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On the design of a credit agreement with peer monitoring

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Abstract

This paper analyses the optimal design of collective credit agreements with joint responsibility. First, we demonstrate that these agreements can potentially induce peer monitoring, reduce the incidence of strategic default, and enhance the lender's ability to elicit debt repayments. The resulting benefits in terms of extended credit should, however, be weighted against the higher monitoring effort that such agreements impose upon participant borrowers. Second, we show that the relative benefits from peer monitoring are maximized when risks are positively correlated across borrowers, and also when the size of the group is neither too small (due to a ''joint responsibility'', ''cost sharing'', and ''commitment'' effects) nor too large (due to a ''free riding'' effect). Third, we compare among different monitoring structures. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

A major obstacle to growth in poor countries is known to be the lack of access to bank credit, especially in rural areas, where a large majority of individuals do not have adequate collateral to secure a loan. [1] These individuals, largely as a result of the inability of (formal) credit institutions to monitor and enforce loan

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[1] Illustrations on this point abound (see, e.g., Mosley, 1986; Udry, 1990).

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repayments, are forced either to borrow from (informal-sector) and moneylenders at usurious interest rates, [2] or are simply denied access to credit and therefore investment.

This paper focuses on a potential solution to the above problem, namely, on the implementation of ‘‘peer-monitoring’’ contracts by formal credit institutions. In contrast to the standard bilateral (creditor–borrower) debt contracts, such agreements involve, on a collective basis, a group of borrowers without collateral who are linked by a ‘‘joint-responsibility’’ default clause: if any member of the group defaults, other members have to repay her share of the debt, or else the entire group loses access to future refinancing.

Collective credit agreements with joint responsibility have the property of inducing peer monitoring among group members, thereby transferring part of the costly monitoring effort normally incurred by credit institutions onto the borrowers. In practice, the use of peer monitoring arrangements has been extensive, particularly in developing countries. [3] However, results as measured by repayment rates, have been mixed, according to a large number of descriptive and empirical articles on the subject. [4] These articles have inspired various theoretical contributions first by Stiglitz (1990) and Varian (1990), and more recently by Banerjee et al. (1994), Besley and Coate (1995), Conning (1996), Madajewicz (1997), Sadoulet (1997), and Diagne (1998). These papers are also concerned with delegated monitoring, and by the comparison between individual liability with joint liability loans in an economic environment in which monitoring is costly. Yet, neither of these contributions has come close to explicitly analysing how the design of peer monitoring groups — and, in particular, how the distribution of risk within the peer group, the group size, and the different monitoring structures — in the presence of peer monitoring costs, may account for the contrasting evidence on successes and failures. [5] Are successes (or failures) in any way related to the

[2] These rates may exceed 75% a year (see Aleem, 1990; Hoff and Stiglitz, 1990; Siamwalla et al., 1990).

[3] Cuevas (1988) reports about approximately 88,000 group lending associations worldwide which in 1986 lent as much as 380 billion dollars.

[4] See, e.g., Hossain (1988) on the successful Grameen Bank of Bangladesh, Siamwalla et al. (1990) on the successful Bank for Agriculture and Agricultural Cooperatives in Thailand, Thomas (1993) on the very mixed peer group experiments in Latin America, and also the empirical work by Conning (1996) and Madajewicz (1997).

[5] While emphasizing the benefits of delegated monitoring, most articles (except for Besley and Coate, 1995) rule out ex post ‘‘strategic default’’ considerations and focus instead on ex ante moral hazard. But Besley and Coate (1995) does not consider endogenous monitoring incentives, and how these incentives can be affected by *crucial design issues* such as the degree of risk correlation, the optimal size of peer groups, and the optimal ‘‘structure of monitoring’’ within groups. Finally, Banerjee et al. (1994), Sadoulet (1997) and Diagne (1998), while focusing on some different design aspects, do not allow for *costly* monitoring which in turn restricts the scope of their analysis to close knit societies and peer groups of relatively small size.

distribution of risk among participant borrowers? Or to the size of the peer group? Or to the ''structure'' of monitoring?

This paper sheds light on the optimal design of collective agreements with joint responsibility. First, we demonstrate that these agreements can potentially induce peer monitoring, reduce the incidence of strategic default, and enhance the lender's ability to elicit debt repayments. The resulting benefits in terms of extended credit should, however, be weighted against the higher monitoring effort that such agreements impose upon participant borrowers. Second, we show that the relative benefits from peer monitoring are maximized when risks are positively correlated across borrowers, and also when the size of the group is neither too small (due to a ''joint responsibility'', ''cost sharing'', and ''commitment'' effects) nor too large (due to a ''free-riding'' effect). Third, we compare among several monitoring structures.

Borrowers may either be *unable* or *unwilling* to meet their debt obligations. In this paper, we argue that joint responsibility agreements can prevent defaults of the latter kind, namely, ''strategic'' defaults. [6] Our argument relies on two stylized facts. First, relative to commercial banks, borrowers in numerous developing economies have a comparative advantage in monitoring each other, e.g., due to geographical proximity and trade links. Second, those borrowers have access to a superior enforcement technology, in the sense that they can impose social sanctions upon peers who default strategically. These two features provide a rationale for formal credit institutions to engage in group lending, i.e., in collective debt contracting whereby participant borrowers within a group are being held jointly responsible for the group loan. The intuition is simple. Borrowers under joint responsibility lose access to future credit in case the group defaults. They therefore have an incentive to monitor each other, and to enforce debt repayments by threatening to impose social sanctions upon peers who default strategically. Given the comparative advantage that borrowers have with regards to monitoring and loan enforcement, joint-responsibility contracts involve efficiency gains. We will argue that these gains can, however, be mitigated by the existence of *peer monitoring costs*. A number of authors who have written on the subject have assumed away such costs, and this has in turn prevented them from addressing some *crucial* aspects of optimal peer group design.

The remainder of the paper is organized as follows. Section 2 develops the basic model of group lending. Section 3 extends the model to the case where individual project returns are positively or negatively correlated, thereby addressing the issue of the optimal diversification of risks within peer groups. Section 4

[6] The term ''strategic default'' has been used before in the contract theory literature, notably by Bolton and Sharfstein (1990) and Gromb (1994).

focuses on the optimal size of peer groups. Section 5 sheds some light on optimal ‘‘monitoring structures’’, and, finally, Section 6 spells out some concluding remarks.

2. The basic model

Consider a loan contract between two borrowers and a bank. The loan enables each borrower to invest in a one-period project which requires a fixed cost K at the beginning of the period, and yields a random return equal to $\bar{\theta} > 0$ with probability α, and $\underline{\theta} = 0$ with probability $1 - \alpha$ at the end of the period. Each borrower's project has a positive NPV so that $\alpha\bar{\theta} > K$. Project returns are for now assumed to be uncorrelated across borrowers, and each borrower's return realisation is private information unless that borrower is being monitored by a third party. We shall denote by V the value that an individual borrower derives from being able to re-access future refinancing. V is lost if the borrower does not meet her debt repayment obligation. [7]

Assuming that it is prohibitively costly for the bank to directly monitor the borrowers, and assuming that the bank has all the bargaining power at the contracting stage, [8] the maximum repayment, R, that the bank can elicit (from each individual borrower) in the absence of peer monitoring is given by:

$$\bar{\theta} - R + V = \bar{\theta} \tag{1}$$

where the LHS is what a borrower with a high return realisation obtains by repaying, and the RHS is what the borrower obtains by choosing to default

[7] A natural way to interpret the loss of V is as a reputational loss vis-a-vis other lenders. But V could also be interpreted as the loss of future revenues from not being refinanced by the same bank which provided the initial loan. The latter interpretation, however, requires an explicit formalization of at least a second period of production which we do in Appendix A.

