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European Economic Review 44 (2000) 1951–1980

EUROPEAN ECONOMIC REVIEW

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Sharing default information as a borrower discipline device☆

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Received 1 April 1997; received in revised form 1 October 1999

Abstract

Creditors often share information about their customers' credit records. Besides helping them to spot bad risks, this acts as a disciplinary device. If creditors are known to inform one another of defaults, borrowers must consider that default on one lender would disrupt their credit rating with all the other lenders. This increases their incentive to perform. However, sharing more detailed information can reduce this disciplinary effect: borrowers' incentives to perform may be greater when lenders only disclose past defaults than when they share all their information. In some instances, by 'fine-tuning' the type and accuracy of the information shared, lenders can raise borrowers' incentives to their first-best level. © 2000 Elsevier Science B.V. All rights reserved.

JEL classification: D82; G21

Keywords: Information sharing; Credit markets; Incentives

☆ This paper was presented at the CEPR/ESF Summer Symposium in Financial Markets and at seminars at IDEI (Université de Toulouse), MIT (Sloan School of Management), Northwestern University, Universidad Carlos III (Madrid), Università Bocconi (Milan), University of Helsinki, and Università di Napoli Federico II. We are indebted to Philippe Aghion, Sudipto Bhattacharya, Patrick Bolton, Mathias Dewatripont, Michael Fishman, Denis Gromb, Tullio Jappelli, Inés Macho, George Mailath, David Martimort, David Pérez, Raghuram Rajan, Rafael Repullo, Mike Riordan, Oren Sussman, Dimitri Vayanos, Xavier Vives and Marie-Odile Yanelle for helpful comments and discussions. This research was supported by the CEPR/ESF Network in Financial Markets Research Exchange Programme, the Fondation Banque de France and the Italian Ministry of University and Scientific and Technological Research (MURST).

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PII: S0014-2921(00)00055-6

1. Introduction

Creditors often share information about the credit history of their borrowers. In several countries this exchange of information is intermediated by credit bureaus, rating agencies and the like. In the United States, credit bureaus issued some 600 million reports about credit seekers in 1997, and coverage of households applying for consumer credit is virtually complete. Similarly, credit rating agencies such as Standard & Poor and Moody's constantly monitor companies, pooling data from public sources and private information from financial institutions and regularly updating their ratings. In several countries, especially in Europe, governments actively favor such information exchange via public credit registers under central bank supervision. Each bank must report information about its loans to these registers, which then disseminate it to other banks. Jappelli and Pagano (1999) provide a detailed description of such arrangements around the world.

This massive exchange of information can hardly fail to affect the functioning of the underlying credit market. First, it should reduce adverse selection problems due to bad risks in the population of credit seekers (Pagano and Jappelli, 1993). Second, it tends to homogenize the information on which banks base their lending decisions. The resulting increase in competition reduces the information-based monopoly power of banks and thereby raises the incentive of borrowers to perform (Padilla and Pagano, 1997). Third, it should exert a disciplinary effect on borrowers. If creditors are known to inform one another of defaults, borrowers realize that defaulting on their current lender will damage their rating with all other potential sources of credit and thus try harder to avoid default. This paper analyzes precisely this 'disciplinary effect'.

The disciplinary effect of information sharing has long been clear to market practitioners. For instance, in 1949 the official manual of the National Retail Credit Association in the U.S. observed:

> When an individual realizes that a record is kept by the [credit] bureau as to how he pays his bills, and that this record is consulted by credit grantors whenever he applies for credit, he is naturally more careful as to how he takes care of his obligations. (Phelps, 1949, p. 442.)

Similarly, it is well known that the financial choices of companies and governments are highly sensitive to the threat of a downgrading of their credit rating, because this would worsen the terms on which they could obtain new loans or renegotiate existing debt.

In this paper we show that the intensity of this disciplinary effect depends on the type and the accuracy of the information exchanged by lenders. This may help to explain why information sharing arrangements among lenders vary considerably by country and credit market. In some cases lenders share only data about past defaults ('black information'), while in others they also pool data

on the characteristics of borrowers ('white information', such as business sector, overall debt exposure, family and job history, criminal records, etc.).

Here, we use a simple two-period model of banking with moral hazard and adverse selection to establish four main results. First, sharing only information about defaults may increase borrowers' incentives more than sharing information about their characteristics as well: our model indicates that fuller information sharing weakens the incentive to perform. Second, default rates and interest rates are predicted to be lowest if only defaults are disclosed (when one focuses on the equilibrium with the lowest default rate in each regime). Third, information on defaults only may induce banks to lend in situations where they would not under complete information sharing. Finally, in some instances disclosing past defaults may lead borrowers to exert too much effort to perform relative to the first-best level, but lenders can then 'fine-tune' the type and amount of information shared to achieve the first best.

Our model can be described as follows. Borrowers can reduce the risk of default by spending more 'effort' on their project. Effort is not contractible, which creates moral hazard. Moreover, some entrepreneurs are less capable or face greater cost of effort than others. We posit two types of entrepreneur: low- and high-ability. For simplicity, low-ability entrepreneurs are assumed to exert zero effort and always default. In the first period, they cannot be told apart from high-ability borrowers, so that banks also face an adverse selection problem. Over time, each bank learns the quality of its customers, so that in the second period it no longer faces the adverse selection problem within its customer base.[1] If it does not disclose this information, each bank can extract informational rents from its customers in the second period, as in Sharpe (1990). But due to ex-ante competition for customers, banks set their rates so low in the first period that their period-2 informational rents are precisely offset by period-1 losses.

When banks share their information about *defaults*, moral hazard is reduced. Borrowers care about their performance, as they fear being reported as defaulters. Default becomes a signal of bad quality for other banks, so that defaulters are penalized by higher rates. To avoid this penalty, entrepreneurs exert greater effort.

When banks share *all* their information about customers, however, the adverse selection problem is eliminated but so is the disciplinary effect. Default *per se* is no longer a stigma, since banks disclose the characteristics that determine the borrower's riskiness. As a result, entrepreneurs choose the same level of effort as under *no* information sharing. This result contrasts with the incentive effect of information sharing about borrowers' characteristics in

[1] Fama (1985) argues that the distinctive feature of banks is that, in their repeated interaction with their borrowers, they gain access to the borrowers' inside information. The evidence in Lummer and McConnell (1989) confims that banks acquire 'soft' information only by lending.

Padilla and Pagano (1997), where disclosure of borrowers' quality increases the net profits – and the incentives to perform – of high-ability borrowers by reducing the informational rents of banks. The key difference lies in the assumptions concerning banking competition: in our earlier paper banks could extract informational rents from borrowers, thereby creating a hold-up problem, whereas in our present model they compete them away ex ante. Here we show that by sharing default information banks can affect borrowers' incentives even if this 'income effect' is absent, i.e. if disclosing borrowers' characteristics is ineffective.

The result that sharing only information about behavior may be a more effective discipline device than sharing information about characteristics as well bears a resemblance to the work of Diamond (1991) and Crémer (1995). In both models a principal (e.g. a bank) can increase the incentives of agents (e.g. borrowers) by refusing to acquire information about their quality or else by monitoring ineffectively. The principal precommits to compensate agents mainly on the basis of their performance, so that they will try harder to perform well. In our case, the mechanism is more complex: the principal (the inside bank) has information about both the agent's behavior and characteristics, and increases the agent's incentive by informing competing principals (outside banks) only about behavior rather than characteristics, since this makes the agent's outside option (the interest rates offered by outside banks) contingent on his performance.

The disciplinary effect we identify in this paper is also present in Diamond (1989) and Vercammen (1995). They use a multiperiod framework with adverse selection and moral hazard where default is publicly observable and borrowers build a good reputation by avoiding default, and study how incentives to perform evolve over time.[2] While Diamond finds that these incentives gradually strengthen, Vercammen finds that as credit histories lengthen, both adverse selection and reputation effects vanish.[3] The distinctive feature of our model is the comparison of a regime in which defaults are made public with one in which banks also share other data about borrowers and one in which they keep all their information private. These various types of communication among lenders naturally affect the nature of banking competition, borrowers' incentives and efficiency.

Section 2 describes the model. Section 3 characterizes the outcome of banking competition under each information regime. Section 4 characterizes the first-best outcome, derives the equilibrium level of borrowers' effort in each regime and compares the equilibrium outcomes in terms of efficiency, interest rates and lending. Section 5 shows that in some instances the first-best outcome can be

[2] Another related paper is Holmström (1982), where managers are spurred to exert effort because their current performance affects future bids for their talents.

[3] As a result, he argues that efficient government policies should restrict the flow of information from borrowers to lenders, e.g. by preventing credit bureaus from releasing old information.

achieved by an appropriately designed information-sharing system and ventures some conjectures about whether this may occur as an endogenous market outcome. Section 6 concludes.

2. The basic model

There is a continuum $[0, 1]$ of risk-neutral entrepreneurs who are active for two periods. At any time they have access to one-period investment projects requiring 1 unit of capital. Since they have zero initial wealth, they must borrow this sum entirely from one of two competing banks, A and B. Entrepreneurs differ in their ability to identify profitable projects. There are high- (H) and low-ability (L) types, whose respective proportions in the population are γ and $1-\gamma$ for $\gamma \in (0, 1)$. In each period, high-ability entrepreneurs have access to one-period projects which, if successful, yield R^* units of output and, if unsuccessful, yield nothing.[4] The probability of success of a high-ability entrepreneur, p, depends on his effort, which is chosen once and for all[5] prior to any borrowing and is *non-contractible*.[6] Since p is monotonic in effort, we consider it as the H-type borrowers' choice variable. Low-ability borrowers, instead, are not creditworthy: they only have access to projects with no return. Alternatively, they can be assumed to have a very large marginal disutility of effort.

