ELSEVIER

Journal of Development Economics
Vol. 60 (1999) 27–50

JOURNAL OF Development ECONOMICS

www.elsevier.com/locate/econbase

Group lending, local information and peer selection [1]

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Abstract

This paper analyzes how group lending programs use joint liability to utilize local information that borrowers have about each other's projects through self-selection of group members in the group formation stage. These schemes are shown to lead to positive assortative matching in group formation. Faced with the same contract, this makes the effective cost of borrowing lower to safer borrowers: because they have safer partners, conditional on success their expected dues to the lender are lower than that of riskier borrowers. The resulting improvement in the pool of borrowers is shown to increase repayment rates and welfare. © 1999 Elsevier Science B.V. All rights reserved.

JEL classification: D82; L14; 012; 017
Keywords: Group lending; Local information; Peer selection

1. Introduction

Recent research on rural credit markets in developing countries has focused on imperfect information and transaction costs in the lending process as the key to understand the reported phenomena of high interest rates, market segmentation and credit rationing. [2] This has, led to a greater appreciation of the fundamental disadvantages faced by formal lending institutions (e.g., the commercial banking

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[1] This paper is based on the first chapter of my PhD thesis entitled *Essays on the Economics of Contracts* submitted to Harvard University (June, 1996) that was circulated earlier as the working paper ''Group Lending and the Peer Selection Effect'' (November, 1995).

[2] See Hoff and Stiglitz (1990) for a review of the recent theoretical and empirical literature.

PII: S0304-3878(99)00035-8

sector and government lending agencies) in this market owing to the costliness of screening loan applicants, monitoring borrowers, and writing and enforcing contracts due to imperfections in the judicial system, backward infrastructure (e.g., transport and communication), and low levels of literacy (Besley, 1995). It has also rekindled interest in the role of alternative institutional arrangements, such as group-lending programs, credit cooperatives, and rotating saving and credit associations, to overcome these problems.

In this paper we focus on group-lending programs under which borrowers who cannot offer any collateral are asked to form small groups. Group members are held jointly liable for the debts of each other. [3] Formally speaking, what joint liability does is to make any single borrower's terms of repayment conditional on the repayment performance of other borrowers in a pre-specified and self-selected group of borrowers.

The remarkably successful experience of some recent group-lending programs in terms of loan recovery rates, such as those in Bangladesh, Bolivia, Malawi, Thailand and Zimbabwe, has aroused a lot of interest in replicating them in other countries (Huppi and Feder, 1990). A careful examination of the existing evidence on the relative performance of these programs compared to standard lending programs across different countries yields a mixed picture (Morduch, 1998; Huppi and Feder, 1990). Still, group lending programs where loans were made to homogenous self-selected groups of individuals belonging to the same village and with similar economic standing have tended to be more successful than others (Huppi and Feder, 1990).

We provide a theory based on two contractual features of group lending programs to explain why they can potentially achieve high repayment rates despite the fact that borrowers are not required to put in any collateral: the existence of joint liability and the selection of group members by borrowers themselves. As mentioned above, screening potential loan applicants is a costly activity for the lender. At the same time, borrowers from the same locality are expected to have some information about each other's projects. Therefore, one way of looking at contracts based on self-formed groups is that they are a means of deliberately inducing borrowers to select their group members in a way that exploits this local information.

We use a simple adverse selection model to analyze this issue. In our model the borrowers know each others' types, namely the probability of success of their

[3] See Ghatak and Guinnane (1999) for a discussion of how joint liability works in practice. Credit cooperatives, which differ from group lending programs in that they borrow from outside sources as well as raise deposits from its own members, too often have some degree of joint liability. For example, in German credit cooperatives, which first appeared in the middle of the last century and soon became very successful and influenced cooperative design everywhere else, all members of the cooperative were liable in whole or in part for any loan from an outside source on which a cooperative member defaulted. See Guinnane (1994).

projects, but the outside bank does not. At the same time, collateral cannot be used because of the poverty of the borrowers. This means loans have to be offered to all borrowers at the same nominal interest rate. Then, as in the lemons model of Akerlof (1970), the presence of enough risky borrowers can push the initial equilibrium interest rate high enough to drive the safe borrowers away from the market. We show that the joint liability aspect of group lending programs induces borrowers of the same type group together in equilibrium. Given positive assortative matching in group formation, the *effective* borrowing costs facing risky and safe borrowers are no longer the same. Conditional on success, a risky borrower faces a higher expected borrowing cost than a safe borrower because her partners are more likely to have failed. But this is precisely what a full-information credit contract would like to do — borrowers with riskier projects, because they succeed less often should pay more when they succeed. Facing a more favorable effective rate of interest, safer borrowers are shown to be attracted back into the market. This reduces the equilibrium interest rate, leads to an improvement of the pool of borrowers, and increases the average repayment rate. Also, by attracting in safer and productive projects, which were not initially in the borrower pool as a result of the lemons problem, joint liability improves welfare from the point of view of aggregate social surplus.

Interestingly, even though riskier borrowers are burdened with higher expected joint-liability payments because they have riskier partners, the overall decrease in the interest rate permitted by the entry of safe borrowers maybe significant enough to improve the welfare of all types of borrowers in the pool. Hence we show that by exploiting an intangible resource, namely local information, that is embodied in specific social networks the institution of joint liability based group lending can alleviate credit market failures. Hence, it serves the objectives of both efficiency and equity by helping the poor escape from the trap of poverty by financing small-scale productive projects. [4]

We examine one possible mechanism through which group lending can improve efficiency based on the self-selection of borrower groups and the effect on the *pool* of borrowers. The existing research on the topic, until very recently, has explored other mechanisms focusing mainly on the effect of joint liability on the *behavior* of individual borrowers. [5] Early work by Stiglitz (1990) and Varian (1990) explore how joint liability may induce borrowers in a group to monitor each other, thereby alleviating moral hazard problems. Besley and Coate (1995) address the question how joint-liability contracts affect the willingness to repay. They show how they may induce borrowers to put *peer pressure* on delinquent

[4] For an analysis of how an economy may get stuck in a poverty trap due to credit market imperfections see Banerjee and Newman (1993).