[8] As we shall argue below, this assumption involves no major loss of insights; in particular, analysis based on it can easily be reinterpreted in the polar case where the borrowers have all the bargaining power ex ante and therefore seek to maximize their expected utility (equal to their expected revenues net of the debt repayments to the bank minus the expected monitoring cost) subject to the bank's participation constraint. In this paper, we shall implicitly assume that the opportunity cost of bank funds is sufficiently small that the bank's participation constraint is always strictly satisfied. Similarly, unless we explicitly raise the issue, we shall also implicitly assume that the IR-constraint of the borrowers is satisfied. However, it is clear that a rising monitoring effort (e.g., as induced by peer monitoring structures) will tend to push the borrowers up to their participation constraint, so that for plausible parameter values, peer monitoring agreements become infeasible.

strategically. In other words, the highest net expected payoff that the bank can expect on total through 'individual' loan contracts with two borrowers is given by:[9]

$$\Pi_N = -2K + 2V\alpha \tag{2}$$

Now, suppose that, relative to the bank, borrowers have a comparative advantage in monitoring each other, for example, as a result of geographical proximity and/or long-standing trade links. The bank may then contemplate the possibility of inducing peer monitoring between the two borrowers, typically through the introduction of the following joint responsibility clause: each borrower has to repay at least a fraction η of the debt owed by her defaulting peer, or else the two borrowers are excluded from future refinancing with probability β.[10] Peer monitoring, in turn, will help to deter strategic default if, following Besley and Coate (1995), we assume that a borrower who is found by her peer to have strategically defaulted is subject to *social sanctions*.[11] Let W denote the (private) cost that social sanctions impose upon a borrower who defaults strategically.[12]

Fig. 1 below shows the timing of the joint-responsibility model. At the beginning of the period, each borrower obtains K from the bank as part of a

[9] Here, we assume that $V < \bar{\theta}$ so that a borrower with a high return realisation can indeed repay V. [See Appendix A where we endogenize this assumption in the context of a two-period lending model.]

[10] The two variables η and β can a priori take any value between 0 and 1. However, we will show in Lemma 1 that when the unit cost of peer monitoring is sufficiently small, and/or the social sanctions imposed by peers on defaulting borrowers are sufficiently large, then it is optimal for the bank to impose $\eta = \beta = 1$. The high return $\bar{\theta}$ must naturally be sufficiently large in order for $\eta = 1$ to be enforceable, which we implicitly assume throughout the paper. Otherwise, the optimal renegotiation proof η will have to satisfy: $(1+\eta)\bar{R} = \bar{\theta}$, where $\bar{R}$ denotes the repayment obligation which the bank imposes upon each borrower (See [16] below).

[11] This assumption is not straightforward: indeed, ex post why should a borrower ever impose a social sanction on a "friend" or "relative" who has defaulted. I.e., why not renegotiate ex post. Yet, anecdotal evidence suggests that social sanctions are observed in practice. For example, in agricultural cooperatives, social sanctions often involve the exclusion of defaulters from privileged access to input supplies and marketing facilities. One explanation as to why social sanctions are enforced in practice may be the impossibility to keep the information about strategic defaults secret. Another reason may be reputation and credibility. If a borrower that has uncovered strategic default by a peer does not impose social sanctions and instead "colludes" with the defaulter, then that borrower incurs the risk of being himself uncovered and subsequently excluded from peer group lending. Here, we are implicitly assuming that the probability of collusion being made public is positive, and that the borrowers are infinitely risk averse to the risk of being "uncovered".

[12] The social sanction W is taken to be exogeneously given — we think for example of the exclusion of defaulting borrowers from the community or from certain kinds of trade credit and/or input supply facilities. Our focus instead is on the endogeneity of the monitoring probability, i.e., on the probability that a defaulting borrower will be punished.

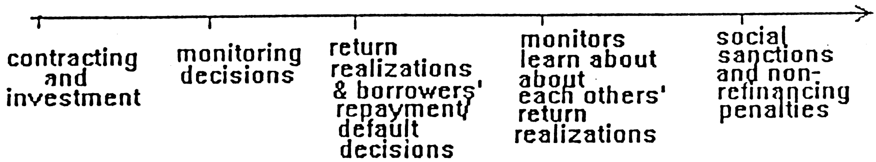

Fig. 1. The timing of the model.

'collective' loan contract offered by the bank. Each borrower then decides whether or not to monitor her peer, and, also, how much monitoring effort to sink in. [13] Then, returns are realised. In case of a high return realisation, a borrower can decide whether or not to strategically default. [She will naturally default for liquidity reasons whenever $\theta = 0$.] Each borrower then learns about her peer's return realisation, and social sanctions are imposed upon borrowers who are found to have strategically defaulted. Finally, all borrowers lose the benefit V of re-accessing the capital market with probability β in case of 'collective' default — that is, whenever the bank loan is not repaid in full. [14]

Let γ denote the probability of monitoring by an individual borrower, which is assumed to be observed by the other borrower, and ρ denote the probability of strategic default by either borrower in a symmetric equilibrium. We shall restrict attention to subgame perfect equilibria where neither of the two borrowers defaults strategically, and then solve the model by straight backward induction. In equilib-

[13] We assume that borrowers commit ex-ante to a given monitoring effort, which is thus irrespective of their own return realisations. Having monitoring decisions which are taken *after* the realisation of returns would complicate the analysis, without adding new insights. In particular, ex post monitoring decisions open the possibility that a borrower monitors her peer when, either her own return realisation is low, or in order to prevent strategic default by her peer, even if she herself decides to strategically default. That is, ex post monitoring would allow for each borrower to better ''free-ride'' on her peers.

[14] In the above timing, borrowers decide whether to repay or default strategically *before* they learn about their peers' return realisations, and *before* they know whether they will be (successfully) monitored. The latter assumption is commonly made in corporate finance models with costly (and random) state verification, and more generally, by the literature on random inspection. The former assumption is logically consistent with the latter: indeed, the only way borrowers can learn about each other's returns is through peer monitoring. Also, we restrict our analysis to symmetric structures where monitoring decisions among the various group members are made simultaneously. [See Armendariz de Aghion (1995) for a variant of this model where repayment decisions are made *after* monitoring has actually taken place.] Finally, in the above timing a borrower observes the monitoring *effort* of her peer *before* making her own repayment decision. One may think of observable sunk investments (such as tools and equipment) being made by peers in the group, and which would commit them to a higher monitoring intensity. This sequentiality between monitoring efforts and repayment decisions turns out to greatly simplify the analysis, however, without affecting any of the qualitative results of the paper.

rium, a borrower with a high return realisation, $\bar{\theta}$, will avoid strategic default whenever:

$$\bar{\theta} - \alpha \bar{R} - (1-\alpha)(1+\eta)\bar{R} + V \geq \bar{\theta} + \alpha V + (1-\alpha)(1-\beta)V - \gamma W \tag{3}$$

On the LHS, a borrower's payoff from not defaulting strategically equals her return $\bar{\theta}$ when she is fortunate, less the repayment, $\bar{R}$, that she must make to the bank when her peer is fortunate and therefore can pay for herself (which occurs with probability α), less the repayment, $(1+\eta)\bar{R}$, that she must make when her peer is unfortunate in order to avoid collective default — the latter situation occurs with probability $1-\alpha$; plus the benefit V of re-accessing future refinancing. On the RHS, the borrower's payoff from defaulting strategically is simply equal to the high return, $\bar{\theta}$, plus the expected value of re-accessing future refinancing, V, which is now only obtained with probability $\alpha + (1-\alpha)(1-\beta)$, i.e., when the other borrower is fortunate, or when she is unfortunate but collective default does not prevent re-access to the capital market [remember that we are looking for a subgame perfect equilibrium where no borrower defaults strategically]; less the social sanctions W which the borrower will incur with probability γ. Thus, in equilibrium, an individual borrower will decide not to default, that is, to set $\rho = 0$, whenever $\gamma \geq \gamma^*(\bar{R})$, where:

$$\gamma^*(\bar{R}) = \frac{-(1-\alpha)\beta V + (1-\alpha)(1+\eta)\bar{R} + \alpha \bar{R}}{W} \tag{4}$$