Unlike the effort level, the return of the investment project is observable and contractible by the current lender, though not observable by the outside lender. That is, if the project succeeds the entrepreneur must repay the loan, and if he defaults the event is only observed by his current lender. Furthermore, for simplicity, we assume that default is forgiven: each investment project is run as a separate limited liability company and the entrepreneur cannot be disqualified after default.[7]

[4] A project's output cannot be stored, so that it does not generate additional collateral for subsequent operations.

[5] This assumption is made for the sake of simplicity but is not needed for our main result, namely the disciplinary effect associated with information sharing about defaults. To see this, consider an alternative scenario where the probability of success in period 2 cannot be affected by the choice of effort in period 1. The disciplinary effect in period 1 would still be present, insofar as default conveys information about the entrepreneur's type and thus determines the interest rate in period 2.

[6] Relevant examples are the choice of a good manager, the preparation of a good business plan, the acquisition of managerial skills, and the development of a new product. All these activities are hard to verify and enforce in court because of their qualitative nature.

[7] As is shown in Padilla and Pagano (1997), assuming that default is forgiven does not affect the qualitative outcome of these information-sharing games. Of course, if default were not forgiven, the total interest burden on defaulting borrowers would be greater, and this would decrease their effort level in period 1. Yet, this 'income effect' would be constant across information regimes, and therefore would not change their ranking in terms of effort incentives.

If high-ability entrepreneur i gets no credit, his expected utility is zero. If, instead, he gets credit and chooses a success probability $p(i)$, his total (undiscounted) utility is equal to:

$$U_{\mathrm{H}}(p(i)) = p(i)[(R^* - R_{j1}) + (R^* - \mathrm{E}(R_{j2}^{\mathrm{H}}))] - V(p(i)) \tag{1}$$

where R_{j1} is the gross period-1 interest rate charged by bank j; $\mathrm{E}(R_{j2}^{\mathrm{H}})$ is the expected gross period-2 interest rate charged to high-ability entrepreneurs by bank j; and $V(p(i))$ is the total disutility of effort exerted to achieve $p(i)$. $V(\cdot)$ is increasing and convex, with $\infty > V' \geq 0$ and $V'' > 0$. We assume that $V'(0) = 0$ and $V'(1) > 2R^*$, so as to ensure that the first-best effort level is an interior solution to the choice of effort p.

Low-ability entrepreneurs derive no monetary payoff from borrowing, because their projects are certain to yield no return, and for the same reason they spend no effort on their project. But they are assumed to derive positive utility from 'being in business', which is why they still participate in the credit market.

Lenders can raise capital at a gross interest rate $\bar{R}$ and compete in interest rates given their respective information sets. They offer one-period contracts.[8] At the beginning of the first period, banks have symmetric information concerning their potential customers: they know the average probabilities of success of the two types, p and 0, but they cannot distinguish between the two. By the beginning of the second period, each bank learns its customers' true type, acquiring an informational advantage over its rivals with respect to these entrepreneurs.[9] This assumption is intended to capture the fact that customer relationships enable banks to gather information about many characteristics of their clientele (honesty, the technological or demand uncertainty of their business, etc.; see Fama, 1985). These characteristics are intrinsic to each borrower in that they lie outside of his control, even though they affect his probability of default.[10]

Since effort is assumed to be non-contractible, interest rates cannot be conditioned on the individual borrower's probability of repayment, even though they will obviously depend on the average probabilities of repayment of high and low-ability entrepreneurs, p and 0 respectively.

[8] The assumption of one-period contracts is not restrictive, since in this model the effort choice is assumed to be sunk before the loan contract is signed. Hence, the bank cannot precommit to anything other than the time-consistent policy, even if long-term contracts are available.

[9] These informational assumptions differ from those in Padilla and Pagano (1997), where banks are assumed to have an information advantage in lending to their customers in both periods and, therefore, earn positive informational rents over the course of their relationships with entrepreneurs. In the current model, instead, all informational rents are competed away ex ante when banks are symmetrically informed.

[10] We assume that banks learn this kind of information costlessly.

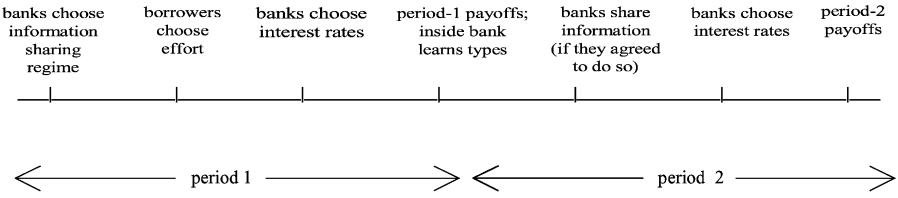

Fig. 1. Timing of the actions in the model.

The two banks set their rates sequentially (simultaneous price-setting creates problems for the existence of a pure strategy equilibrium). In period 2, each borrower receives the first offer from the bank that he was patronizing in period 1, which is now informed about his type. Let R^t_{j2} $(t = \mathrm{H}, \mathrm{L})$ denote the period-2 offers of bank j $(j = A, B)$.[11] Each bank chooses its offers so as to maximize expected period-2 profits, Π_{j2}. In period 1, bank A is assumed to move first, without loss of generality.[12] In this period, each bank chooses a single rate R_{j1} $(j = A, B)$ to maximize its total undiscounted expected profits, $\Pi_j = \Pi_{j1} + \Pi_{j2}$. This reflects the inability of banks to precommit to a given path of interest rates. The rates posted by each bank are public knowledge, but the rival bank cannot observe to whom they are offered.

Entrepreneurs rationally anticipate future interest rates, but assume that they cannot affect them; that is, they behave as price takers. They always borrow from the bank offering the lowest interest rate, but if the two banks charge the same interest rate they allocate themselves randomly. In particular, independently of his type, each borrower chooses bank A or bank B with probabilities σ and $1 - \sigma$ respectively, where $\sigma \in [0, 1]$. This allocation rule is common knowledge and, together with the continuum of borrowers, it ensures that in period 1, if banks set an identical single rate for both types, each bank's customer base will comprise the two types of borrowers in proportions γ and $1 - \gamma$.

The order of moves described above is summarized by the time line in Fig. 1.

We analyze the model under three different scenarios. Initially, we assume that the two banks do not communicate any information about their borrowers'

[11] As we shall see below, under some information regimes banks also condition their offers on performance-related variables such as defaults (besides borrowers' types), so that our notation will be slightly amended. For instance, when banks share information about defaults, the second-period interest rates offered by bank j will be $R^t_{j2}(D)$ for defaulters and $R^t_{j2}(\bar{D})$ for non-defaulters.

[12] Simultaneous rate-setting in period 1 would yield the same results, provided each borrower, irrespective of type, allocates himself across banks which offer the same rates randomly, according to a common probability function. The assumption of a continuum of borrowers then ensures that, in period 1, the shares of the two types of borrower in each bank's portfolio equal their proportions in the population.

credit history. Second, we consider what happens when banks share information about first-period defaults. Third, we analyze the case in which they share information about the entrepreneurs' types. For each case, we shall assume that banks precommit to the corresponding information regime.

We are always looking for the *subgame perfect equilibria* (SPE) of the model, that is, a vector $\{p, (R_{j1}, R_{j2}^{\mathrm{H}}, R_{j2}^{\mathrm{L}})_{j=A,B}\}$ such that:

(i) Each high-ability entrepreneur i chooses $p(i)$ to maximize his expected utility, correctly anticipating the interest rates in both periods and for both banks and taking the effort choices of other entrepreneurs as given. Since high-ability entrepreneurs are all identical and their payoffs are strictly quasi-concave in $p(i)$, in equilibrium $p(i) = p$ for all i.

(ii) Banks maximize their profits given the average probability of success of high-ability entrepreneurs, p, and their fraction γ, so that the interest rates $(R_{j1}, R_{j2}^{\mathrm{H}}, R_{j2}^{\mathrm{L}})_{j=A,B}$, constitute a subgame perfect equilibrium for the banking competition subgame.[13]

3. Banking competition

To characterize the equilibria of the model described above, we proceed in two steps for the sake of expositional clarity. First, in this section we characterize the outcome of the banking competition subgame under alternative information arrangements, for a given level of borrowers' effort. In the next section, we deal with the incentive effects of information sharing.

3.1. Interest rates without information sharing

To ensure perfection of equilibrium, interest rates are found by backward induction, taking p as given. For this reason, our first step is to find equilibrium rates and profits in period 2.

Suppose that bank A has won the competition for the entire market in period 1. Accordingly, in period 2 bank A knows the probability of success of each borrower while bank B does not. In equilibrium, bank A moves first, offering the interest rate

$$R_{A2}^{\mathrm{H,ns}} = \begin{cases} \bar{R}/\gamma p & \text{if } p \geq \bar{R}/\gamma R^*, \\ R^* & \text{if } \bar{R}/R^* \leq p < \bar{R}/\gamma R^*, \\ \text{no lending} & \text{otherwise,} \end{cases} \tag{2}$$

[13] Our notation allows only for a single interest rate in period 1. This is because under our assumptions, there must be pooling in equilibrium in period 1, when both banks are unaware of their customers' types.

to high-ability types (where the superscript 'ns' indicates no sharing of information) and refusing to lend to low-ability types. Bank A makes its offer anticipating the optimal pricing response of bank B. The latter, being unable to distinguish among borrower types and taking bank A's offer as given, refuses to lend to anyone.