[5] See Ghatak and Guinnane (1999) for a more detailed discussion.

group members, which may lead to an improvement in repayment rates. However, none of these papers with the exception of Varian (1990) examine a crucial feature of these schemes, namely that group members self-select each other. Varian (1990) proposes a model where the bank directly screens loan applicants and joint liability takes the following form: if the member who is interviewed turns out to be a bad risk all group members are denied loans. This induces safe borrowers to undertake the task of screening out bad risks on behalf of the bank. In contrast, we show that joint liability lending can improve efficiency even if there is no *direct* screening so that risky borrowers too can form a group and apply for a loan. Because borrowers are shown to end up with partners of the same type, for the same joint liability contract offered to all borrowers, safer borrowers face lower expected borrowing costs conditional on success.

Apart from the current paper, a number of recent papers have studied various roles group lending can play in alleviating adverse selection problems in rural credit markets. Among them, Van Tassel (1999) has analyzed group lending in a similar informational environment and has obtained some similar results on its effect on the formation of groups and repayment rates. However, our papers differ in terms of the model in several respects. For example, we allow for a general distribution of borrower types and arbitrary group sizes, while Van Tassel allows for variable loan sizes. Armendariz de Aghion and Gollier (1998) is another paper that looks at a similar environment and shows that joint liability can improve the pool of borrowers if borrowers have perfect knowledge of their partners. However, their paper does not formalize the group formation game. Also, it does not explore the optimal degree of joint liability (by assuming full joint liability) or the welfare implications of group lending. On the other hand, their paper, and more recently that of Laffont and N'Guessan (1999), address a question we do not consider at all — namely, whether group lending can improve efficiency in environments with adverse selection where borrowers do not necessarily have better information about each other.

2. The economic environment

We take a simple version of the standard model of a credit market with adverse selection.[6] Everyone lives for one period. Borrowers are risk neutral and are endowed with a risky investment project that needs one unit of capital and one unit of labor. There is no moral hazard and agents supply labor to the project inelastically. But they have no initial wealth and need to borrow the required amount of capital to launch their project.

[6] See Stiglitz and Weiss (1981).

A borrower is characterized by the probability of success of her project, $p \in [\underline{p}, 1]$ where $\underline{p} > 0$. The *return* of a project of a borrower of type p is a random variable $\tilde{y}$ which takes two values, $R(p) > 0$ if successful, and 0 if it fails for all $p \in [\underline{p}, 1]$. The *outcome* of a project is binary random variable, $x \in \{S, F\}$ where S denotes 'success' and F denotes 'failure'. The outcomes of the projects are assumed to be independently distributed for the same types as well as across different types.[7] Borrowers of all types have an exogenously given reservation payoff u which can be thought of as the market wage rate.

We assume that the type of a borrower is private information so that lenders cannot distinguish between different types of borrowers. However, borrowers know each other's types. This informational environment is fundamental to our model and it may be helpful to think of lenders as institutions 'external' to the village (e.g., city-based) whereas borrowers are all residents of the same village. The outcome of a project, i.e., whether it has succeeded or failed, is costlessly observable by the bank and is verifiable as well. But the return of a project, i.e., how much it yields if successful, is not observed by the bank. Hence, lenders can use only outcome-contingent contracts such as debt contracts and not return-contingent contracts, such as equity.[8] Borrowers have no wealth they can offer as collateral and moreover non-monetary punishments are ruled out by a limited-liability constraint. We assume that enforcement costs are negligible — once the bank receives the verifiable signal that a borrower's project has been successful, the borrower cannot default.[9]

We are going to focus on two types of credit contracts in this environment: *individual-liability contracts* and *joint-liability contracts*. The former is a standard debt contract between a borrower and the bank with a fixed repayment r in the non-bankruptcy state (here $x = S$), and maximum recovery of debt in the bankruptcy state $(x = F)$ which happens to be 0 in our model. The latter involves asking the borrowers to form groups of a certain size, and stipulating an individual liability component r, and a joint liability component, c. As in standard debt contracts, if the project of a borrower fails then owing to the limited-liability constraint, she pays nothing to the bank. But if a borrower's project is successful, then apart from repaying her own debt to the bank, r, she has to pay an additional

[7] Elsewhere (Ghatak, 1999) we study the implications of relaxing this assumption.

[8] In Ghatak and Guinnane (1999), we show how this could be derived from an underlying costly state verification model (Townsend, 1979).

[9] The problem of enforcement is undoubtedly of great practical importancein lending to the poor (because of limited sanctions against strategic default), and existing research (e.g., Besley and Coate, 1995) has shown how group lending may alleviate this problem. We make this assumption to focus on the effect of joint liability on the selection of borrowers which is admittedly only one of several possible channels through which group lending can improve repayment rates, but one which has been largely neglected in the literature so far.

joint-liability payment, c, per member of her group whose projects have failed. Thus, unlike standard debt contracts, repayment is not fixed in non-bankruptcy states: it is contingent on the project outcomes of a pre-specified set of other borrowers. [10]

We model the lending side of the credit market as one where there is a single risk neutral bank that chooses the terms of the loans in order to maximize expected aggregate surplus subject to a zero profit constraint and the relevant informational constraints. As a social welfare function, expected aggregate surplus can be interpreted as the ex ante expected utility of the borrower before she knows her type. [11]

The bank can be thought of as a public lending institution or a non-governmental organization (NGO) which is most often the case for observed group lending schemes. We assume that the bank faces a perfectly elastic supply of funds from depositors at the safe rate of interest, ρ.

We model group lending as the following sequential game: first, the bank offers a contract specifying the interest rate, r, and the amount of joint liability, c, to the borrowers; second, borrowers who wish to accept the contract select their partners; finally, projects are carried out and outcome-contingent transfers as specified in the contract are met. Borrowers who choose not to borrow enjoy their reservation payoff of u.

