *Assume that $\overline{\tau} > \breve{\tau}$. The first stage competition in interim monitoring has two pure strategy Nash equilibria $\{(s_1 = \overline{s}, s_2 = \underline{s}), (s_1 = \underline{s}, s_2 = \overline{s})\}$ in which the banks choose (maximally) different monitoring technologies, and a unique mixed strategy equilibrium in which each bank uses interim monitoring with probability*

$$\alpha = \frac{\pi^C}{\pi^B + \pi^C} = \frac{\frac{1}{9}\frac{\overline{p}^2}{\underline{\underline{p}}}\overline{\tau}\Delta s}{\frac{5}{9}\frac{\overline{p}^2}{\underline{\underline{p}}}\overline{\tau}\Delta s - \frac{(1-\gamma)\gamma}{\underline{\underline{p}}}(p(1-\kappa))^2 \rho} \quad \textit{where } \alpha \in (0,1).$$[8]

[8] Note that if $\overline{\tau} < \breve{\tau}$, there is a unique (pure strategy) equilibrium $\{(s_1 = \overline{s}, s_2 = \overline{s})\}$ in which both banks choose to monitor. The equilibrium is not however robust to introducing a positive fixed cost for monitoring.

Proposition 3 tells us that as long as it yields non-negative profits to both bank, "product differentiation" in the form of different monitoring technologies is the pure strategy equilibrium. As this differentiation would redistribute profits from borrowers to banks at the cost of reducing the private benefits of borrowers even under symmetric information, we call this "mis-use" of interim monitoring.

In this model, one of the banks adopts an interim monitoring technology to avoid tough price competition with its rival. As a consequence, it can also alleviate the adverse selection problem it faces, as borrowers of less than average quality (in terms of probability of success) are, everything else constant, more likely to choose the non-monitoring rival. The monitoring bank effectively compensates its borrowers for the loss of private benefit by charging them a lower interest rate than its non-monitoring rival.

It is interesting to contrast proposition 3 to the seminal result of Shaked and Sutton (1982) in a vertical product differentiation model. Our model is formally almost identical to a model where the private benefit is a measure of borrowers' taste for quality, and the level of bank monitoring is an inverse measure of "service quality". With this interpretation, the non-monitoring bank would be the "high-quality" bank. We thus find that in our model, it is not necessarily the case that the high-quality (non-monitoring) bank makes larger expected profits, nor is it always the case that banks choose maximal differentiation in equilibrium even when the quality choice is costless.

The proposition can be generalized to allow for a fixed monitoring cost, and for entry. If monitoring requires paying a fixed cost and the cost is such that it leads to non-negative profits for the monitoring bank in the asymmetric case, the two pure strategy equilibria in which the banks choose different monitoring technologies, exist provided that $\overline{\tau} \geq \breve{\tau}$. If $\overline{\tau} < \breve{\tau}$, no pure strategy equilibrium exists because the non-monitoring bank would not be able to make positive profits whenever the other bank monitors.[9] Further, if $\overline{\tau} \geq \breve{\tau}$ and if the cost is such that it leads to negative profits for the monitoring bank in the asymmetric case, there is (unsurprisingly) a pure strategy equilibrium $\{(s_1 = \underline{s}, s_2 = \underline{s})\}$ in which neither bank chooses to monitor. If entry is allowed, an additional set of cases can be analyzed; for brevity, we do not pursue them here.

4 EX-ANTE SCREENING

In this section, we allow the banks to choose both whether or not to monitor and whether or not to employ a costless ex-ante screening technology that gives them perfect information on the success probability of a borrower (but no information on the level of her private benefit). The choice of ex-ante screening is discrete and denoted $e_i \in \{\underline{e}, \overline{e}\}$. If $e_i = \overline{e}$, bank *i* observes a creditworthiness signal that perfectly reveals the success probability of a borrower; if $e_i = \underline{e}$, the bank observes no signal. We assume that the choice of whether or not to employ the ex-ante screening technology is made simultaneously with the choice of the interim monitoring technology.

[9] A symmetric mixed strategy equilibrium exists under certain conditions.

For the sake of brevity, we focus on pure strategy equilibria in technology choices. Further, we assume that $\kappa pX - \rho < 0$. This assumption implies that the bank with the screening technology never finances the less creditworthy borrowers.