For given $\bar{R}$, $\gamma^*(\bar{R})$ is decreasing in V, because the higher the expected cost of not being refinanced, the lower the required monitoring effort in order to prevent strategic default. Also, $\gamma^*(\bar{R})$ is decreasing in W, because higher social sanctions imply that the borrower becomes increasingly fearful about her peer discovering that she has strategically defaulted, and, therefore, the lower the required monitoring effort in order to prevent strategic default. However, $\gamma^*(\bar{R})$ is increasing in $\bar{R}$, because the higher the repayment that the bank requests from borrowers in the initial loan contract, the higher a borrower's incentive to strategically default in order to avoid making such a repayment, and, therefore, the higher the required peer monitoring effort to prevent strategic default. [15]

[15] In the above analysis, we focused on the existence of a Nash equilibrium in which none of the borrowers defaults. As pointed out by a referee, this equilibrium is also an equilibrium in dominant strategies. Indeed, if the other borrower defaults, then the same term $\gamma(1-\beta)V$ must be simply subtracted each side of Eq. (3) when analysing a borrower's default decision. □

We now move backward in time, taking as given the fact that both borrowers are being subsequently monitored, and examine a borrower's monitoring decision. The main objective of peer monitoring is to avoid strategic default. Assuming a linear cost of monitoring, equal to $c\gamma$, a borrower will choose a monitoring effort γ either equal to $\gamma^*(\bar{R})$ or to zero depending on whether:

$$\alpha^2\eta\bar{R} + V\left[1-(1-\alpha)^2+(1-\alpha)^2(1-\beta)\right] - c\gamma^*(\bar{R}) \geq V[\alpha+(1-\alpha)(1-\beta)] \tag{5}$$

In words: (a) by monitoring with probability $\gamma^*(\bar{R})$, the borrower ensures that her peer will repay her share of the debt, $\bar{R}$, whenever both borrowers are fortunate — which occurs with probability α^2, therefore, the first borrower avoids having to repay for a successful peer and thereby saves the amount $\alpha^2\eta\bar{R}$; and (b) the borrower obtains the benefit, V, from future refinancing either when at least one of the two borrowers is fortunate [which occurs with probability $1-(1-\alpha)^2$], or with probability $(1-\beta)$ when neither of the two borrowers is fortunate and therefore collective default cannot be avoided [which occurs with probability $(1-\alpha)^2$]. By not monitoring, the borrower can access future refinancing when she is fortunate, or with probability $(1-\beta)$ when she is unfortunate; that is, with overall probability $\alpha+(1-\alpha)(1-\beta)$ — since in this case her peer will default with probability 1.

We now turn to the initial contracting stage where the bank chooses $\bar{R}$ and η in order to maximize net profits. Specifically, the bank's objective function is:

$$\underset{\eta,\bar{R}}{\text{Max}}\left\{-2K+2\bar{R}\left[\alpha^2+\alpha(1-\alpha)(\eta+1)\right]\right\} \tag{6}$$

subject: (a) to $\bar{R} \leq \bar{\theta}$ because of limited liability; (b) to Eq. (4) in order to ensure that the borrowers will not default strategically; (c) to Eq. (5) so as to induce peer monitoring with threshold probability $\gamma^*(\bar{R})$ [a lower monitoring effort would indeed result in the two borrowers defaulting with probability 1 and, therefore, the bank would get a negative payoff equal to $-2K$]; (d) and, of course, to $\eta \leq 1$.

Lemma 1. *It is optimal for the bank to fully punish collective default (i.e., to set $\beta^*=1$) and, also, whenever c/W is sufficiently small, to require full joint responsibility (i.e., to set $\eta^*=1$).*

Proof. First, note that the incentive constraint (5) can be rewritten as follows:

$$\alpha^2\eta\bar{R} + V\beta\alpha(1-\alpha) - c\gamma^*(\bar{R}) \geq 0 \tag{5'}$$

Since $\gamma^*(\bar{R})$ expressed in Eq. (4) above is a decreasing function of the probability β of denying future refinancing to a defaulting group, we immediately obtain that an increase in β relaxes the incentive constraint (5) and thereby allows for a higher repayment schedule $\bar{R}$ to be sustained in equilibrium. Hence, $\beta^* = 1$ at the optimum.

Now, fixing $\beta = \beta^* = 1$, let us derive the optimal ''joint-liability share'' η^*. By substitution of Eq. (4) into Eq. (5), we obtain:

$$\alpha^2\eta\bar{R} + V\left(1-(1-\alpha)^2\right) - \frac{c}{W}\left[-(1-\alpha)V + (1-\alpha)(1+\eta)\bar{R} + \alpha\bar{R}\right] - \alpha V \geq 0 \tag{7}$$

Maximizing the bank's objective function with respect to η subject to Eq. (7), and letting λ denote the corresponding Lagrange multiplier, we obtain:

$$\eta = 1 \Leftrightarrow 2\bar{R}\alpha(1-\alpha) + \lambda\left[\alpha^2\bar{R} - \frac{c}{W}(1-\alpha)\bar{R}\right] \geq 0 \tag{8}$$

In particular, for c/W sufficiently small that $\alpha^2 > c/W(1-\alpha)$, then $\eta^* = 1$. This establishes Lemma 1. □

We now turn to the optimal repayment schedule, $\bar{R}$, chosen by the bank. Substituting for $\eta = 1$ in the incentive constraint (7) and using the fact that this constraint is binding at the optimum, we obtain:

$$\bar{R} = (1-\alpha)V\left[\frac{\alpha W}{c} + 1\right]\frac{1}{2-\alpha-\alpha^2\frac{W}{c}} \tag{9}$$

where the parameter values $(\bar{\theta}, W, c, V, \alpha)$ are implicitly taken to satisfy the inequality $2\bar{R} \leq \bar{\theta}$ so that a borrower can always, when she is fortunate, repay both for herself and for her peer. [16]

[16] In the opposite case where the repayment schedule $\bar{R}$ defined in Eq. (9) lies strictly above $\bar{\theta}/2$, the limited liability constraint $(1+\eta)R \leq \bar{\theta}$ will bind at the optimum. This, together with the incentive constraint (7) which is also binding at the optimum, yields the following value for the maximum feasible repayment that the bank can impose upon each borrower in that case:

$$\bar{\bar{R}} = \frac{\left(\alpha^2 - \frac{c}{W}(1-\alpha)\right)\bar{\theta} + (1-\alpha)V\left(\alpha + \frac{c}{W}\right)}{\alpha\left(\alpha - \frac{c}{W}\right)}$$

Again, for c/W sufficiently small, we have:

$$\Pi_{\mathrm{P}} = -2K + 2\left(1-(1-\alpha)^2\right)\bar{\bar{R}} > \Pi_{\mathrm{N}} = -2K + 2\alpha V$$

where Π_{P} and Π_{N}, respectively, are the bank's optimal payoffs under peer monitoring and non-peer monitoring contracts, so that Proposition 0 remains valid in this case.