To show that this is an equilibrium, let us focus on the case where $p \geq \bar{R}/\gamma R^*$ and specify each bank's strategy. Take bank A's rate as given. If this rate were to exceed $\bar{R}/\gamma p$, then bank B would undercut bank A. Otherwise, bank B would refuse to lend. In fact, if it were to set its interest rate above $\bar{R}/\gamma p$, it would only serve low-ability borrowers, and make losses. If instead it were to set its rate below $\bar{R}/\gamma p$, the break-even rate out of the entire pool of borrowers, it would serve the entire market but at a loss. Thus, its optimal response in this case is not to lend. Anticipating bank B's strategy, bank A will set the interest rate for high-ability borrowers at $\bar{R}/\gamma p$.[14] It is easy to see that this is the unique SPE of the period-2 banking competition subgame for $p \geq \bar{R}/\gamma R^*$.

In the intermediate region $\bar{R}/R^* \leq p < \bar{R}/\gamma R^*$, the break-even rate for the entire pool exceeds the maximum rate that borrowers can pay, R^*, so that bank A cannot charge more than this rate. As in the previous case, bank B has no incentive to undercut. Finally, if $p < \bar{R}/R^*$, then not even high-ability applicants are creditworthy, so neither bank will lend to them.

As a result of its informational advantage in period 2, for levels of p such that there is lending, bank A earns profits equal to:

$$\Pi_{A2}^{\mathrm{ns}} = \gamma(pR_{A2}^{\mathrm{H,ns}} - \bar{R}) > 0 \quad \text{for } p \geq \bar{R}/R^*, \tag{3}$$

where $pR_{A2}^{\mathrm{H,ns}} - \bar{R}$ is the per capita expected profit that the bank earns on high-ability borrowers and γ is their fraction in the population.

The previous results are qualitatively unaffected if bank A does not capture the whole market. If the two banks offered the same rates in period 1, then under our tie-breaking rule each bank will get a (non-negative) share of the market and each of the two customer bases will be a mirror image of the whole population. In this case, each bank j would charge its high-ability customers the rate $R_{j2}^{\mathrm{ns}} = R_{A2}^{\mathrm{ns}}$ given by Eq. (2) and would refuse credit to its rival's former customers. Of course, bank j would earn profits equal to $\Pi_{j2}^{\mathrm{ns}} = \Pi_{A2}^{\mathrm{ns}}\sigma_j$.

In period 1, bank j chooses R_{j1}^{ns} to maximize its total undiscounted profits as given by

$$\Pi_j^{\mathrm{ns}} = \Pi_{j1}^{\mathrm{ns}} + \Pi_{j2}^{\mathrm{ns}} = [(\gamma p R_{j1}^{\mathrm{ns}} - \bar{R}) + \gamma(pR_{j2}^{\mathrm{H,ns}} - \bar{R})]\sigma_j \quad \text{for } j = A, B, \tag{4}$$

where σ_j denotes bank j's market share in period 1. Bank A's market share, σ_A, equals 1 when $R_{A1}^{\mathrm{ns}} < R_{B1}^{\mathrm{ns}}$; it is σ if the two banks charge the same interest rate in

[14] Strictly speaking, bank A sets an interest rate equal to $\bar{R}/\gamma p - \varepsilon$, with $\varepsilon > 0$ arbitrarily small, and obtains positive profits. In this way, bank A ensures that its rate will not be matched by bank B and, therefore, that all its period-1 customers remain loyal.

period 1;[15] and it equals 0 when $R^{ns}_{A1} > R^{ns}_{B1}$. The first term in the square brackets is the per capita period-1 profit Π^{ns}_{j1}[16] and the second is the per capita period-2 profit Π^{ns}_{j2} from Eq. (3). It should be remembered that this expression is valid only for levels of p such that there is positive lending in period 1.

Whenever there is positive lending, competition in period-1 rates ensures that the expected profits over the two periods in (4) are equal to zero. This implies that period-1 rates are:

$$R^{ns}_{j1} = \begin{cases} \bar{R}/p & \text{if } p \geq \bar{R}/\gamma R^*, \\ (\bar{R}/p)(1+\gamma)/\gamma - R^* & \text{if } (\bar{R}/\gamma R^*)(1+\gamma)/2 \leq p < \bar{R}/\gamma R^*, \\ \text{no lending} & \text{otherwise.} \end{cases} \tag{5}$$

It is clear that R^{ns}_{j1} is less than the break-even rate, $\bar{R}/\gamma p$, so that banks make negative profits in period 1 which are exactly offset by the positive informational rents in period 2. Since the period-1 interest rates are equal ($R^{ns}_{A1} = R^{ns}_{B1}$), in equilibrium the two banks share the market equally: $\sigma_A = \sigma$ and $\sigma_B = 1 - \sigma$.

Note that positive lending requires that $p \geq (\bar{R}/\gamma R^*)(1+\gamma)/2$. This condition derives from the fact that, for lending to occur in period 1, the interest rate on high-ability borrowers R^{ns}_{j1} must not exceed their total return in case of success, R^*.

The previous results are summarized as follows:

Proposition 1. Under no information sharing, the unique SPE rates of the banking competition subgame are given by

Value of p	Period-1 interest rate (R^{ns}_{j1})	Period-2 interest rate (R^{ns}_{j2})
$p \geq \bar{R}/\gamma R^*$	$\bar{R}/p$	$\bar{R}/\gamma p$
$(\bar{R}/\gamma R^*)(1+\gamma)/2 \leq p < \bar{R}/\gamma R^*$	$(\bar{R}/p)(1+\gamma)/\gamma - R^*$	R^*
Otherwise	no lending	no lending

[15] Recall that $\sigma \in [0, 1]$ denotes the probability with which a borrower, irrespective of type, selects bank A when he faces the same rate from both banks.

[16] To derive this expression, we rely on our tie-breaking assumption that borrowers of either type allocate themselves randomly, according to a common probability function, when the two banks set the same rate.

Notice that in all the cases in which there is positive lending, the total interest burden on high-ability borrowers is the same, as is clear from Eqs. (2) and (5):

$$R_{j1}^{\mathrm{ns}} + R_{j2}^{\mathrm{ns}} = \frac{\bar{R}}{p}\frac{1+\gamma}{\gamma}. \tag{6}$$

3.2. Interest rates with information sharing about defaults

As before, take p as given and consider period-2 competition. Recall that both banks have learned the probability of success of every one of their borrowers. This time, however, we posit that before competition in period 2 each bank informs its competitor about which of its customers defaulted in period 1. Thus, if someone who borrowed from bank A in period 1 were to seek a loan from bank B in period 2, bank B's offer will be conditioned on whether or not he defaulted in period 1; and conversely for those who borrowed from bank B in period 1.

Let $\mu(H\,|\,D)$ denote the posterior probability of being a high-ability borrower conditional on having defaulted in period 1, and $\mu(H\,|\,\bar{D})$ be that of being a high-ability borrower conditional on not having defaulted. (Similarly, we denote the posterior probabilities of being a low-ability type as $\mu(L\,|\,D)$ and $\mu(L\,|\,\bar{D})$, respectively.) Then, using Bayes' rule we have

$$\mu(H\,|\,D) = 1 - \mu(L\,|\,D) = \frac{\gamma(1-p)}{\gamma(1-p)+(1-\gamma)} \in (0,1), \tag{7}$$

$$\mu(H\,|\,\bar{D}) = 1 - \mu(L\,|\,\bar{D}) = 1, \tag{8}$$

where Eq. (8) just restates our assumption that only high-ability entrepreneurs have positive NPV projects. Given that low-ability types are assumed to default with certainty, non-defaulters are recognized as high-ability borrowers by both banks. Therefore, $\mu(H/\bar{D}) = 1 > \gamma > \mu(H/D)$: that is, the prior probability of being a high-ability borrower, γ, lies between the two posterior probabilities defined above.

As in the case with no information sharing examined above, equilibrium rates are found by backward induction. We will show that in equilibrium each bank lends only to its high-ability customers from period 1, charging different interest rates depending on past performance, and refuses credit to its low-ability customers and to entrepreneurs who borrowed from its rival in period 1. The period-2 equilibrium rate charged by bank j (for $j = A, B$) to its period-1 high-ability customers who defaulted in period 1 is

$$R_{j2}^{\mathrm{H,is}}(D) = \begin{cases} \bar{R}/\mu(H|D)p & \text{if } p_A \le p \le p_B, \\ R^* & \text{if } \bar{R}/R^* \le p < p_A \text{ or } p_B \le p \le 1, \\ \text{no lending} & \text{otherwise,} \end{cases} \tag{9}$$

where p_A and $p_B \in (\bar{R}/R^*, 1)$ are the solutions of the quadratic equation $\bar{R}/\mu(H \mid D)p = R^*$. For levels of p outside the interval (p_A, p_B), the interest rate $\bar{R}/\mu(H \mid D)p$ would exceed the return to successful entrepreneurs; hence the bank cannot charge more than R^*. The period-2 interest rate that bank j charges to its high-ability customers who did not default in period 1, instead, is

$$R_{j2}^{\mathrm{H,is}}(\bar{D}) = \begin{cases} \bar{R}/p & \text{if } p \geq \bar{R}/R^*, \\ \text{no lending} & \text{otherwise.} \end{cases} \tag{10}$$

The superscript 'is' denotes the regime of information sharing about defaults.