Ideally, we would like to provide the reader with a general charaterization of the existence of "non-use"- equilibria (and other equilibria, should they exist). Following Stiglitz and Weiss (1981) and Hellman and Stiglitz (2000), our aim here is to show that there is a *possibility* that a bank does not want to use the ex-ante screening technology that would allow it to get rid of the asymmetric information. We therefore concentrate on establishing the less general claim that it is possible that one of the banks does not wish to utilize the free and perfect ex-ante screening technology.

For brevity, we do not solve in detail the second stage interest rate game here. Instead, we present in Table 2 the ensuing reduced form expected profits (see Appendix 1) and the normal form of the first stage game. In the four-by-four matrix shown in the table, $s_i = \overline{s}$ ($s_i = \underline{s}$) stands for (no) interim monitoring, and $e_i = \overline{e}$ ($e_i = \underline{e}$) for (no) ex-ante screening. The reduced form expected profits have been computed as follows:

- If both banks choose the same screening-monitoring technology-pair, they compete in Bertrand-fashion and will make zero profits.
- If *neither* or *both* decide to use interim monitoring, and one chooses to use the ex-ante screening technology, there are no pure strategy equilibria in the interest rate game. The reason is that when bidders have asymmetric information, there is a winner's curse: each bank can always attract more creditworthy borrowers and thus improve the distribution of borrowers by undercutting its rival. Such undercutting would be profitable, because it would result in a discrete jump in expected profits (see Broecker 1990, Hauswald and Marquez 2001). Hauswald and Marquez (2001) have recently shown in a similar framework as the particular case considered here that the "informed" bank using the screening technology will make positive expected profits, whereas the "uninformed" rival makes zero profits.
- If *neither* or *both* decide to use the ex-ante screening technology, and one chooses to use interim monitoring, we are back in the cases that we have already analyzed.

Table 2. Interim Monitoring and Ex-Ante Screening Decisions

Bank 2 / Bank 1	$(s_2 = \underline{s}, e_2 = \underline{e})$	$(s_2 = \underline{s}, e_2 = \overline{e})$	$(s_2 = \overline{s}, e_2 = \underline{e})$	$(s_2 = \overline{s}, e_2 = \overline{e})$
$(s_1 = \underline{s}, e_1 = \underline{e})$	$0,0$	$0,\pi^A$	π^C,π^B	π^E,π^D
$(s_1 = \underline{s}, e_1 = \overline{e})$	$\pi^A,0$	$0,0$	π^G,π^F	π^I,π^H
$(s_1 = \overline{s}, e_1 = \underline{e})$	$\pi^B,\pi^C,$	π^F,π^G	$0,0$	$0,\pi^A$
$(s_1 = \overline{s}, e_1 = \overline{e})$	π^D,π^E	π^H,π^I	$\pi^A,0$	$0,0$

Note: The definitions of these various reduced form profit expressions are given in Appendix 1.

What is important for our analysis is that when neither or both decide to use interim monitoring, and one chooses to use the ex-ante screening technology, the profits of banks are *not* a function of either differences in the interim monitoring technology, nor in the maximum private benefit $\overline{\tau}$. Building on this observation, we can prove our final proposition, the "non-use" result (for proof, see Appendix 2):

Proposition 4. *Provided that borrowers are sufficiently heterogeneous, i.e.,* $\overline{\tau} > \tilde{\tau}$ *where*

$$\tilde{\tau} \equiv \max\left\{ \frac{9\gamma(1-\gamma)(1-\kappa)}{4\Delta s\left[2\gamma+(1-\gamma)\kappa\right]\kappa}\rho, \frac{9\gamma^2(1-\gamma)(1-\kappa)}{\Delta s\left[\gamma+(1-\gamma)\kappa\right]^3}\rho \right\},$$

there exists two pure strategy Nash equilibria $\{(s_i = \overline{s}, e_i = \overline{e}), (s_j = \underline{s}, e_j = \underline{e})\}$ *for* $i \neq j, i = 1,2$, *in which one of the banks chooses both to interim monitor and to adopt the perfect ex-ante screening technology and in which the other bank chooses not to interim monitor and not to adopt the perfect ex-ante screening technology.*

Proposition 4 shows that strategic considerations can override banks' desire to learn a payoff-relevant characteristic of its borrowers. The intuition behind the result is that by not adopting the ex-ante screening technology, the non-monitoring bank's marginal profitability from charging a higher loan interest rate increases. The marginal profitability increases because the interest rate elasticity of the loan demand that the non-monitoring bank faces is lower in the case where it does not screen out the price-insensitive (captured) but less creditworthy borrowers. The lower elasticity and the strategic complementarity of the two banks' interest rates lead to higher equilibrium interest rates (than would prevail if the non-monitoring bank screened). If $\overline{\tau} > \tilde{\tau}$, the increase in the equilibrium interest rate increases the expected profit of the non-monitoring bank more than the financing of the less creditworthy borrowers reduces it. Hence, the non-use of a useful information acquisition technology follows.