The optimal bank's payoff under group-lending and peer-monitoring is then:

$$\Pi_P = -2K + 2\left(1-(1-\alpha)^2\right)\bar{R} \tag{10}$$

which is clearly greater than the maximum achievable payoff, Π_N, under individual lending whenever the ratio W/c is sufficiently large. We have thus established:

Proposition 0. *Group lending with joint responsibility on the borrowers' side strictly dominates individual lending from the bank's point of view whenever the unit cost of peer monitoring is sufficiently low relative to the size of the social sanctions.*

Now, by substituting $\bar{R}$ back into the expression for $\gamma^*(\bar{R})$, we obtain that the equilibrium monitoring effort is:

$$\gamma^* = \frac{(1-\alpha)V\alpha}{c}\,\frac{2}{2-\alpha-\alpha^2\dfrac{W}{c}}. \tag{11}$$

From Eqs. (9) and (11) above, we also obtain the following comparative statics result:

Proposition 1. *The maximum repayment $\bar{R}$ that can be extracted by the bank while inducing peer-monitoring in order to avoid strategic default is: (a) increasing in the borrowers' benefit V from obtaining future refinancing; (b) increasing in the social sanctions W; and (c) decreasing in the peer-monitoring cost c. The equilibrium monitoring effort is an increasing function of the benefit from obtaining future refinancing and of the size of social sanctions; and a decreasing function of the peer-monitoring cost.*

Remark: We have compared between individual lending and group lending under joint responsibility from the standpoint of the bank and ignored the participation constraint of the borrowers — which we have implicitly assumed to be systematically satisfied. However, and as a result of group lending, the monitoring cost incurred by each individual borrower is increased from zero to γ^*.

A borrower's utility under group lending is equal to:

$$U_P = \alpha\left(\alpha(\bar{\theta}-\bar{R}) + (1-\alpha)(\bar{\theta}-2\bar{R})\right) + \left(1-(1-\alpha)^2\right)V - \gamma^* c \tag{12}$$

whereas her utility under individual lending is equal to:

$$U_{\mathrm{N}} = \alpha(\bar{\theta} - V) + \alpha V = \alpha\bar{\theta} \tag{13}$$

Group lending will thus dominate from the standpoint of the borrower if and only if $U_{\mathrm{P}} > U_{\mathrm{N}}$, which is not the case for all parameter values (e.g., when V is small and $(\alpha + \alpha^2(W/c))$ is too close to 2) but which holds when V is sufficiently large and α is small. [17] Then, the borrowers' participation constraint is automatically satisfied. Intuitively, group lending will tend to dominate when V is large first because it increases the probability for each individual borrower to re-access the capital market and thereby obtain V in the second period, second because peer monitoring increases the expected maximum repayment that can be extracted by the bank without inducing strategic default by the individual borrowers. □

3. Correlated risk

Group lending is mostly observed in rural areas where borrowers are often too poor to afford adequate collateral for a loan. Investment returns across borrowers in agriculture, however, are likely to be positively correlated, and this is often perceived as an impediment to the success of rural credit programs (see, for example, Mosley, 1986). In this section, we extend the basic peer-monitoring model of Section 2 to allow for correlated risk.

Let $P = pr(\theta_i = \bar{\theta} | \theta_j = \bar{\theta})$ and $Q = pr(\theta_i = \bar{\theta} | \theta_j = \underline{\theta})$, where θ_i and θ_j, respectively, are the investment returns of borrowers i and j. Then, $P = Q = \alpha$ corresponds to the case where borrowers' investment returns are uncorrelated. This case was analysed in Section 2. $P > \alpha > Q$ (respectively $P < \alpha < Q$) corresponds to the case where investment returns across borrowers are positively (respectively negatively) correlated. In any case, P, Q and α are linked by the equation:

$$\alpha P + (1 - \alpha)Q = \alpha \tag{14}$$

A borrower's decision not to default strategically will now depend upon whether:

$$\bar{\theta} - P\bar{R} - (1 - P)2\bar{R} + V \geq \bar{\theta} + PV - \hat{\gamma}W \tag{15}$$

[17] For example, for $W/c = (2 - \alpha)/(\alpha)$ and for α small, one can easily show that: $\Pi_{\mathrm{P}} > \Pi_{\mathrm{N}}$ for V sufficiently large. □

is satisfied, where $\hat{\gamma}$ denotes the probability of being monitored by a peer. Notice that the inequality (15) is identical to Eq. (3) when $\eta = \beta = 1$, except that the conditional probability of the other borrower being successful is now equal to P rather than α. The corresponding (minimum) required monitoring effort is now:

$$\hat{\gamma}(\bar{R}) = \frac{-(1-P)V + P\bar{R} + (1-P)2\bar{R}}{W} \tag{16}$$

[Note that $\hat{\gamma}$ is an increasing function of P whenever $V < R$. This, in turn, as we shall see below, is automatically satisfied when W/c is sufficiently large, namely, when $W/c > 1/\alpha$.]

Let us now examine the ex-ante monitoring decision. A borrower, say borrower 1, will monitor her peer with the required probability $\hat{\gamma}(\bar{R})$ iff:

$$\alpha P\bar{R} + [\alpha + (1-\alpha)Q]V - c\hat{\gamma}(\bar{R}) \geq \alpha V. \tag{17}$$

In words: by adequately monitoring her peer, borrower 1 prevents borrower 2 from defaulting strategically. This means, first, that borrower 1 will avoid paying $\bar{R}$ for borrower 2 when borrower 2's returns are *also* high, which occurs with probability αP; and, second, that borrower 1 will re-access future refinancing V not only when she is fortunate, but also when she is unfortunate and borrower 2 is fortunate — which occurs with probability $(1-\alpha)Q$. The former consideration dominates when positive realisations of borrowers 1 and 2 are *likely* to coincide. That is, when P is high. Likewise, the latter consideration gains importance when negative realisations for the two borrowers are *unlikely* to coincide. That is, when Q is high. Again, we look for a subgame perfect equilibrium where no borrower defaults strategically.

Moving back to the initial contracting stage, the bank will seek to maximize its expected net repayment subject to: (a) the limited liability constraint ($\bar{R} \leq \bar{\theta}$), and, (b) the incentive-compatibility constraint (17). Substituting for $\hat{\gamma}(\bar{R})$ in Eq. (17) and for Q using Eq. (14) leads to the maximum feasible repayment:

$$\bar{R} = \frac{V\left[\alpha(1-P)\dfrac{W}{c} + 1 - P\right]}{2 - P - \alpha P\dfrac{W}{c}}. \tag{18}$$

Thus, the degree of positive correlation P has an ambiguous effect on $\bar{R}$: on the one hand, a higher P increases the borrowers' incentives to invest the required monitoring effort — since a higher P implies that by monitoring her peer a fortunate borrower will often avoid having to repay the debt of her peer; on the other hand, a higher P increase the borrowers' incentives to strategically default for a given monitoring probability γ. Indeed, a higher P means a higher probability of re-accessing future refinancing for a borrower that defaults strategically, and, therefore, relies on her peer for debt repayment. However, Eq. (18) implies that the latter effect is dominated when W/c is sufficiently large.[18,19]

The expected return to the bank is then simply equal to

$$\Pi_{\mathrm{P}} = [1-(1-\alpha)(1-Q)]2\bar{R}(P) \tag{19}$$

Or, equivalently, and making use of the above Eq. (14):

$$\Pi_{\mathrm{P}} = \alpha(2-P)2\bar{R}(P) \tag{19'}$$

Thus, when the risks on the two projects become *more positively* correlated, i.e., when P increases, the maximum enforceable repayment $\bar{R}(P)$ goes up but at the same time the probability of at least one borrower being insolvent, $\alpha(2-P)$, goes down. Hence, an ambiguous effect of P on the expected bank's return.

The reason why, contrary to the conventional wisdom, a higher degree of positive correlation may sometimes increase the expected return of the bank, is that a higher P increases the incentive to monitor and it therefore enhances the bank's ability to extract revenues from each successful borrower. True, a more positively correlated risk is also ''bad'' from a ''risk diversification'' point of view, but this latter effect tends to be dominated when W/c is large and α is sufficiently close to 1.