To show that the previous rates define an equilibrium, we can use an argument similar to that offered in the case without information sharing. The only difference is that now each bank knows which of its rival's borrowers have defaulted in period 1. Hence, to prevent profitable undercutting on its high-ability customers, each bank must offer the rates $R_{j2}^{\mathrm{H,is}}(D)$ and $R_{j2}^{\mathrm{H,is}}(\bar{D})$ to high-ability defaulters and non-defaulters, respectively: if its rival undercuts either, it makes losses.

Since $\mu(H \mid \bar{D}) = 1 > \mu(H \mid D)$, we have that, for a *given* value of p, the period-2 rates that high-ability borrowers pay under information sharing about defaults bracket the rate that they pay under no information sharing. This is because each bank now rightly regards debtors who borrowed from its rival in period 1 and defaulted as riskier than those who did not default: the average probability of success of defaulters, $\mu(H \mid D)p$, is lower than the prior average probability, γp, and this in turn is lower than that of non-defaulters, p. Hence,

$$R_{j2}^{\mathrm{H,is}}(\bar{D}) < R_{j2}^{\mathrm{H,ns}} < R_{j2}^{\mathrm{H,is}}(D). \tag{11}$$

Bank j's profits in period 2 are given by

$$\Pi_{j2}^{\mathrm{is}} = \gamma(p\mathrm{E}(R_{j2}^{\mathrm{H,is}}) - \bar{R})\sigma_j, \tag{12}$$

where the expected interest rate paid by a high-ability borrower in period 2, $\mathrm{E}(R_{j2}^{\mathrm{H,is}})$, equals $pR_{j2}^{\mathrm{H,is}}(\bar{D}) + (1-p)R_{j2}^{\mathrm{H,is}}(D)$, for $p \geq \bar{R}/R^*$. Turning now to period 1, whenever there is positive lending, bank j chooses R_{j1}^{is} to maximize its total profits, which are given by

$$\Pi_j^{\mathrm{is}} = \Pi_{j1}^{\mathrm{is}} + \Pi_{j2}^{\mathrm{is}} = [(\gamma p R_{j1}^{\mathrm{is}} - \bar{R}) + \gamma(p\mathrm{E}(R_{j2}^{\mathrm{H,is}}) - \bar{R})]\sigma_j \quad \text{for } j = A, B.$$

Competition in period 1 ensures zero expected profits over the two periods. The resulting period-1 interest rate is

$$R_{j1}^{\mathrm{is}} = \begin{cases} \bar{R}/p & \text{if } p_A \leq p \leq p_B, \\ (\bar{R}/p)(1+\gamma)/\gamma - (1-p)R^* - \bar{R} & \text{if } p_C \leq p < p_A \\ & \quad \text{or } p_B \leq p \leq 1, \\ \text{no lending} & \text{otherwise,} \end{cases} \tag{13}$$

where p_C is defined such that $R_{j1}^{\text{is}} = R^*$. The condition involving this threshold derives from the fact that, if lending is to occur in period 1 the interest rate R_{j1}^{is} on high-ability borrowers must not exceed the total return that they generate in case of success, R^*. As without information sharing, banks make negative profits in period 1 by setting R_{j1}^{is} lower than the break-even rate, $\bar{R}/\gamma p$, in order to reap positive informational rents in period 2.

The previous results are summarized as follows:

Proposition 2. With information sharing about defaults, the unique SPE rates of the banking competition subgame are given by

Value of p	Period-1 interest rate (R_{j1}^{is})	Period-2 interest rate (R_{j2}^{is})
$p_A \leq p \leq p_B$	$\bar{R}/p$	default (D): $\bar{R}/\mu(H \mid D)p$ no default ($\bar{D}$): $\bar{R}/p$
$p_C \leq p < p_A$ or $p_B \leq p \leq 1$	$(\bar{R}/p)(1+\gamma)/\gamma - (1-p)R^* - \bar{R}$	default (D): R^* no default ($\bar{D}$): $\bar{R}/p$
Otherwise	no lending	no lending

As without information sharing, when there is positive lending the total (expected) interest burden on high-ability borrowers is the same. Furthermore, it coincides with the total burden in the absence of information sharing:

$$R_{j1}^{\text{is}} + \mathrm{E}(R_{j2}^{\text{is}}) = \frac{\bar{R}}{p}\frac{1+\gamma}{\gamma}. \tag{14}$$

3.3. Interest rates with information sharing about types

In the foregoing section, banks were assumed to share only information about past defaults, not about the intrinsic riskiness of borrowers. Recall that in period 1 each bank is assumed to learn the *type* of its customers, not just whether they have defaulted or not. Banks may also share this kind of information by directly reporting the types of borrowers. We now analyze the impact of this alternative regime on equilibrium interest rates and profits. Since in equilibrium a borrower's probability of repayment is completely determined by his type, once this is revealed all information about past credit performance (defaults) is superfluous. Since disclosing the borrower's 'type' is tantamount to sharing information

completely, we denote this regime by the superscript 'cs', for 'complete sharing' of banks' private information.[17]

If banks share this information, both banks distinguish perfectly between high- and low-ability borrowers in period 2, whether or not they lent to them in period 1. This implies that equilibrium rates are such that banks make zero profits out of each group of borrowers, i.e. they charge $R_{A2}^{\mathrm{H,cs}} = R_{B2}^{\mathrm{H,cs}} = \bar{R}/p$ to high-ability entrepreneurs for $p \geq \bar{R}/R^*$ and refuse credit if $p < \bar{R}/R^*$. They will also refuse credit to low-ability customers. Sharing this kind of information dissipates all period-2 informational rents, i.e. $\Pi_{A2}^{\mathrm{cs}} = \Pi_{B2}^{\mathrm{cs}} = 0$.

Since there are no informational rents to be had in period 2, competition in period 1 is attenuated. Banks price so as to break even in each of the two periods, i.e. $\Pi_A^{\mathrm{cs}} = \Pi_B^{\mathrm{cs}} = 0$. The period-1 pooling interest rate is just the pooling zero-profit interest rate $R_{A1}^{\mathrm{cs}} = R_{B1}^{\mathrm{cs}} = \bar{R}/\gamma p$, for $p \geq \bar{R}/R^*$. As in period 2, the bank refuses to lend to high-ability entrepreneurs if $p < \bar{R}/R^*$.

The previous results are summarized as follows:

Proposition 3. With information sharing about types, the unique SPE rates of the banking competition subgame are given by

Value of p	Period-1 interest rate (R_{j1}^{cs})	Period-2 interest rate (R_{j2}^{cs})
$p \geq \bar{R}/R^*$	$\bar{R}/\gamma p$	$\bar{R}/p$
Otherwise	no lending	no lending

As in the previous two regimes, when there is positive lending the total interest burden on high-ability borrowers is the same; it coincides with the value computed for the other regimes:

$$R_{j1}^{\mathrm{cs}} + R_{j2}^{\mathrm{cs}} = \frac{\bar{R}}{p}\frac{1+\gamma}{\gamma}. \tag{15}$$

For a given p, the equality of the expected interest burden in all three regimes follows from the zero-profit condition for the banks and the zero-effort assumption for low-ability borrowers. But the distribution of the interest burden between periods differs significantly between regimes. From the previous

[17] This would not be true if in this regime borrowers were to randomize their effort choice. In this case, default would still be informative about their effort choice, even conditional on knowledge of their type. In our model, however, no borrower will ever adopt a mixed strategy since his objective function is strictly concave in $p(i)$, for a given average probability of repayment p.

propositions, it is clear that as we move towards greater information sharing, interest rates decrease in period 2 and increase in period 1, for a given effort p: information sharing dissipates period-2 rents via more intense competition.

Note, finally, that the set of effort levels p for which there is positive lending also varies across information regimes. If we denote by I^{ns} the set of effort levels for which there is positive lending without information sharing, and define I^{is} and I^{cs} analogously, then it can be shown from the previous results that

$$I^{\mathrm{cs}} \subseteq I^{\mathrm{is}} \subseteq I^{\mathrm{ns}}, \tag{16}$$

that is, as more information is shared, a higher level of effort by high-ability borrowers is needed to elicit lending. The intuitive reason is that as no informational rents are possible in period 2, banks compete less aggressively for customers in period 1, given the probability of repayment p. They do not lend unless the probability of repayment allows them to break even in period 1.

4. Effort choices: Equilibrium and efficiency

In the previous section, we took the effort choices of borrowers as given. In equilibrium, however, these are endogenously determined. In this section we characterize the equilibrium effort choice of borrowers and examine how it is affected by information sharing. To provide a relevant benchmark, we start this section by computing the first-best choice of effort.

4.1. The first-best benchmark

Since in this model banks' expected profits are zero, the first-best effort level, $\hat{p}$, is the value of p that maximizes the expected utility of high-ability borrowers in the absence of both moral hazard and adverse selection, that is

$$U_{\mathrm{H}}(p) = 2\left(R^* - \frac{\bar{R}}{p}\right)p - V(p), \tag{17}$$

where the interest rate in both periods is $\bar{R}/p$ because banks have symmetric and complete information in both periods. Therefore, $\hat{p}$ must satisfy the first-order condition

$$\partial U_{\mathrm{H}}(\hat{p})/\partial p = 2R^* - V'(\hat{p}) = 0. \tag{18}$$

This equation has just one root, since $V'(p)$ is strictly increasing in p. Given our assumptions on $V'(\cdot)$, the root $\hat{p}$ lies in the interval (0,1), so it is never optimal to set the probability of repayment at 1. The second-order condition follows directly from the convexity of $V(\cdot)$ with respect to p.