3. Equilibrium in the group formation game

In this section we study the group formation game under group lending. For simplicity of exposition we consider groups of size 2 in the paper. In Appendix A, we show how all our results generalize to groups of any size $n \geq 2$.

We require the equilibrium in the group formation game to satisfy the *optimal sorting property* (Becker, 1993): borrowers not in the same group should not be able to form a group without making at least one of them worse off. [12] Our main

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[10] While there are some similarities between standard debt contracts with a *cosigner* and joint-liability contracts used in group-lending, there are two important differences: in the latter case the partner who can be viewed as a *cosigner* does not have to be an individual who is known to the bank and/or owns some assets, and all members of the group can be borrowers as well as co-signors on each other's loans at the same time.

[11] Changes in social welfare can be measured by changes in aggregate surplus for *any* social welfare function when preferences are quasi-linear so long as the planner can make lump sum transfers. Although borrowers are risk-neutral in our context and hence their preferences are quasi-linear, since there is private information, lump sum transfers across borrower types are not feasible. Hence, aggregate expected surplus is no longer a valid welfare measure for *any* social welfare function.

[12] The size of a group that qualifies for a loan under a group lending program is fixed by institutional design. In game theoretic terms, an assignment satisfying the optimal sorting property is in the core given this restriction on the size of possible coalitions.

result is that for any given joint-liability credit contract (r,c) offered by the bank in the first stage, borrowers will choose partners of the same type in the second stage.

Consider a borrower with probability of success p. The expected payoff of this borrower under a given joint-liability contract (r,c) when her partner has probability of success p' is:

$$\begin{aligned}\mathrm{EU}_{p,p'}(r,c) &= pp'(R(p)-r)+p(1-p')(R(p)-r-c).\\ &= pR(p)-\{rp+cp(1-p')\}.\end{aligned}$$

We establish the following important property of joint liability:

Lemma 1: *A borrower of any type prefers a safer partner, but the safer the borrower herself, the more she values a safer partner.*

Proof: The difference in the expected payoff of a borrower of type p from having a partner who has probability of success p' instead of p'' is

$$\mathrm{EU}_{p,p'}(r,c)-\mathrm{EU}_{p,p''}(r,c)=cp(p'-p''). \tag{1}$$

Suppose $p' > p''$. In choosing between two potential partners with different probabilities of success p' and p'', any borrower will be willing to pay a strictly positive amount to have the borrower whose probability of success is p'. But the maximum amount a borrower of type p is willing to pay to have a partner of type p' over a partner of type p'', $cp(p'-p'')$, is increasing in her *own* probability of success. ■

The intuition is as follows: conditional on her own project being successful, the maximum amount a borrower of any type would be willing to pay to have a partner who is safer than her existing partner is the amount of joint liability times the difference in the respective probabilities of not defaulting. [13] But this expected gain from having a safer partner is realized only when the borrower herself is successful, and hence is higher the safer her type.

Let us assume that the population of borrowers is balanced with respect to group size, i.e., there are $2N(p)$ borrowers of each type p, where $N(p)$ is a positive integer. This ensures that any borrower can always find another borrower

[13] Since we assume borrowers have no wealth that can be used as collateral, when we talk about side payments among borrowers, we mean that these transfers take forms that are not feasible with the bank. For example, borrowers within a social network can make transfers to each other in ways that are not possible with an outsider (namely, the bank), such as providing free labor services, or writing contracts based on the output (as opposed to outcome) of their projects.

of the same type to form a group. In this case, we prove the following result regarding the equilibrium in the group formation stage:

Proposition 1: *If the population of borrowers is balanced with respect to group size, the unique assignment satisfying the optimal sorting property under group-lending schemes based on joint liability is one where all borrowers in a given group have the same probability of success.*

Proof: Start with the assignment where all groups are perfectly homogeneous. Consider the possibility that a risky borrower might try to induce a safe borrower to be her partner by offering a side payment. By Lemma 1, the expected gain to a borrower of type p' from leaving a partner of the same type and having a partner of type p where $p' < p$, namely, $cp'(p - p')$, is less than the expected loss to a borrower of type p from leaving a partner of the same type and having a partner of type p',namely, $cp(p - p')$. Hence, a mutually profitable transfer from a borrower of a riskier type to a borrower of a safer type to induce the latter to form a group with the former does not exist and the initial assignment satisfies the optimal sorting property.

Conversely, start with an assignment where all groups are not perfectly homogeneous and suppose it satisfies the optimal sorting property. Within the set of all mixed groups, consider the subset of groups which have one borrower of the highest type, namely, 1. Since the population of borrowers is balanced with respect to group size, for every borrower of type 1 in a mixed group with a partner of type $p < 1$, there will be another borrower of type 1 in a mixed group with a partner of type $p' < 1$. By Lemma 1, if the two borrowers of type 1 leave their existing partners and match together, their existing partners will not find it profitable to induce them to remain by offering side payments. Repeating this argument within the set of all remaining mixed groups iteratively, we complete the proof that only perfectly homogeneous groups satisfy the optimal sorting property. ■

Intuitively, because a borrower with a high probability of success place the highest value on having a partner with a high probability of success, they bid the most for these borrowers. As a result, borrowers of the same probability of success are matched together, just as partners of similar quality of are matched together in Becker's marriage model or to take a more recent example, workers of the same skill are matched together in firms when they have Kremer's O-Ring production function. [14] The underlying force driving the positive assortative matching result is also similar in these models: the types of agents are complementary in the payoff functions. [15]

[14] See Becker (1993), Chap. 4, and Kremer (1993).

[15] For example, in our model $(\partial^2 \mathrm{EU}_{p,p'}(r,c))/(\partial p \partial p') = c > 0$.

Notice that our proof uses only the fact that borrowers have different probabilities of success and does not depend on whether safe and risky borrowers have the same or different expected project returns (i.e., we make no assumptions about $R(p)$). In Appendix A we show that it also does not depend on whether borrowers have some wealth or not. However, if the population distribution of borrowers is not balanced with respect to group size that requires some modifications to this result. In Appendix A we analyze this case.