5 CONCLUSIONS

Our analysis shows that banks may invest in an interim monitoring technology even when the standard reason for its use (i.e. alleviating moral hazard problem) does not exist. The reason is that the technology can be mis-used to soften price competition. Specifically, what we find is that asymmetric equilibria emerge in which only one bank invests in interim monitoring and that the bank investing in interim monitoring faces a less severe adverse selection problem than the bank not investing in it. In other words, our analysis shows that a bank can use its interim monitoring technology to alleviate adverse selection at the cost of worsening its rival's adverse selection problem and at cost of reducing borrowers' private benefits.

In the second part of the paper we consider endogenous interim monitoring simultaneously with endogenous ex-ante screening. If banks are given the possibility to costlessly adopt a perfect ex-ante screening technology that reveals each borrowers' success probability, an equilibrium exists where one bank adopts the interim monitoring technology and screens but where its rival foregoes the option of operating under symmetric information. This shows that in banking, the non-use of a useful technology can be an equilibrium outcome.

Taken together, our analysis suggests banks may misuse monitoring techniques available to them, and sometimes not to use them at all, to soften interbank competition. Such possibilities have to our best knowledge not been considered in the previous literature.

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Appendix 1. Computation of the reduced form profits in Table 2

We compute the reduced form profits for the left hand side of the table; the right hand side profits are a mirror image of them. The interest rate competition during the second stage of the game goes, for the various subgames that can be reached, as follows:

i) If $s_i = s_j$ and $e_i = e_j$, i.e. in the subgames corresponding to the diagonal cells of the table, the two banks make zero expected profits, because they compete in Bertrand-fashion.

ii) If $(s_1 = \underline{s}, e_1 = \overline{e})$ and $(s_2 = \underline{s}, e_2 = \underline{e})$, or if $(s_1 = \overline{s}, e_1 = \overline{e})$ and $(s_2 = \overline{s}, e_2 = \underline{e})$, the two banks are in a subgame in which they compete in Bertrand-fashion but bid under asymmetric information in the sense that one is "informed" and the other "uninformed". Hauswald and Marquez (2001, Proposition 1) show that there does exist no pure strategy equilibrium and that in the unique mixed strategy equilibrium the expected profits of the uninformed bank are zero. Further, they also show that the equilibrium expected profits of the informed bank are (in terms of our notation and remembering that we are assuming a perfect screening technology):

$$\pi^A \equiv \frac{\gamma(1-\gamma)(1-\kappa)}{\gamma + (1-\gamma)\kappa}\rho . \tag{A1}$$

iii) If $(s_1 = \overline{s}, e_1 = \underline{e})$ and $(s_2 = \underline{s}, e_2 = \underline{e})$, neither bank screens, implying that the subgame corresponds to the case we have already studied (see the main text). The expected profits are given by equations (5a) and (5b), so that after reversing the banks' indices, the reduced form profits of the monitoring bank 1 are

$$\pi^B \equiv \frac{1}{9}\frac{\overline{p}^2}{\overline{\overline{p}}}\overline{\tau}\Delta s \tag{A2}$$

and those of the non-monitoring bank 2 are:

$$\pi^C \equiv \frac{4}{9}\frac{\overline{p}^2}{\overline{\overline{p}}}\overline{\tau}\Delta s - \frac{(1-\gamma)\gamma}{\overline{\overline{p}}}(p(1-\kappa))^2\rho . \tag{A3}$$

iv) If $(s_1 = \overline{s}, e_1 = \overline{e})$ and $(s_2 = \underline{s}, e_2 = \underline{e})$ no less creditworthy borrower applies for a loan from bank 1, as they know that it would not finance them. They all apply for a loan from bank 2, as it cannot distinguish between the more and less creditworthy borrowers. It follows that the banks effectively compete only for the more creditworthy borrowers and that bank 2 is forced to finance also the less creditworthy borrowers at the interest rate it quotes. The difference in interim monitoring means, however, that the interest rate elasticity of the more creditworthy borrowers is not infinite, and thus that there is no discrete jump in profits from undercutting the rival's interest rate offer. Therefore, a pure strategy Nash equilibrium exists for this subgame. Solving the subgame follows the same steps as outlined in the main text (see section 3.A). The ensuing reduced form profits of bank 1 are