4.2. Effort choice under no information sharing

When banks do not share information, the high-ability borrower's i choice of effort, $p^{\mathrm{ns}}(i)$, is given by the first-order condition

$$\frac{\partial U_{\mathrm{H}}(p^{\mathrm{ns}}(i))}{\partial p^{\mathrm{ns}}(i)} = MR^{\mathrm{ns}}(p^{\mathrm{ns}}(i)) - V'(p^{\mathrm{ns}}(i))$$

$$= \max[2R^* - (R_1^{\mathrm{ns}} + R_2^{\mathrm{H,ns}}),\ 0] - V'(p^{\mathrm{ns}}(i)) = 0, \tag{19}$$

where MR^{ns} is for the marginal return to effort without information sharing. Note that $MR^{\mathrm{ns}}(p^{\mathrm{ns}})$ takes the value of zero for those values of p^{ns} which lead to zero lending. The second-order condition is trivially satisfied, because of the convexity of $V(\cdot)$.

In equilibrium, $p^{\mathrm{ns}}(i) = p^{\mathrm{ns}}$ for all i, so

$$MR^{\mathrm{ns}}(p^{\mathrm{ns}}) = V'(p^{\mathrm{ns}}). \tag{20}$$

This equation admits several solutions. This multiplicity of equilibria derives from the strategic complementarity of effort choices: if everybody chooses low effort, interest rates will be high, so that no individual borrower will have an incentive to raise his effort level; and conversely. We define the set of equilibrium effort levels in the no-sharing regime by $P^{\mathrm{ns}} \equiv \langle p^{\mathrm{ns}} \rangle$, and illustrate them in Fig. 2.

First, note that there is always an equilibrium involving zero effort, where the credit market collapses. This is because if everybody is expected to exert zero effort, banks expect all borrowers to default and do not lend. In this situation, no one has any incentive to exert positive effort. Equilibria involving positive p^{ns} may or may not exist, and there may be one or more of them. Fig. 2 shows a case in which there are two equilibria with positive lending.

The figure also illustrates that the marginal return to effort $MR^{\mathrm{ns}}(p^{\mathrm{ns}})$ is strictly smaller than the efficient benchmark level $2R^*$ for all values of p^{ns}. This implies that:

Proposition 4. Under no information sharing, the equilibrium level of effort is inefficiently low: $p^{\mathrm{ns}} < \hat{p}$ for all $p^{\mathrm{ns}} \in P^{\mathrm{ns}}$.

The degree of inefficiency is decreasing in the level of effort exerted in equilibrium:

Proposition 5. Under no information sharing, equilibria involving higher effort are Pareto superior.

Proof. Suppose p_1^{ns} and p_2^{ns} are two equilibrium effort levels, with $p_2^{\mathrm{ns}} > p_1^{\mathrm{ns}}$. Consider the equilibrium in which the level of effort is p_2^{ns} and the interest rates

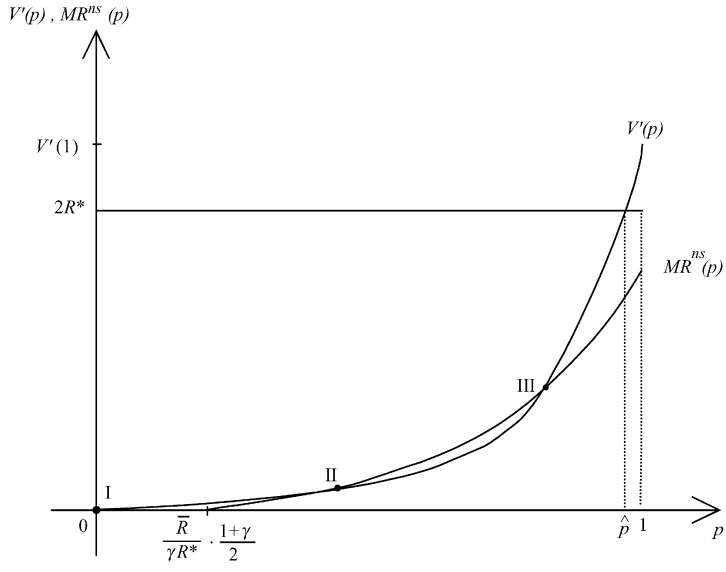

Fig. 2. Effort choice under no information sharing: equilibria. The locus $MR^{\mathrm{ns}}(p)$ illustrates the marginal return to effort for high-ability borrowers under no information sharing. $V'(p)$ denotes the marginal disutility of effort. The intersection points I, II and III define the equilibria of the no information sharing regime. The horizontal line $2R^*$ represents the social return to effort and $\hat{p}$ the first-best effort level. All equilibria exhibit an inefficiently low level of effort.

are correspondingly set at $R_1^{\mathrm{ns}}(p_2^{\mathrm{ns}})$ and $R_2^{\mathrm{H,ns}}(p_2^{\mathrm{ns}})$. In this equilibrium, the utility of a high-ability borrower is maximized at effort level p_2^{ns}, and is thus higher than at effort p_1^{ns}:

$$p_2^{\mathrm{ns}}[2R^* - (R_1^{\mathrm{ns}}(p_2^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_2^{\mathrm{ns}}))] - V(p_2^{\mathrm{ns}})$$

$$> p_1^{\mathrm{ns}}[2R^* - (R_1^{\mathrm{ns}}(p_2^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_2^{\mathrm{ns}}))] - V(p_1^{\mathrm{ns}}).$$

But the interest rate burden in the higher effort equilibrium, $R_1^{\mathrm{ns}}(p_2^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_2^{\mathrm{ns}})$, is lower than that with low effort, $R_1^{\mathrm{ns}}(p_1^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_1^{\mathrm{ns}})$, so that:

$$p_1^{\mathrm{ns}}[2R^* - (R_1^{\mathrm{ns}}(p_2^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_2^{\mathrm{ns}}))] - V(p_1^{\mathrm{ns}})$$

$$> p_1^{\mathrm{ns}}[2R^* - (R_1^{\mathrm{ns}}(p_1^{\mathrm{ns}}) + R_2^{\mathrm{H,ns}}(p_1^{\mathrm{ns}}))] - V(p_1^{\mathrm{ns}}),$$

which shows that high-ability borrowers are better off in equilibria with higher p^{ns}. Low-ability borrowers are indifferent because they always default, and banks are indifferent because they make zero profits. □

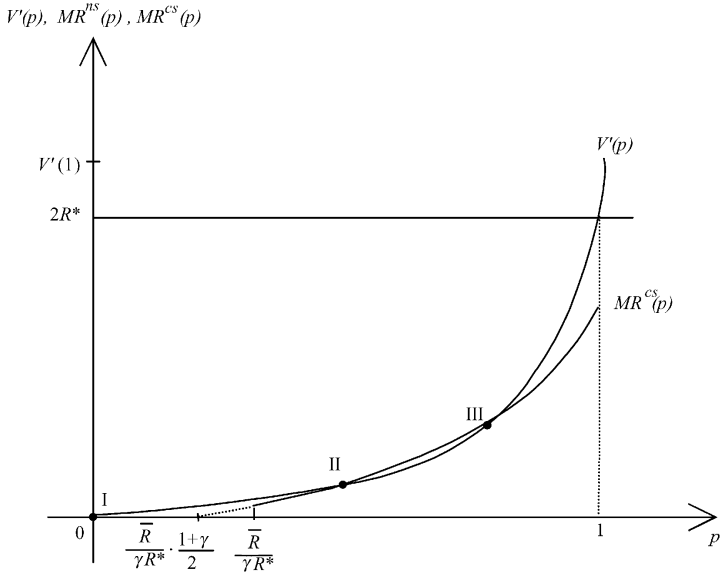

Fig. 3. Effort choice with complete information sharing: equilibria. The locus $MR^{\mathrm{cs}}(p)$ illustrates the marginal return to effort for high-ability borrowers with complete information sharing and $V'(p)$ denotes the marginal disutility of effort. Intersections I, II and III define the equilibria of the complete information sharing case. All equilibria exhibit an inefficiently low level of effort. $MR^{\mathrm{ns}}(p)$, the marginal return to effort under no information sharing coincides with $MR^{\mathrm{cs}}(p)$ except for the interval $[(\bar{R}/\gamma R^*)\cdot(1+\gamma)/2,\ \bar{R}/\gamma R^*]$, where $MR^{\mathrm{ns}}(p)$ is given by the dotted line.

4.3. Effort choice with information sharing about types

When banks disclose their borrowers' quality or, equivalently, share information completely, the choice of effort by a high-ability borrower i, $p^{\mathrm{cs}}(i)$, is given by the first-order condition

$$\begin{aligned}\frac{\partial U_{\mathrm{H}}(p^{\mathrm{cs}}(i))}{\partial p^{\mathrm{cs}}(i)} &= MR^{\mathrm{cs}}(p^{\mathrm{cs}}(i)) - V'(p^{\mathrm{cs}}(i)) \\ &= \max[2R^* - (R_1^{\mathrm{cs}} + R_2^{\mathrm{H,cs}}),0] - V'(p^{\mathrm{cs}}(i)) = 0,\end{aligned} \tag{21}$$

where MR^{cs} stands for the marginal return to effort with information sharing about types.