Let us now express the equilibrium intensity of monitoring as a function of the primary parameters of the model. Substituting the above expression for $\bar{R}$ back into $\hat{\gamma}(\bar{R})$, we obtain:

$$\hat{\gamma} = \min\left(2\alpha\left(\frac{V}{c}\right)\left(\frac{1-P}{2-P-\alpha\frac{W}{c}P}\right),1\right) \tag{20}$$

[18] To see this, let us re-express Eq. (18) as follows:

$$\bar{R} = V\frac{(1-P)x}{2-Px} = f(P)$$

where $x=\alpha(W/c)+1$. We have:

$$f'(P) \approx x(x-2) = \left(\alpha\frac{W}{c}\right)^2 - 1$$

which is indeed positive for $\alpha(W/c)>1$. That is, for (W/c) sufficiently large. □

[19] Note that the above analysis implicitly assumes that P is *not too close* to 1 so that $2-P-\alpha P(W/c)>0$. Whenever this latter inequality is violated, then $\bar{R}$ is equal to the maximum value consistent with limited liability, namely, $\bar{R}=\bar{\theta}/2$, which in turn is independent of P. In sum, the bank's payoff $\bar{R}$ is a non-decreasing function of the degree of positive correlation between the borrowers' returns. □

That $\hat{\gamma}$ is an ambiguous function of the degree of positive correlation P reflects the two counteracting effects pointed out above, respectively, on a borrower's incentive to monitor her peer (conditionally on not defaulting), and on her incentive to strategically default for a given monitoring effort by her peer. However, it follows from Eq. (20) that, for W/c sufficiently large (namely, for $\alpha(W/c) > 1$) the former effect dominates and, therefore, $\hat{\gamma}$ is a non-decreasing function of the degree of positive correlation P.

We have thus established:

Proposition 2. *For W/c sufficiently large, the peer-monitoring effort $\hat{\gamma}$ in equilibrium is a non-decreasing function of the degree of positive correlation P between the two borrowers' returns. The same is true for the bank's expected pay-off when α is sufficiently close to 1.* [20]

4. Group size

Our analysis thus far has remained restricted to the two-borrower case. In practice, however, peer groups involve up to as many as 15 borrowers, for example, in Thailand, down to as few as five borrowers as in the case of Bangladesh. [21] In this section, we provide a first attempt at analysing the issue of the optimal size of peer groups by extending the basic set-up of Section 2 from two to three borrowers. Unlike in the two-borrower case where peer monitoring is necessarily mutual, the three-borrower case opens the scope for various kinds of monitoring ‘‘structures’’. We will, however, momentarily focus on ‘‘mutual structures’’, whereby each borrower monitors all her peers, and compare between the per-borrower expected payoffs, respectively, in the two- and three-borrower case.

In the three-borrower case, the bank lends a total amount of $3K$ and requests a total repayment $3\bar{R}$. As before, each borrower first decides whether or not to monitor her peers. Second, returns are realised, and, finally, the three borrowers make their repayment decisions. In particular, they decide whether or not to default strategically. In what follows, we shall assume that whenever two borrowers default simultaneously, and the third borrower enjoys a high return realisation,

[20] This result can easily be extended to more general monitoring cost functions, although the condition on W/c becomes more stringent with more convex cost functions.

[21] See Siamwalla et al. (1990) for the former case, and Hossain (1988) for the latter. It appears that the ‘‘optimal’’ group size in each of these two cases was reached after a trial-and-error period. In the case of Bangladesh, the Grameen Bank started with groups of 20 borrowers, and it slowly narrowed that number down to five, at which number it has remained for several years.

the latter borrower can afford to repay for herself and for her two defaulting peers. In particular, when one borrower defaults and the other two borrowers enjoy a high return realisation and do not default, then, each of those two borrowers will honor their own debt obligation plus one half of the debt obligation of the defaulting peer.

As before, we shall reason by backward induction. We examine first a borrower's decision whether or not to default strategically. Borrower 2 will decide against strategic default if and only if:

$$\bar{\theta} - \bar{R}\left[1 - (1-\alpha)^2 - 2\alpha(1-\alpha)\right] - \frac{3}{2}\bar{R}[2\alpha(1-\alpha)] - 3\bar{R}(1-\alpha)^2$$
$$+ V \geq \bar{\theta} + V(1-(1-\alpha)^2 - [1-(1-\gamma_3)(1-\gamma_1)]W \tag{21}$$

where γ_1 denotes the probability that borrower 1 monitors borrower 2, and γ_3 the probability that borrower 3 monitors borrower 2. The LHS of Eq. (21) states that by choosing not to default strategically, borrower 2 obtains $\bar{\theta}$, less the repayment $\bar{R}$ that she has to make when her other two peers are also successful, less the repayment $(3/2)\bar{R}$ that she has to make when *one* of her peers is unfortunate, less the repayment $3\bar{R}$, that she has to make when both of her peers are unfortunate, plus the benefit V from re-accessing future refinancing. On the other hand, by choosing to default strategically, borrower 2 obtains $\bar{\theta}$, plus the benefit from re-accessing future refinancing — which she obtains only when at least one other peer is fortunate, less the social sanctions which are incurred when at least one other borrower, either borrower 1 or borrower 3, monitors the (defaulting) borrower 2. Eq. (21) can be re-written as follows:

$$\bar{\theta} - \alpha\bar{R} - (1-\alpha)2\bar{R} + V \geq \bar{\theta} + V\left(1-(1-\alpha)^2\right) - \Gamma W \tag{22}$$

where $\Gamma = 1 - (1-\gamma_1)(1-\gamma_3)$ is the probability of borrower 2 being monitored by at least one of her peers. Let us now compare between Eqs. (3) and (22). For a given probability Γ of being monitored, the incentive for borrower 2 to strategically default is higher in the three-borrower case than in the two-borrower case, simply because the probability of being refinanced is higher in the former case where there is a large number of peer borrowers who can repay the debt of potential defaulters. This free-riding effect will tend to increase the required monitoring probability, $\Gamma(\bar{R})$, and thus decrease the maximum repayment schedule $\bar{R}$ which is consistent with efficient peer monitoring.

Let us now turn to the monitoring decision by borrower 1. Let $\Gamma(\bar{R})$ denotes the threshold probability of borrower 2 being monitored by at least one of her peers in order for borrower 2 not to default strategically [$\Gamma(\bar{R})$ satisfies Eq. (19) with equality]. Then, given the monitoring effort γ_3 spent by borrower 3 on borrower 2, the minimum required monitoring effort $\gamma_1(\gamma_3)$ that must be spent by borrower 1 on borrower 2 in order to prevent strategic default by borrower 2 must be such that $\Gamma(\bar{R}) = 1-(1-\gamma_1)(1-\gamma_3)$, that is:

$$\gamma_1(\gamma_3) = 1 - \frac{1-\Gamma(\bar{R})}{1-\gamma_3}. \tag{23}$$

Borrower 1's decision to monitor borrower 2 will, in turn, depend upon whether:

$$\bar{R}\epsilon + \alpha(1-\alpha)^2 V \geq c\left[1 - \frac{1-\Gamma(\bar{R})}{1-\gamma_3^{\mathrm{E}}}\right], \tag{24}$$

where $\epsilon - \alpha^2(\alpha + 3/2)$, and γ_3^{E} is the monitoring effort which borrower 3 is *expected* to exert on borrower 2.[22] This condition states that by monitoring borrower 2, borrower 1 will avoid strategic default by borrower 2 and thereby: (a) avoid having to repay for borrower 2 and/or repaying more for borrower 3 when borrower 2's return realisation is high; and (b) re-access future-refinancing when at least one of the three borrowers is fortunate. But borrower 1 has to pay the cost of monitoring borrower 2 which, as we have seen above, is increasing in $\Gamma(\bar{R})$ and decreasing in γ_3^{E}.