$$\pi^D \equiv \frac{1}{9}\bar{\tau}\Delta s\gamma(1+\frac{1-\gamma}{\gamma}\kappa)^2 \tag{A4}$$

and those of bank 2

$$\pi^E \equiv \frac{4}{9}\bar{\tau}\Delta s\gamma(1+\frac{1-\gamma}{\gamma}\kappa)^2 - (1-\gamma)(1-\kappa)\rho\,. \tag{A5}$$

v) If $(s_1 = \overline{s}, e_1 = \underline{e})$ and $(s_2 = \underline{s}, e_2 = \overline{e})$, no less creditworthy borrower applies for a loan from bank 2, as they know that it would not finance them. They all apply for a loan from bank 1, as it cannot distinguish between the more and less creditworthy borrowers. It follows that the banks effectively compete only for the more creditworthy borrowers and that bank 1 is forced to finance also the less creditworthy borrowers at the interest rate it quotes. The difference in interim monitoring means, however, that the interest rate elasticity of the more creditworthy borrowers is not infinite, and thus that there is no discrete jump in profits from undercutting the rival's interest rate offer. Therefore, a pure strategy Nash equilibrium exists for this subgame. Again, we solve the subgame following the same steps as outlined in the main text. The ensuing reduced form profits of bank 1 are

$$\pi^F \equiv \frac{1}{9}\bar{\tau}\Delta s\gamma(1+\frac{1-\gamma}{\gamma}2\kappa)^2 - (1-\gamma)(1-\kappa)\rho\,, \tag{A6}$$

and those of bank 2 are:

$$\pi^G \equiv \frac{1}{9}\bar{\tau}\Delta s\gamma(2+\frac{1-\gamma}{\gamma}\kappa)^2\,, \tag{A7}$$

vi) If $(s_1 = \overline{s}, e_1 = \overline{e})$ and $(s_2 = \underline{s}, e_2 = \overline{e})$ both banks use the perfect ex-ante screening technology and no less creditworthy borrower receives financing. This case corresponds to the two banks competing for the more creditworthy borrowers under symmetric information. The expected profits of the monitoring bank 1 are

$$\pi^H \equiv \frac{1}{9}\bar{\tau}\Delta s\gamma \tag{A9}$$

and those of the non-monitoring bank 2 are:

$$\pi^I \equiv \frac{4}{9}\bar{\tau}\Delta s\gamma\,. \tag{A10}$$

To sum up, the reduced form profits corresponding to the subgames of the diagonal cells of Table 2 are all zero. Equations (A1)-(A10) provide us with the entries for the cells of the left hand side of the table. Finally, the right hand side profits are a mirror image of them.

Appendix 2. Proof of proposition 4

We prove the result for the left hand side of Table 2 only, as the analysis for the right hand side is analogous. What needs to be shown is that there exists a parameter region such that $\pi^D > \max\{\pi^A, \pi^B, 0\}$ and $\pi^E > \max\{\pi^I, 0\}$ hold simultaneously. First, it can be shown i) that $\pi^D > \pi^B$, ii) that $\pi^E > \pi^I$ implies $\pi^E > 0$ and iii) that $\pi^D > \pi^A$ implies $\pi^D > 0$. These inequalities imply that we only need to show that $\pi^D > \pi^A$ and $\pi^E > \pi^I$ hold simultaneously. Straightforward algebraic steps show that the two conditions hold if

$$\overline{\tau} > \tilde{\tau} \equiv \max\left\{ \frac{9\gamma(1-\gamma)(1-\kappa)}{4\Delta s\left[2\gamma+(1-\gamma)\kappa\right]\kappa}\rho, \frac{9\gamma^2(1-\gamma)(1-\kappa)}{\Delta s\left[\gamma+(1-\gamma)\kappa\right]^3}\rho \right\}. \tag{A11}$$

This condition is thus necessary and sufficient to establish that there exists an equilibrium in which bank 1 chooses both to interim monitor and to adopt the perfect ex-ante screening technology and in which bank 2 chooses not to interim monitor and not to adopt the perfect ex-ante screening technology. By symmetry, there exists two such pure strategy Nash equilibria, i.e. $\{(s_i = \overline{s}, e_i = \overline{e}), (s_j = \underline{s}, e_j = \underline{e})\}$ for $i \neq j, i = 1, 2$ **QED.**

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