In equilibrium, $p^{\mathrm{cs}}(i) = p^{\mathrm{cs}}$ for all i, so

$$MR^{\mathrm{cs}}(p^{\mathrm{cs}}) = V'(p^{\mathrm{cs}}). \tag{22}$$

As in the previous case, this equation admits several solutions. We define the set of equilibrium effort levels in this regime by $P^{\mathrm{cs}} \equiv \langle p^{\mathrm{cs}} \rangle$. These equilibria are illustrated in Fig. 3. Again, there is always an equilibrium at zero effort,

corresponding to credit market collapse, and several, one, or no equilibria with positive effort and lending. Also in this case, all the equilibria involve too little effort compared to the first best and they are Pareto-ranked in effort.

Proposition 6. With complete information sharing, the equilibrium level of effort is inefficiently low: $p^{cs} < \hat{p}$ *for all* $p^{cs} \in P^{cs}$, *and equilibria involving higher effort are Pareto superior.*

The proof is identical to that of Proposition 5 above.

To determine the incentive effects of information sharing about types, we now compare the equilibrium effort choices in this regime with those under no information sharing.

Proposition 7. If $V'(p) > MR^{ns}(p)$ *for all* $p \geq \bar{R}/\gamma R^*$, *then the set of equilibrium effort levels that obtain under no information sharing is identical to those that obtain with complete information sharing*: $P^{ns} \equiv P^{cs}$.

Proof. Note that for any $p \geq \bar{R}/\gamma R^*$, $MR^{ns}(p) \equiv MR^{cs}(p)$. Since $V'(p) > MR^{ns}(p)$ for all $p \geq \bar{R}/\gamma R^*$, then there is no equilibrium effort choice under no information sharing p^{ns} in the interval $(0,\bar{R}/\gamma R^*)$. So this assumption ensures that the equilibrium conditions (19) and (21) yield the same solutions. □

From Fig. 3, it is easy to see that the marginal return to effort, when positive, is identical in these two information regimes, provided p exceeds the threshold $\bar{R}/\gamma R^*$. This is the minimum value of p for which there is positive lending with complete information sharing. For lower levels of p, the marginal return to effort without information sharing is larger than (or at least equal to) that with complete sharing. The condition $V'(p) > MR^{ns}(p)$ for all $p \geq \bar{R}/\gamma R^*$ in the previous proposition implies that no equilibrium without information sharing can occur in the region where the marginal returns to effort differ in these two information regimes. So the proposition establishes a sufficient condition, which is entirely based on primitives, for the coincidence of the two sets of equilibria.

When this condition is violated, there may be equilibria with positive lending under no information sharing but not under complete information sharing. This case is illustrated in Fig. 4. The reason is that the dissipation of period-2 informational rents forces banks to break even in each single period. So banks will refrain from lending unless the probability of repayment allows them to break even in period 1, while without information sharing they only have to break even over the two periods as a whole – a less stringent condition. Thus the credit market may not be viable for relatively low values of p when banks share information about types, whereas with no information sharing it would be active. This result, which in (16) was established for exogenous values of p, here is

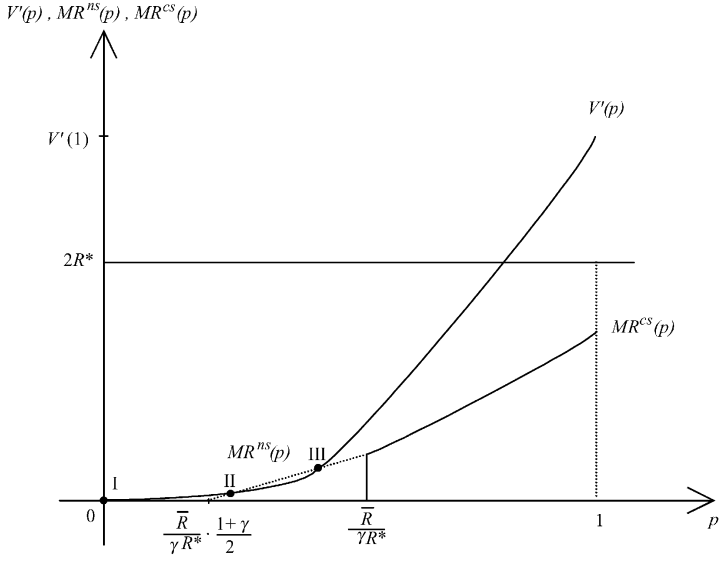

Fig. 4. Effort choice with complete information sharing: complete information sharing leads to market collapse. Equilibria II and III, involving positive lending, exist only under no information sharing. With complete information sharing, the only equilibrium (at I) involves zero effort. The equilibrium also arises under no information sharing.

shown to hold when p is endogenously determined. The following proposition summarizes this point together with that of the previous proposition:

Proposition 8. Complete information sharing does not increase the equilibrium level of effort compared to the no information sharing case and may even lead to a collapse of the credit market that would not occur under no information sharing.

The model thus predicts that banks' disclosure of information about their borrowers' quality does not alter equilibrium default rates and interest rates and may even harm the viability of the credit market. This result contrasts sharply with Padilla and Pagano (1997), where it is shown that information sharing about borrowers' quality induces them to exert more effort to repay, lowers equilibrium interest rates and may lead the credit market to operate in situations in which it would not otherwise be viable. The reason for these conflicting predictions lies in differing assumptions about banking competition. In the 1997 paper, banks have an informational monopoly on their customers and are tempted to exploit it by charging predatory rates. Information sharing on borrowers' quality prevents such opportunism, by fostering competition and reducing informational rents. Solving this hold-up problem raises borrowers' ex-ante incentive to perform.

No such hold-up problem exists in the present model, because ex-ante competition is assumed to eat away all the potential informational rents. When banks disclose information about their customers' quality, their expected rents stay unchanged, and at zero, and so does the overall interest burden on their borrowers: this is just reallocated over time. As a result, borrowers have no reason to change their effort level, and equilibrium default and interest rates are unchanged. But, although ex-ante competition makes disclosure of borrowers' quality ineffective, the incentives of borrowers can still be sharpened by limiting disclosure to defaults, as we shall see below.

4.4. Effort choice with information sharing about defaults

When banks share only information about their customers' past defaults, the effort choice by a high-ability borrower i, $p^{\mathrm{is}}(i)$, is given by the first-order condition

$$\begin{aligned}\frac{\partial U_{\mathrm{H}}(p^{\mathrm{is}}(i))}{\partial p^{\mathrm{is}}(i)} &= MR^{\mathrm{is}}(p^{\mathrm{is}}(i)) - V'(p^{\mathrm{is}}(i)) \\ &= \max\left\{\begin{matrix} 2R^* - [R_1^{\mathrm{is}} + \mathrm{E}(R_2^{\mathrm{H,is}})] \\ -p^{\mathrm{is}}(i)[R_2^{\mathrm{H,is}}(\bar{D}) - R_2^{\mathrm{H,is}}(D)], 0 \end{matrix}\right\} - V'(p^{\mathrm{is}}(i)) = 0, \end{aligned} \tag{23}$$

where MR^{is} stands for the marginal return to effort with information sharing about defaults.

In equilibrium, $p^{\mathrm{is}}(i) = p^{\mathrm{is}}$ for all i, so

$$MR^{\mathrm{is}}(p^{\mathrm{is}}) = V'(p^{\mathrm{is}}), \tag{24}$$

where

$$MR^{\mathrm{is}}(p) = \max\{2R^* - [R_1^{\mathrm{is}} + \mathrm{E}(R_2^{\mathrm{H,is}})] + \Delta(p), 0\} \tag{25}$$

and

$$\begin{aligned}\Delta(p) &= p[R_2^{\mathrm{H,is}}(\bar{D}) - R_2^{\mathrm{H,is}}(D)] \\ &= \begin{cases} pR^* - \bar{R} & \text{if } p_C \le p < p_A \text{ or } p_B \le p \le 1, \\ \bar{R}/\mu(H \mid D) - \bar{R} & \text{if } p_A \le p \le p_B. \end{cases}\end{aligned} \tag{26}$$

where p_A, p_B and p_C are defined in Section 3.2.

$\Delta(p)$, which represents the 'disciplinary effect' of information sharing about defaults, is positive and strictly increasing in p. When banks share information about defaults in period 2, the interest rate to high-ability borrowers is contingent on default: $R_2^{\mathrm{H,is}}(\bar{D}) - R_2^{\mathrm{H,is}}(D) > 0$. Recall that borrowers that did not default in period 1 are recognized as high-ability entrepreneurs by the outside bank and are thus charged $\bar{R}/p^{\mathrm{is}}$ by the incumbent. High-ability borrowers that

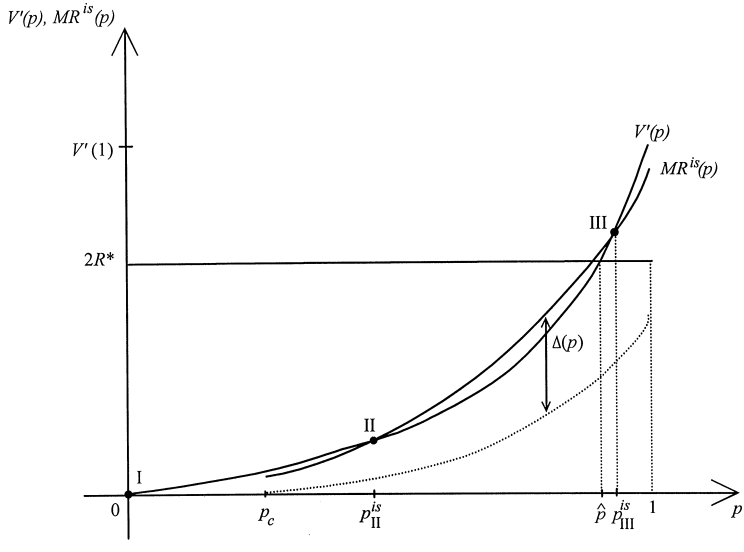

Fig. 5. Effort choice with information sharing about defaults: equilibria and efficiency. The locus $MR^{\text{is}}(p)$ illustrates the marginal return to effort for high ability borrowers with information sharing about defaults, and $V'(p)$ denotes the marginal disutility of effort. Intersections I, II and III define the equilibria with information sharing about defaults. $\Delta(p)$ denotes the 'disciplinary effect' of information sharing about defaults, and $\hat{p}$ is the first-best effort level. Equilibrium II featuring effort $p^{\text{is}}_{\text{II}}$ involves underinvestment in effort. Equilibrium III with effort $p^{\text{is}}_{\text{III}}$ involves over-investment in effort.

defaulted in period 1, instead, are mixed with low-ability types and so are charged a higher rate. More precisely, they are charged $\max(\bar{R}/\mu(H \mid D)p^{\text{is}}, R^*)$. So high-ability borrowers have an incentive for extra effort in period 1 to avoid defaulting and being pooled with low-ability borrowers. In the other information regimes, this effect is lacking.