4. Credit market equilibrium with adverse selection

Let us assume now that there is a continuum of borrowers with probability of success $p \in [\underline{p},1]$ where $\underline{p} > 0$ following the continuously differentiable density function of the probability of success $g(p)$. The corresponding distribution function is denoted by $G(p) \equiv \int_{\underline{p}}^{p} g(s)\mathrm{d}s$ for $p \in [\underline{p},1]$. The size of the total population of borrowers in the village is normalized to unity.

Following Stiglitz and Weiss (1981) we assume that projects have the same mean and differ only in terms of riskiness (in the sense of second-order stochastic dominance): [16]

$$pR(p) = R \text{ for all } p \in [\underline{p},1] \qquad \textbf{Assumption 1}$$

We assume that the projects of borrowers are socially productive in terms of expected returns given the opportunity costs of labor and capital:

$$R > \rho + u. \qquad \textbf{Assumption 2}$$

4.1. Lending with individual liability

We model lending with individual liability as the following sequential game: the bank moves first and announces an interest rate, r. Borrowers who wish to borrow at the interest rate r do so, projects are carried out and outcome-contingent transfers as specified in the contract are met. Borrowers who choose not to borrow enjoy their reservation payoff of u.

As a benchmark, consider the case where the bank has full information about a borrower's type. It can then offer loan contracts under which a borrower whose probability of success is p pays the 'full-information interest rate' $r = \rho/p$ when her project succeeds, and nothing otherwise (by limited liability). Since safe borrowers repay their loan more often they are charged a lower interest rate than risky types. Given this contract, the bank earns zero expected profit per loan, all

[16] Elsewhere (Ghatak, 1999) we study the implications of relaxing this assumption on the distribution of project returns.

types of borrowers borrow in the second stage and hence aggregate expected surplus is maximized.

If the bank cannot identify a borrower's type then charging separate interest rates to different types of borrowers would not work. A risky borrower would have an incentive to pretend to be a safe borrower and pay a lower interest rate, but the bank would not be able to break even if all types of borrowers borrow at that rate. It, therefore, has to offer the same interest rate to all borrowers given the absence of collateral or any other screening instrument in our environment. The expected payoff to borrower of type p when the interest rate is r is $\mathrm{EU}_p(r) = R - rp,\ p \in [\underline{p},1]$.

Let $\hat{p}$ denote the probability of success of the marginal borrower, i.e., one who is indifferent between borrowing and not. Under lending with individual liability, at the interest rate r the marginal borrower has a probability of success given by:

$$\hat{p} = \frac{R-u}{r}. \tag{2}$$

It follows that

$$\frac{\mathrm{d}\hat{p}}{\mathrm{d}r} = -\frac{R-u}{r^2} < 0. \tag{3}$$

Intuitively, borrowers who strictly prefer to borrow at the interest rate r must have $R - pr > u$ or, $p < \hat{p}$. That is, they are riskier than the marginal borrower. This is a consequence of the fact under a debt contract borrowers of all types pay nothing if the project fails and pay the same nominal interest rate r when their project is successful. As a result, riskier borrowers face a lower expected interest rate and so an increase in r always reduces $\hat{p}$.

Let $\tilde{p}$ denote the average probability of success in the pool of borrowers who choose to borrow at the interest rate r. In this case:

$$\tilde{p} = \frac{\int_{\underline{p}}^{\hat{p}} sg(s)\mathrm{d}s}{G(\hat{p})} \tag{4}$$

Since all borrowers who strictly prefer to borrow at the interest rate r are riskier than the marginal borrower,

$$\hat{p} > \tilde{p}. \tag{5}$$

Moreover, differentiating Eq. (4) with respect to r and using Eqs. (3) and (5) we get:

$$\frac{\mathrm{d}\tilde{p}}{\mathrm{d}r} = \frac{\hat{p}g(\hat{p})}{G(\hat{p})}\left(1 - \frac{\tilde{p}}{\hat{p}}\right)\frac{\mathrm{d}\hat{p}}{\mathrm{d}r} < 0$$

i.e., an increase in the interest rate reduces the *average* probability of success in the pool of borrowers.

The bank's objective is to choose an interest rate that maximizes expected aggregate surplus subject to the constraint that its expected profit per loan is zero. Since the bank's profits are negative for $r < 0$, we will restrict our attention to non-negative values of r. If it offers an interest rate r in the first stage, it anticipates an average probability of repayment of $\tilde{p}$ per loan given the expected pool of borrowers in the second period. The equilibrium of the lending game with individual liability contracts is an interest rate r^* which is the outcome of the bank's optimization problem:

$$\max_{r \geq 0} \int_{\underline{p}}^{\hat{p}} (R - rs) g(s) \mathrm{d}s$$

$$\text{s.t. } r\tilde{p} - \rho = 0.$$

Let $V(r) \equiv \int_{\underline{p}}^{\hat{p}} (R - rs)\ g(s)\mathrm{d}s = (R - r\tilde{p})G(\hat{p})$ and $\pi(r) \equiv r\tilde{p} - \rho$. Substituting $r\tilde{p} = \rho$ from the zero profit condition into the bank's objective function we get $V(r) \equiv (R - \rho)G(\hat{p})$. As a result, the bank's optimization problem can be reformulated as one where it chooses the minimum possible value of r (which ensures the maximum possible level of $\hat{p}$ and hence $V(r)$) subject to the zero profit condition:

$$r^* = \min\{r \geq 0 : \pi(r) = 0\}$$

Therefore, by definition

$$\pi(r^*) = 0. \tag{6}$$

Let $\hat{p}^*$ and $\tilde{p}^*$ denote the probability of success of the marginal borrower and the average probability of success of the borrower pool at $r = r^*$. Let μ denote the unconditional mean of the probability of success in the borrower population:

$$\mu \equiv \int_{\underline{p}}^{1} s g(s) \mathrm{d}s.$$

Now we are ready to prove:

Proposition 2: *An equilibrium interest rate r^* exists and is unique under lending with individual liability for all parameter values satisfying Assumptions 1 and 2. If in addition $\rho > (R - u)\mu$, then individual liability achieves a lower level of expected repayment rate and aggregate surplus compared to full information. However, for $\rho \leq (R - u)\mu$ individual liability achieves the same expected repayment rate and aggregate surplus as under full information.*

Proof: If the bank charges the interest rate $r' = (R-u)/\underline{p}$ then only borrowers with the lowest probability of success will be willing to borrow. Now

$$\lim_{r \to r'} \pi(r) = r' \lim_{r \to r'} \tilde{p} - \rho$$

$$= r' \lim_{\hat{p} \to \underline{p}} \frac{\int_{\underline{p}}^{\hat{p}} s g(s) \mathrm{d}s}{G(\hat{p})} - \rho$$

Applying L'Hopital's rule we have $\lim_{\hat{p} \to \underline{p}}((\int_{\underline{p}}^{\hat{p}} sg(s)\mathrm{d}s)/(G(\hat{p}))) = \underline{p}$. Hence, $\lim_{r \to r'} \pi(r) = r'\underline{p} - \rho = R - u - \rho > 0$ by Assumption 2. Also, for $r > r'$, no one borrows so that $V(r) = 0$ and the zero profit condition is satisfied trivially. On the other hand, $\lim_{r \to 0} \pi(r) = -\rho < 0$. Since $\pi(r)$ is continuous in r (which follows from the fact that $g(p)$ and $\hat{p}$ are continuous functions) there exists at least one value of $r \in (0, r')$ and correspondingly $\hat{p} \in (\underline{p}, 1)$ such that $\pi(r) = 0$. By the continuity of $\pi(r)$, the set of values r satisfying $\pi(r) = 0$ is closed and bounded and so $r^* = \min\{r \geq 0\colon\ \pi(r) = 0\}$ exists and is unique. Since all borrowers of type $p < \hat{p}^*$ borrow at this interest rate and so $V(r^*) > 0$. Hence, an equilibrium exists and is unique.

Since $\pi(0) < 0$, and by definition r^* is the lowest value of $r \in [0, r']$ satisfying $\pi(r) = 0$, it must be the case the expected profit of the bank should be positively sloped with respect to r at $r = r^*$. That is, using Eqs. (2) and (4), and the zero-profit condition (which yields $\tilde{p}^* = \rho/r^*$):

$$\pi'(r^*) = \tilde{p}^* + r^* \left.\frac{\mathrm{d}\tilde{p}}{\mathrm{d}r}\right|_{r=r^*}$$

$$= \tilde{p}^* \left[1 - \frac{\hat{p}^* g(\hat{p}^*)}{G(\hat{p}^*)} \frac{(R-u-\rho)}{\rho}\right] > 0 \tag{7}$$

where $\pi'(r) \equiv \mathrm{d}\pi(r)/\mathrm{d}r$. We are ruling out the degenerate case where $\pi(r)$ is tangent to the horizontal axis at $r = r^*$, i.e., the possibility that $\pi'(r^*) = 0$. If condition (7) is not satisfied, the bank can cut the interest rate which will attract in more safe borrowers (thereby raising aggregate expected surplus) and make positive profits, which is inconsistent with equilibrium. Together, the conditions (6) and (7) completely characterize the equilibrium under lending with individual liability.

Notice that if $\pi(r) > 0$ for $r = R - u$, then $\hat{p} = 1$. In that case, in equilibrium, r will go down such that $\pi(r) = 0$ and $\hat{p}$ will continue to remain at 1. In this case, the equilibrium under individual lending will achieve the first-best. On the other hand if $\pi(R-u) = (R-u)\mu - \rho < 0$ then $\hat{p}^* < 1$ and $\tilde{p} < \mu$ and the expected repayment rate and aggregate surplus will be less than their first-best levels. ■

If borrowing costs are low relative to project returns less of labor costs, the problem of adverse selection does not bind and the expected repayment rate and aggregate surplus under individual liability lending are at their first-best levels. However, safe borrowers cross-subsidize risky borrowers and hence are worse off compared to a full information environment. In such a situation, there will be no reason to explore alternative mechanisms to improve efficiency, such as group lending. However, if borrowing costs are relatively high, then some socially profitable projects will not be carried out in equilibrium because of the informational problem. Hence, repayment rates and social surplus will be lower than under full information. [17] This brings us to Section 4.2 where we consider whether group lending schemes based on joint liability can achieve an improvement in such a situation.

4.2. Lending with joint liability

The bank's objective is to choose a joint liability contract (r,c) that maximizes expected aggregate surplus subject to the constraint that its expected profit per loan must be zero. There is an additional constraint that needs to be taken into account in this case: since borrowers do not have any wealth by assumption, the sum of individual and joint liability payments, $r+c$, cannot exceed the realized revenue from the project when it succeeds for all types of borrowers that choose to borrow under that contract. [18] Formally, there is a *limited liability constraint* that requires:

$$r + c \leq R(p) \text{ for all } p \leq \hat{p}$$

Since $pR(p) = R$ by Assumption 1, $R(p)$ is decreasing in p. Hence this condition will be satisfied if

$$r + c \leq R(\hat{p}) \tag{8}$$

where $\hat{p}$ is the probability of success of the marginal borrower.

[17] This is the well-known under-investment result of Stiglitz and Weiss (1981) in credit markets with adverse selection. Notice that we abstract from the possibility of equilibrium credit rationing, another important result in the literature, by assuming a perfectly elastic supply of loanable funds at the given safe rate of interest ρ. The bank chooses a unique r^* corresponding to ρ and at that value of r the supply of loans is perfectly elastic and so the demand for loans at r^* equal to $G(p(r^*))$ can be fully satisfied.

[18] This constraint appears under lending with individual liability as well, since the bank cannot receive transfers from a borrower if her project fails.