Now, subgame perfection implies that γ_3^{E} is the correctly anticipated monitoring effort by borrower 3 in the unique symmetric Nash equilibrium. That is, $\gamma_3^{\mathrm{E}} = \gamma^* = 1 - \sqrt{1-\Gamma(\bar{R})}$.

The maximum repayment $\bar{R}$ that the bank can elicit from each borrower is the one that satisfies condition (24) with equality, namely, after substituting for γ_3^{E}:

$$\bar{R}\epsilon + \alpha(1-\alpha)^2 V = c\left(1 - \sqrt{1-\Gamma(\bar{R})}\right) \tag{25}$$

Comparing the above Eq. (25) with its counterpart in the two-borrower case:

$$\bar{R}\alpha^2 + \alpha(1-\alpha)V = c\gamma^*(\bar{R}) \tag{26}$$

we can immediately single out four effects of increasing the size of peer groups.

1: (a) *A free-riding* effect, captured by the LHS term $\alpha(1-\alpha)^2$ in Eq. (25) (instead of $\alpha(1-\alpha)$ in Eq. (26)): a larger group size discourages individual monitoring effort. Indeed, with a larger number of peer borrowers, there is an increased probability that at least one borrower will be fortunate, and will

[22] When deciding whether or not to monitor borrower 2, borrower 1 does not yet observe the *actual* monitoring effort γ_3 incurred on borrower 2 by borrower 3. Instead, borrower 1 bases her monitoring decision on the *expected* effort γ_3^{E} incurred in equilibrium by borrower 3.

therefore be able to repay for a borrower who defaults strategically. Hence, the reduced incentive for individual borrowers to monitor their peers. This *free-riding* effect already underlined the comparison between the no default conditions (3) and (22). Its unambiguous consequence is to reduce the maximum repayment $\bar{R}$ that the bank can extract from peer borrowers as the size of peer groups increases.

(b) *A joint-responsibility* effect, captured by the term $R\epsilon = R\alpha^2(\alpha + 3/2)$ on the LHS of Eq. (25) (instead of $R\alpha^2$ on the LHS of Eq. (26)). As the group size increases, monitoring a peer not only avoids having to repay for that peer (as in the two-borrower case), but it also avoids having to bear the extra burden imposed by that peer's refusal to pay for insolvent *third* parties (the number of which obviously increases with the size of the group). This joint-responsibility effect will thus counteract the above free-riding effect by encouraging more intense monitoring as the number of borrowers in the group increases.

(c) *A cost sharing effect*, captured by the RHS term $1 - \sqrt{1 - \Gamma}$ in Eq. (25). (Instead of a straight Γ in the RHS of Eq. (26).) This effect tends to increase peer-monitoring effort: as the size of the group becomes larger, the cost of monitoring another borrower becomes smaller, given that such a cost is *shared* among an increasingly large number of peers.

(d) *A commitment effect*, captured by difference between the term $\Gamma(\bar{R})$ in Eq. (25) and $\gamma^*(\bar{R})(< \Gamma(\bar{R}))$ in Eq. (26), which, again, tends to encourage peer monitoring. Namely, as the size of the group increases, each borrower becomes increasingly fearful about strategic default by her peers, since she would have to pay for a larger number of defaulting borrowers.

While the free-riding effect will tend to lower the maximum repayment $\bar{R}$, that the bank can extract from borrowers without discouraging the ''required'' peer monitoring effort, the cost-sharing, joint-responsibility and commitment effects will tend to increase $\bar{R}$.

Now, turning back to the bank's (per borrower) payoff in the three-borrower case, we obtain:

$$\Pi_3 = -K + \bar{R}\left[1 - (1 - \alpha)^3\right] \tag{27}$$

which must be compared with its counterpart in the two-borrower case:

$$\Pi_2 = -K + \bar{R}\left[1 - (1 - \alpha)^2\right] \tag{28}$$

We can immediately see that, *for given* $\bar{R}$, a larger group size will benefit the bank. That is, as the size of the group increases the bank becomes better insured against individual defaults.

The above analysis is summarized in the following:

Proposition 3. *A larger group size tends to increase peer monitoring effort, due to a joint-responsibility, a cost-sharing, and a commitment effects. This, together with the fact that the bank is better insured against individual defaults when the* *number of borrowers in the group increases, tends to make the bank's net payoff per borrower an increasing function of group size. This positive correlation between size and efficiency, however, is mitigated by the fact that a larger group size increases the scope for free riding in debt-repayment decisions.* [23]

5. Monitoring structures

Although in practice the mutual monitoring structure — whereby each borrower in the group is being simultaneously monitored by all of her peers — is commonly observed, other monitoring structures deserve consideration. An interesting departure from the mutual structure is the ''rotating pyramid'' structure in which at every period, a different borrower ''at the top'' of the pyramid monitors her peers ''at the bottom'' of the pyramid. [24]

There are two natural arguments in favor of monitoring structures of the latter kind. One is that it saves on fixed monitoring costs. The other is that it avoids duplication of variable monitoring costs. [Duplication in the mutual structure obviously takes place when the number of borrowers in the group exceeds two.]

As a *first and very tentative* attempt to explore the issue of the optimal design of peer monitoring structures, we shall compare in this section between the mutual (MU) structure and the rotating pyramid (RP) structure with regard to the bank's equilibrium payoff and to the equilibrium monitoring efforts. Consider first the two-borrower case. The MU and RP structures in this case are, respectively, shown in Fig. 2a and b. In the MU structure, the borrowers monitor each other every period. In the RP structure, borrowers take turns in monitoring their peers. In, say, even periods (or rounds), borrower 1 monitors borrower 2, and, in odd rounds, borrower 2 monitors borrower 1.

Let F denote the fixed per-period monitoring cost. [So far, we have implicitly assumed that $F = 0$.] And, let us first consider the RP structure. The upstream borrower, who is not being currently monitored, will choose not to strategically default whenever: [25]

$$\bar{\theta} - \alpha\bar{R} - (1-\alpha)2\bar{R} + V \geq \bar{\theta} + \alpha V - (1-\alpha)\delta F \tag{29}$$

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[23] We have assumed that the high return $\bar{\theta}$ is greater than $3\bar{R}$ so that a fortunate borrower can repay for any number of defaulting peers. This will certainly hold for a non-empty set of parameter values. However, for other parameter values, a fortunate borrower may not be able to repay for, say, more than one defaulting peer. In this case, one can easily show that the free-riding effect will be mitigated. All the qualitative conclusions summarized in Proposition 3 will, however, remain valid.

[24] Structures similar to the rotating pyramid, are indeed observed in several credit cooperatives in Latin America, and also in the Grameen Bank of Bangladesh.

[25] We implicitly assume that the bank cannot make the repayment R_j (by borrower j) contingent upon whether j is at the top or at the bottom of the pyramid, for example, because this is not verifiable by a third party.

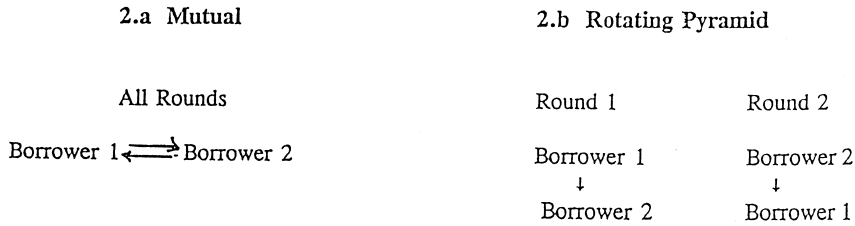

Fig. 2. Monitoring structures.

where the term $-(1-\alpha)\delta F$ on the RHS refers to the ''missed'' opportunity (in case of collective default) of not having the downstream borrower incur the fixed monitoring cost F next period — as should have been the case with probability 1 in the absence of collective default, where $\delta < 1$ is the discount factor.