Therefore, whenever there is positive lending in this regime, i.e. $p \geq p_C$,

$$MR^{\text{is}}(p) > MR^{\text{ns}}(p) \equiv MR^{\text{cs}}(p). \tag{27}$$

As in the other regimes, Eq. (24) has several solutions. We define the set of equilibrium effort levels in this regime by $P^{\text{is}} \equiv \langle p^{\text{is}} \rangle$. These equilibria are illustrated in Fig. 5. Again, there is always an equilibrium involving zero effort, as well as several, one or no equilibria with positive effort and lending. But unlike the other cases, these equilibria cannot be Pareto ranked in the regime with information sharing about defaults. Furthermore, they may involve either inefficiently low effort or inefficiently high effort. In other words, the disciplinary effect can be either too weak or too strong to attain the first best. Fig. 5

illustrates an instance in which there are two equilibria with positive lending, one featuring under-investment and the other over-investment in effort. The following proposition provides sufficient conditions for these two cases. Note that both conditions are based only on primitives.

Proposition 9. With information sharing about defaults, two cases can occur: (a) *if* $MR^{\mathrm{is}}(1) < 2R^*$, *then the equilibrium level of effort is inefficiently low*: $p^{\mathrm{is}} < \hat{p}$ *for all* $p^{\mathrm{is}} \in P^{\mathrm{is}}$; *and* (b) *if* $MR^{\mathrm{is}}(1) > V'(1)$, *then there is at least one equilibrium where the level of effort is inefficiently high, corresponding to* $p^{\mathrm{is}} = 1 > \hat{p}$.

Proof. (a) It is easy to verify that $MR^{\mathrm{is}}(p)$ is increasing in p. Thus, the condition $MR^{\mathrm{is}}(1) < 2R^*$ implies that the marginal return to effort is below its first-best level for all p.

(b) Condition $MR^{\mathrm{is}}(1) > V'(1)$ implies that there is a corner solution at $p^{\mathrm{is}} = 1$. Since $\hat{p} < 1$, this equilibrium features an inefficiently high level of effort. □

Now we can compare the equilibrium effort choices in this regime with those under no information sharing and under complete information sharing. Because of the multiplicity of equilibria, following Milgrom and Roberts (1990, 1994) and Milgrom and Shannon (1994), we shall compare the *extreme* equilibria of the different information regimes, that is, we focus on the equilibria featuring the highest and the lowest level of effort in each regime. The equilibrium involving the lowest level of effort level is at $p = 0$ in all three regimes, so we just need to compare the equilibria with the highest level of effort.

Proposition 10. Define the highest equilibrium level of effort in the three regimes by $\bar{p}^r \equiv \sup(p^r)$, *for* $r = \mathrm{ns}, \mathrm{cs}, \mathrm{is}$. *Then, if* $V'(p) > MR^{\mathrm{ns}}(p)$ *for all* $p \geq \bar{R}/\gamma R^*$, $\bar{p}^{\mathrm{is}} \geq \bar{p}^{\mathrm{cs}} = \bar{p}^{\mathrm{ns}}$.

Proof. Note that for any $p \geq \bar{R}/\gamma R^*$, $MR^{\mathrm{is}}(p) > MR^{\mathrm{ns}}(p) \equiv MR^{\mathrm{cs}}(p)$. Since $V'(p) > MR^{\mathrm{ns}}(p)$ for all $p \geq \bar{R}/\gamma R^*$, then there is no equilibrium effort choice under no information sharing p^{ns} in the interval $(0, \bar{R}/\gamma R^*)$. This leaves us with two possible cases:

(a) There is at least one equilibrium with positive lending under no information sharing with $p \geq \bar{R}/\gamma R^*$. In this case, from Proposition 7 we know that the same equilibrium would also exist with complete information sharing. But since in this case $MR^{\mathrm{is}}(p) > MR^{\mathrm{ns}}(p) \equiv MR^{\mathrm{cs}}(p)$ from (27), then there is at least one equilibrium under information sharing about defaults featuring a higher effort level. Hence, it follows immediately that in this case $\bar{p}^{\mathrm{is}} > \bar{p}^{\mathrm{cs}} = \bar{p}^{\mathrm{ns}}$.

(b) There is no equilibrium with positive lending under no information sharing. So, again from Proposition 7, we know that there is no equilibrium with positive lending also in the regime with complete information sharing. Yet, since

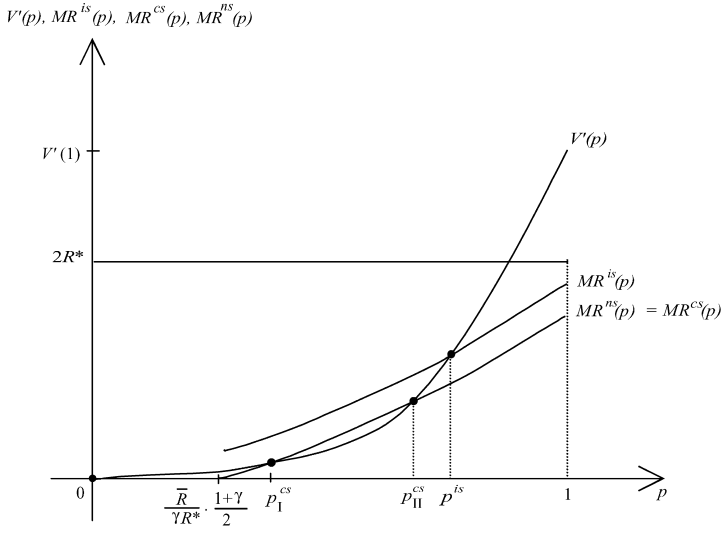

Fig. 6. Effort choice with information sharing about defaults, complete information sharing, and no information sharing: comparison in equilibrium. Effort levels $p_{\mathrm{I}}^{\mathrm{cs}}$ and $p_{\mathrm{II}}^{\mathrm{cs}}$ arise in equilibrium with complete information sharing and with no information sharing. Effort level p^{is} is the only equilibrium effort level implying positive lending with information sharing about defaults. Sharing default information raises the incentives to exert effort: $p^{\mathrm{is}} > p_{\mathrm{II}}^{\mathrm{cs}} > p_{\mathrm{I}}^{\mathrm{cs}}$.

$MR^{\mathrm{is}}(p) > MR^{\mathrm{ns}}(p) \equiv MR^{\mathrm{cs}}(p)$ from (27), there can be an equilibrium with positive lending in the regime with information sharing about defaults. Hence, in this case $\bar{p}^{\mathrm{is}} \geq \bar{p}^{\mathrm{cs}} = \bar{p}^{\mathrm{ns}}$, which completes the proof. □

This proposition is illustrated in Fig. 6, where the marginal return to effort with information sharing about defaults lies above the corresponding locus for the other two information regimes when p exceeds the threshold $\bar{R}/\gamma R^*$. This relationship between marginal returns explains the result about equilibrium effort levels in the proposition.

For values of p in the interval between p_C and $\bar{R}/\gamma R^*$, when banks share information about types there is no lending. However, there may be equilibria with positive lending with information sharing about defaults, because in this region $MR^{\mathrm{is}}(p) > 0$. This result, together with the previous proposition, leads immediately to the following:

Proposition 11. Information sharing about defaults increases the highest equilibrium level of effort compared to complete information sharing and may lead to positive lending when the credit market would not be active under complete information sharing.

This is an important result: in this model more complete information sharing is not necessarily conducive to greater efficiency. Information sharing only about defaults may lead to lower default rates and lower interest rates, and possibly to a viable credit market in situations where no credit would be extended under complete information sharing.

No similar comparison can be effected between the regimes with only default disclosure and that with no information sharing. When there is positive lending in both regimes, Proposition 10 suggests that information sharing about defaults may increase the incentive for effort. However, an active credit market may operate with no information sharing but not under default disclosure. The latter situation occurs for values of $p \in ((\bar{R}/\gamma R^*)(1+\gamma)/2, p_C)$, where $MR^{\mathrm{ns}}(p) > MR^{\mathrm{is}}(p) = 0$. This result arises from the dissipation of period-2 rents due to information sharing, as discussed at the end of the previous subsection.