For any joint liability contract (r,c) offered in the first stage by the bank, by Proposition 1, the payoff of a borrower whose probability of success is p can be written as

$$\mathrm{EU}_{p,p}(r,c) = R - rp - c(1-p)p.$$

For the marginal borrower now we have:

$$R - \{r\hat{p} + c\hat{p}(1-\hat{p})\} = u \tag{9}$$

Solving r from the indifference condition of the marginal borrower, we get:

$$r = \frac{R-u}{\hat{p}} - c(1-\hat{p}) \tag{10}$$

The equilibrium of the group lending game with joint liability is an interest rate r^{**} and an amount of joint liability c^{**} that solves the bank's optimization problem:

$$\max_{r \geq 0, c \geq 0} V(r,c) = \int_{\underline{p}}^{\hat{p}} (R - rs - c(1-s)s) g(s) \mathrm{d}s$$

subject to the new zero-profit condition:

$$r\frac{\int_{\underline{p}}^{\hat{p}} sg(s)\mathrm{d}s}{G(\hat{p})} + c\frac{\int_{\underline{p}}^{\hat{p}} s(1-s)g(s)\mathrm{d}s}{G(\hat{p})} - \rho = 0 \tag{11}$$

and the limited liability constraint (8). Again, substituting the zero profit condition into the bank's objective function, we get $V(r,c) \equiv (R-\rho)G(\hat{p}(r,c))$. Hence the bank's optimization problem can be reformulated as one where it chooses (r,c) so as to achieve the maximum possible level of $\hat{p}$ subject to the zero profit condition and the limited liability constraint. Substituting Eq. (10) in the zero-profit condition and simplifying, we get

$$\left(\frac{R-u}{\hat{p}}\right)\frac{\int_{\underline{p}}^{\hat{p}} sg(s)\mathrm{d}s}{G(\hat{p})} + c\frac{\int_{\underline{p}}^{\hat{p}} s(\hat{p}-s)g(s)\mathrm{d}s}{G(\hat{p})} - \rho = 0. \tag{12}$$

Also, using Assumption 1 and Eq. (10) the limited liability constraint (8) reduces to

$$c \leq \frac{u}{\hat{p}^2}. \tag{13}$$

The bank's optimization problem in this case is to choose a value of c such that $\hat{p}$ is as high as possible subject to Eqs. (12) and (13). Given the values of c and $\hat{p}$, the value of r is determined by the condition (10).

Proposition 3: *An equilibrium* (r^{**}, c^{**}) *exists under lending with joint liability with* $c^{**} > 0$ *for all parameter values satisfying Assumptions 1 and 2. If* $\rho > (R - u)\mu$ *the equilibrium with joint liability is unique and the average repayment rate and aggregate expected surplus are both strictly higher relative to the equilibrium with individual liability. If in addition* $R\mu - u(\sigma^2 + \mu^2) \geq \rho > (R - u)\mu$ *joint liability achieves the same repayment rate and aggregate expected surplus as under full information.*

Proof: First we consider the case where $\rho > (R - u)\mu$ so that individual liability lending does not achieve the first best.

For $c = 0$, the analysis of the previous section applies and $\hat{p} = p^*$ is the highest value of $\hat{p}$ that satisfies Eq. (12) by Proposition 2. Notice that for $\hat{p} = 1$, $\int_{\underline{p}}^{\hat{p}} s(\hat{p} - s)g(s)\mathrm{d}s / G(\hat{p}) = \int_{\underline{p}}^{1} s(1 - s)g(s)\mathrm{d}s = \mu - (\sigma^2 + \mu^2) > 0$ where σ^2 is the (unconditional) variance of p. Then consider the value of $c = c' \equiv \rho - (R - u)\mu/\mu - (\sigma^2 + \mu^2)$. It is readily checked that c' and $\hat{p} = 1$ satisfy Eq. (12). We need to check if c' satisfies Eq. (13). This requires

$$\rho \leq R\mu - u(\sigma^2 + \mu^2).$$

We are considering the case $\rho > R\mu - u\mu$ here. Also $\int_{\underline{p}}^{1} s(1 - s)g(s)\mathrm{d}s = \mu - (\sigma^2 + \mu^2) > 0$. So $R\mu - u(\sigma^2 + \mu^2) > R\mu - u\mu$ and there exist parameter values that satisfy both $\rho > R\mu - u\mu$ and the above condition. For such parameter values, the unique equilibrium under lending with joint liability is $c^{**} = c'$, $\hat{p}^{**} = 1$ and from Eq. (10), $r^{**} = R - u$. This achieves the same repayment rate and aggregate surplus as under full information.

However, if $\rho > R\mu - u(\sigma^2 + \mu^2)$, then an equilibrium, if it exists, must involve $0 \leq c < c'$. We show that $c = 0$ cannot be an equilibrium. Totally differentiating the zero profit condition (12) with respect to c we get

$$\frac{\partial \hat{p}}{\partial c} = \frac{-\int_{\underline{p}}^{\hat{p}} s(\hat{p} - s)g(s)\mathrm{d}s}{-\frac{R-u}{\hat{p}^2}\tilde{p}\left[1 - \frac{\hat{p}g(\hat{p})}{G(\hat{p})}\left(\frac{\hat{p}}{\tilde{p}} - 1\right)\right] + \frac{c}{\hat{p}}\left[\frac{\hat{p}\int_{\underline{p}}^{\hat{p}} sg(s)\mathrm{d}s}{G(\hat{p})}\left(1 - \frac{\hat{p}g(\hat{p})}{G(\hat{p})}\right) + \frac{\hat{p}g(\hat{p})}{G(\hat{p})}\frac{\int_{\underline{p}}^{\hat{p}} s^2 g(s)\mathrm{d}s}{G(\hat{p})}\right]}$$