On the other hand, the downstream borrower will choose not to default whenever:

$$\bar{\theta} - \alpha\bar{R} - (1-\alpha)2\bar{R} + V \geq \bar{\theta} + \alpha V + (1-\alpha)\delta F - \gamma W \tag{30}$$

where the term $+(1-\alpha)\delta F$ on the RHS is what the downstream borrower gains (in case of collective default) by not having to incur the fixed monitoring cost F next period; $-\gamma W$ is the loss in terms of expected social sanctions incurred by the downstream borrower when she is monitored by her upstream peer.

The above inequality (30) implies a minimum required monitoring effort by the upstream borrower equal to:

$$\hat{\gamma} = \frac{-(1-\alpha)V + (1-\alpha)\delta F + (1-\alpha)2\bar{R} + \alpha\bar{R}}{W} \tag{31}$$

which is higher than $\gamma^*(\bar{R})$ in the mutual case due to the new term $(1-\alpha)\delta F$. That is, in the RP structure, the incentive to monitor a peer is higher than in the mutual case as avoiding collective default also implies saving on fixed monitoring costs next period.

Now, the upstream borrower will choose a monitoring effort γ, either equal to $\hat{\gamma}(\bar{R})$, or to zero depending upon whether:

$$\alpha^2\bar{R} + V\left(1-(1-\alpha)^2\right) - c\hat{\gamma}(\bar{R}) - (1-\alpha)^2\delta F - F \geq \alpha V - (1-\alpha)\delta F \tag{32}$$

or, equivalently:

$$\hat{\gamma}(\bar{R}) \leq \frac{\alpha^2\bar{R} + (1-\alpha)\alpha(V+\delta V) - F}{c} \tag{33}$$

i.e.,

$$\bar{R} \leq \frac{1}{2-\alpha-\alpha^2\frac{W}{c}}\left[\left[\frac{(1-\alpha)\alpha(V+\delta F)-F}{c}\right]W\right.$$
$$\left.+(1-\alpha)V-(1-\alpha)\delta F\right]=R_{\mathrm{RP}}. \tag{34}$$

Now, turning to the MU case where the minimum required monitoring effort is $\gamma^*(\bar{R})$ derived in Section 2, any borrower will choose whether or not to incur this effort whenever:

$$\alpha^2 R+V\left(1-(1-\alpha)^2\right)-c\gamma^*(\bar{R})\geq\alpha V \tag{35}$$

that is:

$$\bar{R}\leq\frac{1}{2-\alpha-\alpha^2\frac{W}{c}}\left[\frac{(1-\alpha)\alpha(V-F)W}{c}+(1-\alpha)V\right]=R_{\mathrm{MU}}. \tag{36}$$

Using Eqs. (29) and (34), we see that strategic default will be avoided in the RP case if:

$$\bar{R}\leq\frac{1}{2-\alpha-\alpha^2\frac{W}{c}}\min\left[(1-\alpha)(V+\delta F),\ [(1-\alpha)\alpha(V+\delta F)-F]\frac{W}{c}\right.$$
$$\left.+(1-\alpha)(V-\delta F)\right] \tag{37}$$

where the first term in the bracketed parenthesis is the maximum repayment that the bank can extract without inducing strategic default by the upstream borrower, and the second term is the maximum repayment that the bank can extract without inducing strategic default by the downstream borrower.

Straightforward comparison between Eqs. (36) and (37) shows that the MU structure will always dominate the RP structure when the bank is constrained to set the same repayment scheme $\bar{R}$ for the two borrowers, and seeks to prevent strategic default by *both* borrowers simultaneously. If the bank could discriminate between the two borrowers, it would optimally set

$$\bar{R}_{\mathrm{U}}=\frac{1}{2-\alpha-\alpha^2\frac{W}{c}}(1-\alpha)(V+\delta F) \tag{38}$$

for the upstream borrower, and

$$\overline{R}_{\rm D} = \frac{1}{2-\alpha-\alpha^2\frac{W}{c}}\left[\left[(1-\alpha)\alpha(V+\delta F)-F\right]\frac{W}{c}+(1-\alpha)(V-\delta F)\right] \tag{39}$$

for the downstream borrower. But again, the MU structure would dominate the RP structure since $R_{\rm MU} \geq \overline{R}_{\rm U} + \overline{R}_{\rm D}$ is always satisfied.

Notice, however, that the above analysis has abstracted from individual rationality (IR) considerations. Allowing for the borrowers' IR constraints to be binding at the optimum may actually reverse the above conclusion. For example, suppose that monitoring only involves a fixed cost, but no variable cost $[c=0, F>0]$. Then, the MU structure will be individually rational iff:

$$\mathrm{IR}_{\rm MU}: \overline{\theta} - \alpha\overline{R} - (1-\alpha)2\overline{R} + V - F \geq \overline{U} \tag{40}$$

whereas the RP structure will be individually rational iff:

$$\mathrm{IR}_{\rm RP}: \overline{\theta} - \alpha\overline{R} - (1-\alpha)2\overline{R} + V - \frac{F}{2} \geq \overline{U}. \tag{41}$$

Straightforward inspection of the above inequalities shows that $\mathrm{IR}_{\rm MU}$ is tighter than $\mathrm{IR}_{\rm RP}$, and, thus, the bank is forced to set a lower repayment schedule in the MU case than in the RP case, in order not to violate the borrowers' IR-constraints. The following proposition summarizes our discussion:

Proposition 4. *Abstracting from individual rationality considerations, the MU structure dominates the RP structure. However, when the variable cost of monitoring is small, and the fixed cost of monitoring is large, individual rationality considerations may favor the RP structure over the MU structure.*

Although in practice the MU and RP structures are the most commonly observed structures, other possibilities can be explored. One such possibility is the circular (CI) structure, which is illustrated in Fig. 3, not least because it can potentially avoid duplication of monitoring efforts among borrowers.

In this structure, each borrower monitors (and is monitored) only by one peer and, thus, duplication of monitoring effort is avoided. However, one can show that, relative to the MU structure, the CI structure widens the scope for pair-wise collusion. The intuition is simple. Let us consider the three-borrower case. In the MU structure, pair-wise collusion is very likely to be detected by a third borrower. Now consider the CI structure, and let the return realisations of borrowers 1, 2 and 3, respectively, be $\theta_1 = \overline{\theta}$, $\theta_2 = \underline{\theta}$, and $\theta_3 = \overline{\theta}$. Borrower 1 knows only her own return, and that of borrower 3; and borrower 3 knows only her own return, and that of borrower 1. It is then easy to see that borrowers 2 and 3 can be tempted to

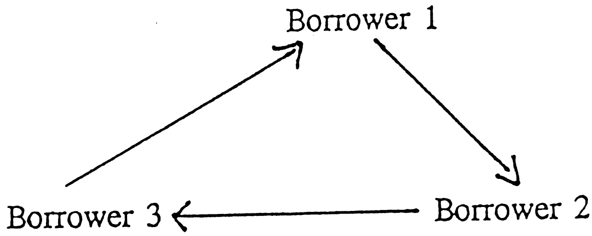

Fig. 3. Circular structure.

collude against borrower 1. [That is, to agree on borrower 3 misreport her return realisation to borrower 1.] By colluding against 1 (whose returns are known by borrower 3), both borrowers 2 and 3 can avoid debt repayments, and thus free-ride on borrower 1. Any positive side-payment from 3 to 2 will sustain such a collusive behavior. [26]

6. Concluding remarks

We have argued that the success of peer monitoring institutions in keeping high repayment rates crucially depends upon the way in which peer groups are designed. We have demonstrated that such institutions may be pursuing excessive risk diversification, and that this may be potentially misleading, as a high degree of positive correlation may actually induce peer monitoring and thereby reduce the incidence of strategic default. Similarly, peer monitoring institutions may have a tendency to favor large groups, mainly on insurance grounds. This too may be potentially misleading, as large groups are more prone to experience free riding on monitoring amongst participant borrowers. Lastly, peer monitoring institutions' restricted attention on the standard mutual structure of monitoring may also be misleading, as other structures such as the rotating pyramid structure are potentially more efficient.