5. Implementing the first best

In the previous section we showed that sharing only information about defaults cannot in general implement the first best. Depending on the relative strength of the disciplinary effect $\Delta(p)$, in equilibrium we may have either too high or too low a level of effort. We also showed that the first best cannot be implemented via complete information sharing either. In this case, effort is always inefficiently low in equilibrium. It is then natural to ask whether banks can 'fine-tune' the degree of information disclosure to achieve the most efficient outcome and – if so – whether they will spontaneously set up such system and stick to its rules.

In this section, we show that under certain circumstances the first-best outcome can be achieved by complementing data on defaults with information about types for some of the high-ability borrowers. More precisely, if the disciplinary effect associated with default disclosure is sufficiently strong, the first best can be successfully implemented if banks not only share information about defaulting customers but also report the type of their high-ability borrowers for a fraction q of them, randomly chosen at the beginning of period 2. To implement this, banks may confer their data about both defaults and borrowers' quality to a third party (a credit bureau) and instruct it to divulge the data according to this rule. A high-ability borrower thus anticipates that, even when he defaults, there is a probability q that he will still be recognized as a high-ability type by outside banks. In this case, his default will be ignored, so that he will pay the actuarially fair interest rate in period 2. This explains the following proposition:

Proposition 12. If $\Delta(\hat{p}) \geq (\bar{R}/\hat{p})(1+\gamma)/\gamma$, then there is a $q \in (0, 1)$ such that if banks commit to report the true type of a randomly selected fraction q of their high-ability

customers in addition to default information for all of them, then the first-best level of effort $\hat{p}$ can be implemented as a subgame perfect equilibrium.

Proof. For a given q, the individual effort choice satisfies the first-order condition

$$qMR^{cs}(p) + (1-q)MR^{is}(p) = V'(p(i)). \tag{28}$$

In equilibrium, $p(i) = p$ for all i, so that the equilibrium condition is

$$qMR^{cs}(p) + (1-q)MR^{is}(p) = V'(p). \tag{29}$$

Therefore, the first-best effort level $\hat{p}$ can be implemented in equilibrium only if there is a value of q such that Eq. (29) holds for $p = \hat{p}$.

From the derivation of $\hat{p}$, we know that $V'(\hat{p}) = 2R^*$. Furthermore, substitution yields

$$qMR^{cs}(\hat{p}) + (1-q)MR^{is}(\hat{p}) = 2R^* - \frac{\bar{R}}{\hat{p}}\frac{1+\gamma}{\gamma} + (1-q)\Delta(\hat{p}). \tag{30}$$

From (30), if $\Delta(\hat{p}) < (\bar{R}/\hat{p})(1+\gamma)/\gamma$ there is no value of $q \in [0, 1]$ such that Eq. (29) holds for $p = \hat{p}$. Instead, if $\Delta(\hat{p}) \geq (\bar{R}/\hat{p})(1+\gamma)/\gamma$, then Eq. (29) holds for $p = \hat{p}$ when

$$1 - q = \frac{\bar{R}}{\hat{p}\Delta(\hat{p})}\frac{1+\gamma}{\gamma} \in (0, 1),$$

which proves our result. □

Note that $1 - q$ is strictly positive, so that implementing the first best requires that banks not commit to share information about types for all their high-ability customers. This is because complete information sharing always leads to underinvestment in effort. Moreover $1 - q$ is decreasing in the disciplinary effect $\Delta(\hat{p})$: the harsher the incentive effects of disclosing defaults, the higher q must be to implement the first best.

Having seen that an appropriately designed information-sharing arrangement may induce the efficient level of effort, it is worth asking whether market forces can be expected to produce such an arrangement. Suppose that different groups of banks have signed different information-sharing agreements. Since in this model high-ability entrepreneurs appropriate the entire surplus from lending, they will prefer to borrow from banks operating under the information-sharing arrangement that maximizes their expected utility.

Each information-sharing arrangement can be characterized by an average probability of repayment p. Under any of these arrangements, the equilibrium

expected utility of any high-ability borrower is equal to:

$$U_{\mathrm{H}}(p) = 2\left(R^* - \frac{\bar{R}}{p}\frac{1+\gamma}{\gamma}\right)p - V(p).$$

This expression is maximized by $p = \hat{p}$, the first-best effort level defined in Eq. (18). We have just shown that, under some circumstances, the arrangement can be designed so as to implement the first-best outcome in equilibrium. This will not always be a unique equilibrium, as shown above, but it is reasonable to suppose that, in the presence of multiple equilibria, banks' customers coordinate on the Pareto-superior one. If so, high-ability entrepreneurs will prefer to borrow from banks adhering to an information-sharing arrangement leading to an equilibrium average probability of repayment $\hat{p}$.

Will banks that do not adhere to such an 'efficient information-sharing system' be driven out of the market? In the spirit of Coase, we conjecture that, unless there are coordination problems, this will indeed happen. Although in equilibrium they make zero profit in all information regimes, banks that sign an efficient information-sharing arrangement generate a higher surplus for their customers, so that they should attract all the business in the market. A formal proof would require adding another stage to our model, where banks can form coalitions bound by information-sharing agreements before making offers to their potential customers. This interesting extension of our model is left for future work.

Suppose, however, that because of coordination problems no coalition of banks succeeds in setting up an information-sharing arrangement in a situation where an efficient one could be designed. Then, according to our model, public intervention would be warranted. If the government can mandate banks' disclosure of credit information via an efficiently designed system, borrowers' welfare will be increased. This is a highly relevant issue, because in practice government intervention is quite common. Jappelli and Pagano (1999) report that 19 of 46 countries sampled have a public credit register – generally managed by the central bank – to which all banks must report data about defaults, arrears and amount of credit granted, and from which banks can draw information when granting a loan. The international and historical evidence is consistent with the idea that public credit registers are set up to compensate for the lack of private information-sharing arrangements, having been created mostly where no private credit bureaus existed. Moreover, public registers have been established more frequently in countries with poorer protection of creditor rights, suggesting that they may be in part regarded as 'disciplinary devices' in markets plagued by moral hazard, as our model suggests.

One assumption of our model is that banks can precommit to a given information regime. Once effort has been exerted, banks are tempted to refrain from disclosing information about high-ability borrowers to their competitors

or else to misrepresent them as low-ability types, in order to extract informational rents. However, precommitment by banks is not necessary *as long as* courts or other third parties (such as credit bureaus) can be called upon to verify the content of borrowers' files upon their request and effectively punish deviant banks. In this case, high-ability borrowers who are damaged by the opportunistic behavior of their banks have both the incentive and the opportunity to punish deviant banks.[18] This may be an additional reason why countries with poor law enforcement need public intervention. If courts cannot be relied upon to enforce private agreements, a public system may be more apt to make banks honor their obligation of truthful and timely reporting of credit data, especially if monitored by the central bank.

It should also be noticed that the ability of third parties to verify misreporting by banks may differ depending on the type of data to be reported. For instance, default information is easier to verify than data about borrowers' characteristics – whose assessment is presumably based on 'soft' information. The lower verification costs are likely to make the commitment to share default information more credible than that involving other types of information. This may help to explain why private information-sharing agreements almost always involve the exchange of default data, while other types of information are less frequently shared. Credit bureaus pool 'black information' in all 30 countries where they currently operate and "white information" in only 18 (Jappelli and Pagano, 1999, Table 1).

6. Conclusions

Lenders often exchange information about their clients, either directly or indirectly – via credit bureaus, rating agencies or public credit registers. This can have several effects. First, it helps lenders to spot bad risks and may thereby reduce adverse selection (Pagano and Jappelli, 1993). Second, it can lower the informational rents that banks extract from borrowers and thereby increase entrepreneurs' incentives to perform (Padilla and Pagano, 1997). Finally, when borrowers know that default information is divulged, they have greater incentive to repay, so as to maintain a good reputation with the generality of lenders. In this paper we focus on this 'disciplinary effect', and show how it can correct moral hazard problems.

To highlight this effect, we assume that banks cannot extract informational rents over the course of their relationship with customers, due to perfect ex-ante competition. As a result, when banks share information about their customers'

[18] Banks do not find it privately profitable to report a low-ability borrower as being a high-ability type.

quality the overall interest burden is not reduced further. This eliminates the incentive effect analyzed in Padilla and Pagano (1997), which operates by reducing the hold-up problem due to banks' monopoly power. However, if the exchange of information is limited to defaults, it can still sharpen borrowers' incentives. To avoid being pooled with lower-grade borrowers by outside banks, high-quality borrowers will try harder to avoid default. In response to this lower default rate, they will be charged a lower interest rate.

An interesting implication is that sharing more information than just defaults reduces rather than increases borrowers' incentive to perform. If a high-grade borrower knows that his bank will disclose not only his past defaults but also data about his intrinsic quality, he is assured that in his case other banks will not interpret a default as a sign of low quality. Therefore, his incentive to avoid default will be no greater than if no information were shared.

However, sharing only information about defaults may be too harsh on debtors – it may lead them to over-invest in effort to avoid default. If so, lenders can 'fine-tune' borrowers' incentives to their first-best level by reporting also data about their quality for a randomly chosen set of borrowers.

An important issue that we leave open to future work is whether we can expect the market to lead to the first-best outcome. We conjecture – but do not show formally – that, when an efficient information-sharing arrangement can be designed, competing banks have the incentive to implement it by signing a binding agreement, for fear of losing customers to competitors. However, lack of coordination and problems of enforcement may make such an agreement hard to strike. In this case a mandatory information-sharing system managed by a public agency can increase credit market efficiency. Such systems – public credit registers – are found in many countries, particularly where banks failed to set up private arrangements to exchange credit data.

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