As c approaches 0 from above $\hat{p}$ tends to $\hat{p}^*$, $\tilde{p}$ tends to $\tilde{p}^*$ and $\hat{p}g(\hat{p})/G(\hat{p})$ tends to $\hat{p}^* g(\hat{p}^*)/G(\hat{p}^*)$. Also, $\lim_{c \to 0+} \int_{\underline{p}}^{\hat{p}} s^2 g(s)\mathrm{d}s = \int_{\underline{p}}^{\hat{p}^*} s^2 g(s)\mathrm{d}s$ which exists and is positive. Hence

$$\lim_{c \to 0+} \frac{\partial \hat{p}}{\partial c} = \frac{-\int_{\underline{p}}^{\hat{p}^*} s(\hat{p}^* - s)g(s)\mathrm{d}s}{-\frac{R-u}{(\hat{p}^*)^2}\tilde{p}^*\left[1 - \frac{\hat{p}^* g(\hat{p}^*)}{G(\hat{p}^*)}\frac{(R - u - \rho)}{\rho}\right]} > 0. \tag{14}$$

as $\lim_{c \to 0+}[1 - \hat{p}g(\hat{p})/G(\hat{p})(\hat{p}/\tilde{p}) - 1)] = 1 - \hat{p}^* g(\hat{p}^*)/G(\hat{p}^*)(\hat{p}^*/\tilde{p}^* - 1) = 1 - \hat{p}^* g(\hat{p}^*)/G(\hat{p}^*)(R - u - \rho)/\rho > 0$ from Eq. (7). At the same time, for arbitrarily small values of c, the limited liability constraint (13) is always satisfied as $\hat{p}$ is bounded below by $\hat{p}^*$. By the continuity of $g(p)$ and $G(p)$ the set of values of $(c, \hat{p})$ that satisfy Eq. (12) is closed and bounded. Also, for $p \in [\hat{p}^*, 1]$, the set of values of c satisfying Eq. (13) is closed and bounded as well. Hence, even when the condition $\rho \leq R\mu - u(\sigma^2 + \mu^2)$ is not satisfied so that the first-best is not attainable under joint liability, a unique equilibrium $c^{**} \in (0, c')$ exists such that $\hat{p}$ has the highest value $\hat{p}^{**}$ and $(c^{**}, \hat{p}^{**})$ satisfy Eqs. (12) and (13). Moreover, given Eq. (14), the probability of success of the marginal borrower $\hat{p}$, and hence the average quality of the borrower pool, $\tilde{p}$ is strictly higher compared to the equilibrium under lending with individual liability.

Finally, we consider the case where $\rho \leq (R - u)\mu$ so that individual liability lending achieves the first best. Under individual liability lending $r^* = \rho/\mu$. Suppose we reduce this interest rate by $\varepsilon > 0$ and introduce joint-liability by an amount such that the bank's zero-profit condition is satisfied. The marginal borrower continues to remain $\hat{p} = 1$. The reason is, this type of a borrower never defaults, nor their partners. Hence, the amount of joint liability does not affect them directly, while a cut in the interest rate makes them strictly better off. Putting $\hat{p} = 1$ in the zero-profit condition under joint liability, Eq. (11), we get the corresponding level of joint liability to be $\mu/\mu - (\sigma^2 + \mu^2)\varepsilon$. We want to compare the expected payoff of a borrower of type p under this new arrangement and that under the equilibrium with individual liability. A borrower of type p will be worse off with this move if and only if $\rho/\mu p < (\rho/\mu) - \varepsilon p + \mu/\mu - (\sigma^2 + \mu^2)\varepsilon p(1 - p)$, or, $p < (\sigma^2 + \mu^2)/\mu$. [19] Also, such borrowers are worse off the greater is the amount of joint liability. Now so long as the participation constraint of the most risky borrower (i.e., $p = \underline{p}$) is satisfied, the new arrangement with joint liability is an equilibrium that achieves the first-best in terms of the repayment rate and aggregate surplus as well. Notice that since we have $\hat{p} = 1$, the limited liability constraint (13) imposes an upper bound on c equal to u. A borrower of type $\underline{p}$ will borrow if and only if $R - u \geq \underline{p}(\rho/\mu) - \varepsilon + \underline{p}(1 - \underline{p})\mu/\mu - (\sigma^2 + \mu^2)\varepsilon$. In the case under consideration, $R - u \geq \rho/\mu$ by assumption and so $R - u > \underline{p}\rho/\mu$ (since $\underline{p} < 1$). Hence for small values of ε the participation constraint of the most risky borrower is satisfied under the new joint liability arrangement. Hence it is satisfied for all types of borrowers. Since the payoff borrowers of type $p \leq (\sigma^2 + \mu^2)/\mu$ is decreasing and continuous in the amount of joint liability, $\mu/\mu - (\sigma^2 + \mu^2)\varepsilon$, there exists $c'' \in (0, u]$ such that for $c \leq c''$ borrowers of all types participate under joint liability lending. Hence an equilibrium with joint liability exists and achieves the first-best even when $\rho \leq (R - u)\mu$ so that individual liability lending achieves the first best as well.

[19] See Section 5 for an intuition for this.

The equilibrium with joint liability is not unique in this case however: any (r^{**}, c^{**}) where $c^{**} \leq c''$ and $r^{**} = (\rho/\mu) - (\mu - (\sigma^2 + \mu^2)/\mu)c^{**}$ is an equilibrium. ■

Intuitively, starting from a situation where the bank uses standard individual-liability credit contracts (i.e., $c = 0$), if it introduces joint-liability credit contracts by increasing c by a little bit, then that permits a reduction in the equilibrium interest rate r. But now the effective interest rates facing risky and safe borrowers are no longer the same. Conditional on success, a risky borrower faces a higher effective interest rate than a safe borrower because her partner is more likely to have failed. But this is precisely what a full-information contract would like to do — riskier projects, because they succeed less often should pay more when it succeeds. This encourages entry of safe borrowers into the pool of borrowers as reflected in the increase in the probability of success of the marginal borrower, $\hat{p}$. But this raises the average probability of success of the pool, $\tilde{p}$ and hence reduces the equilibrium interest rate.