[26] Abstracting from the collusion issue, the comparison between the MU and the CI structures is ambiguous. Indeed, in the CI case a borrower will decide not to default iff: $\bar{\theta} - \bar{R}[1-(1-\alpha)^2 - 2\alpha(1-\alpha)] - 3/2\bar{R}[2\alpha(1-\alpha)] - 3\bar{R}(1-\alpha)^2 + V \geq \bar{\theta} + V(1-\alpha)^2) - \gamma_j W$, where $\gamma_j = \Gamma(\bar{R})$. Then choose $\bar{R}_{CI}$ such that: $\bar{R}\epsilon + \alpha(1-\alpha)^2 V = c\Gamma(\bar{R})$ (where $\epsilon = \alpha^2(\alpha + 3/2)$ as in Eq. (21) above) in the CI case, and compare it with the repayment schedule $\bar{R}_{MU}$ that satisfies: $\bar{R}\epsilon + \alpha(1-\alpha)^2 V \geq c(1 - \sqrt{1-\Gamma(\bar{R})})$ in the MU case. We have: $\bar{R}_{CI} < \bar{R}_{MU}$. But, on the other hand, for a given $\bar{R}$, the CI structure is more likely to satisfy the borrowers' IR-constraint, since it involves any borrower monitoring one rather than two other borrowers. The overall comparison is therefore ambiguous and depends on the tightness of the IR-constraints and also on the size of the *fixed* monitoring cost.

This paper should clearly be seen as no more than a first and modest attempt at analysing important aspects in the design of peer group lending which had not been explored before, namely, risk correlation, group size, and alternative monitoring structures. Thus, the analysis in this paper can be extended in several directions.

A first extension would be to analyse what happens when monitoring costs rise so fast as to make the borrowers' reach their participation constraint and decide against joining a peer group. How does this affect group size and the choice of monitoring structures?

Also, we have assumed throughout that a single borrower can repay the debt of the entire group if need be. In practice, this puts an obvious limit to the effectiveness of large groups, an on joint liability in general. But how important this effect is relative to the other effects of an enlarged group size which were pointed out in Section 3 remains to be formally analysed.

And our analysis of monitoring structures should be extended to the case of more than two borrowers, in a way that would parallel some recent theoretical developments on firms and hierarchies.

Finally, the line of research followed in this paper should aim at delivering policy recommendations, not only on the optimal design of microfinance institutions, but also on the role of donors' agencies. Because peer monitoring institutions lend mainly to poor individuals, such agencies are very keen on helping such institutions, typically by extending 'soft' loans and by providing technical assistance. Our analysis suggests that donor agencies could target aid in two alternative directions. First, peer monitoring costs can be high due to the atomistic nature of rural economies, and these costs may in turn sustain peer groups of very limited size at the expense of insurance benefits. Donor agencies could provide assistance for reducing such costs, in particular, by building adequate infrastructure. Second, donor agencies could stimulate collective learning among peer monitoring institutions operating in different countries through investing in a better communication network.

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Appendix A. Endogenizing the non-refinancing penalty *V*

In this appendix, we provide a straightforward two-period extension of our basic model. There are two production periods, $t=1$ and $t=2$. During each period, a borrower can invest in a one-period risky project with fixed cost K, and random return $\theta \epsilon \{\underline{\theta}=0, \bar{\theta}\}$ at the end of the period. The returns are uncorrelated across periods, and across borrowers. Suppose $\hat{\theta} > K$, where $\hat{\theta} = \alpha\bar{\theta}$ is the expected return of such a project. And suppose that monitoring occurs only in the first period. Then, as in Bolton and Sharfstein (1990), borrowers will always default in the second period. Each defaulting borrower in case of collective default loses access to future refinancing. The corresponding net loss in future expected returns is $\hat{\theta} - K$.

The bank sets $\bar{R}$ at the beginning of each period, and will decide to refinance with probability $\underline{\beta}$ in case of collective default, and refinance with probability $\bar{\beta}$ if both borrowers repay. The timing of the model for each period is the same as the one depicted in Fig. 1, except for the absence of monitoring in period 2.

Again, we solve for a symmetric subgame perfect equilibrium where no borrower defaults, and proceed by backward induction. Each borrower will decide not to strategically default if and only if:

$$\bar{\theta} - \alpha\bar{R} - (1-\alpha)2\bar{R} + \bar{\beta}\hat{\theta} \geq \bar{\theta} + \left(\bar{\beta}\alpha + \underline{\beta}(1-\alpha)\right)\hat{\theta} - \gamma W \tag{A.1}$$

which implies:

$$\gamma^*(\bar{R}) = \frac{-(1-\alpha)\left(\bar{\beta}-\underline{\beta}\right)\hat{\theta} + (1-\alpha)2\bar{R} + \alpha\bar{R}}{W}. \tag{A.2}$$

Then, the bank will set $\bar{R}$ to guarantee the minimum required monitoring effort $\gamma^*(\bar{R})$ by the two borrowers. That is, $\bar{R}$ is chosen so that:

$$\alpha^2\bar{R} + \left(1-(1-\alpha)^2\right)\bar{\beta}\hat{\theta} + (1-\alpha)^2\underline{\beta}\hat{\theta} - c\gamma^*(\bar{R}) \geq \alpha\bar{\beta}\hat{\theta} + (1-\alpha)\underline{\beta}\hat{\theta} \tag{A.3}$$

and by substituting Eq. (A.2) into Eq. (A.3), we obtain:

$$\bar{R} \leq \frac{(1-\alpha)\left(\bar{\beta}-\underline{\beta}\right)\hat{\theta}}{2-\alpha-\alpha^2\dfrac{W}{c}}\left[\frac{\alpha W}{c}+1\right]. \tag{A.4}$$

The bank will then choose $\overline{\beta}$ and $\underline{\beta}$ so as to:

$$\max\left\{-2K+\left[2\frac{(1-\alpha)\left(\overline{\beta}-\underline{\beta}\right)\hat{\theta}}{2-\alpha-\alpha^2\frac{W}{c}}\left[\frac{\alpha W}{c}+1\right]-2\overline{\beta}\left(1-(1-\alpha)^2\right)K\right.\right.$$

$$\left.\left.-2\underline{\beta}(1-\alpha)^2K\right]-\left(1-\alpha\right)^2)\overline{\beta}\hat{\theta}\right\} \qquad (A.5)$$

Thus, whenever:

$$\frac{(1-\alpha)\hat{\theta}}{2-\alpha-\alpha^2\frac{W}{c}}\left[\frac{\alpha W}{c}+1\right]>K \qquad (A.6)$$

which is indeed the case when the ratio W/c is sufficiently large, the bank will set $\overline{\beta}=1$ and $\underline{\beta}=0$ (as in Bolton and Sharfstein, 1990). [27] This in turn implies that the loss $\underline{V}$ incurred by each borrower in case of collective default will simply be equal to $\hat{\theta}$. Note that $\hat{\theta}=V<\overline{\theta}$, in line with the working assumption introduced in footnote 8 above. □

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[27] As shown by Gromb (1994), $\overline{\beta}=0$ may not be renegotiation-proof in the context of an n-period lending model with $n\geq 3$, at least in the absence of any reputational consideration. Extending our peer-monitoring model to $n\geq 3$ lending periods is the subject of future research.

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