Our analysis shows that joint liability will always improve repayment rates and efficiency (in the sense of aggregate surplus) compared to lending with individual liability. These improvements are strict when individual liability lending fails to achieve the first best. This is due to the fact that safer borrowers always prefer joint liability to individual liability because they have safer partners. However, our result is based on various simplifying assumptions such as borrowers know each other's types perfectly, enforcement is costless, borrowers are risk neutral and project return of group members are uncorrelated. Relaxing some of these assumptions will reduce the relative effectiveness of group lending and may help to explain the observed mixed repayment performance of various group-lending programs in practice. [20]

5. Welfare analysis

In Section 4 we showed that group lending based on joint liability can raise expected aggregate surplus compared to lending based on individual liability. Indeed, it is possible to achieve the same repayment rates and expected aggregate surplus as under full information under certain conditions. However, it is not guaranteed that every type of borrower will be better off under group lending. A fall in the interest rate, permitted by banks receiving joint-liability payments from borrowers with defaulting partners and the entry of safe borrowers leading to an improvement in the borrower pool, helps all borrowers. But now each borrower

[20] Ghatak (1999) discusses the implications of allowing borrower risk aversion and correlation of project returns within this framework. Besley and Coate (1995) show that it is possible for group lending to perform worse than individual lending under certain circumstances when strategic default is possible.

has an additional cost of borrowing: a joint-liability payment to cover for the defaulting group partner. This cost is relatively high for risky borrowers who end up with risky partners. Holding the borrower pool constant, a cut in the interest rate balanced by a rise in joint-liability payments makes relatively risky borrowers worse off and the *average* borrower *in the given pool* exactly as well off so long as the bank still earns zero-profits after this change. However, the surplus generated from the projects of safe borrowers who now find borrowing profitable and enter the pool allows the bank to reduce the interest rate further. In this section we provide an example that shows if enough safe borrowers are attracted back into the market by a cut in the interest rate starting from an equilibrium with individual liability, *all* borrowers can be made potentially better-off, including the riskier borrowers in the pre-existing pool.

Example: Assume that the probability of success of borrowers follow the uniform distribution, and that the parameters of the model satisfy the condition $R\mu - u(\sigma^2 + \mu^2) \geq \rho > (R-u)\mu$ in addition to Assumptions 1 and 2. Then all types of borrowers will be better off under joint liability lending compared to individual liability lending.

As we assume $R\mu - u(\sigma^2 + \mu^2) \geq \rho > (R-u)\mu$, we know from Propositions 2 and 3 that individual liability lending does not achieve the first-best but joint liability lending does.

If the probability of success of borrowers follow the uniform distribution, $g(p) = 1/1 - \underline{p}$, $G(p) = p - \underline{p}/1 - \underline{p}$, $\mu = 1 + \underline{p}/2$ and $\sigma^2 = 1 - \underline{p}^2/12$. Also $\tilde{p} = \hat{p} + \underline{p}/2$ and $\pi(r) = (R - u/2 - \rho) + r\underline{p}/2$. Using Proposition 2, $r^* = 2/\underline{p}\,(\rho - (R-u)/2)$. Since $\rho > (R-u)\mu$ by assumption, and $\mu = 1 + \underline{p}/2 > 1/2$ we have $r^* > 0$. Also, $\rho > (R-u)\mu$ implies $R - u < 2/\underline{p}\,(\rho - (R-u)/2) = r^*$, or $\hat{p}^* = R - u/r^* < 1$.

The expected payoff of a borrower of type p in the equilibrium with individual liability is $pR(p) - r^*p - u = (R-u) - 2/\underline{p}(\rho - ((R-u)/2))p$. The expected payoff of a borrower of type p in the equilibrium with joint liability is $pR(p) - r^{**}p - c^{**}p(1-p) - u$. Using Proposition 3, we get $r^{**} = R - u$ and $c^{**} = \rho - (R-u)\mu/\mu - (\sigma^2 + \mu^2)$. The equilibrium with joint liability provides a higher payoff to a borrower of type p compared to the equilibrium with individual liability if and only if

$$r^*p > r^{**}p + c^{**}p(1-p).$$

Since p cancels out of both sides, it is sufficient to check if the borrower with lowest probability of success, i.e., $p = \underline{p}$, is better off under joint liability lending. Substituting the values of r^*, r^{**} and c^{**} and simplifying, the required condition turns out to be $\rho > (R-u)((1+\underline{p})/2)$. This shows that under our assumptions borrowers of every type will be better off under joint-liability lending.

This example takes a very specific distribution and makes strong additional assumptions about the parameters. This is to get simple closed form solutions of the optimal loan contracts under individual and joint-liability lending that makes the welfare comparison straightforward. This example should not be taken as implying that joint liability will make borrowers of every type better off in general. Rather it should be taken as showing the *potential* of the instrument of joint liability to improve welfare. It also shows that the initial equilibrium with individual liability contracts is not necessarily constrained Pareto-efficient. In that equilibrium if safe borrowers were present in the market the risky borrowers would benefit because even though the bank would make losses on them, that would be subsidized by the profits made on safe borrowers. However, an individual risky borrower does not internalize the effect she has on the equilibrium interest rate. Therefore, she would enter the market even though that may push up the interest rate just that much such that all safe borrowers would leave the market. This would cause the equilibrium interest rate to shoot up and make risky borrowers, the only kinds left in the market, worse-off. The reason why joint-liability contracts can improve welfare (even in the Pareto sense as the example shows) is because they use a valuable resource which individual liability contracts do not. It is the local information that borrowers have about each other through the process of endogenous peer selection. This allows group-lending schemes to attract safe borrowers back into the market, which may make all borrowers, including risky ones better-off due to resulting increase in social surplus.

6. Conclusion

In this paper we have provided a theory to explain how joint-liability credit contracts used by group-lending schemes can achieve high repayment rates even when borrowers have no conventional collateral to offer. It is based on the fact that borrowers are asked to self-select group members and this leads to differential expected costs of borrowing to borrowers depending on their type because the types of their partners are different from the same joint-liability contract.

An interesting implication of the assortative matching property proved in the paper is that risky borrowers who will end up with risky partners will be less willing to accept an increase in the extent of joint liability than safe borrowers for the same reduction in the interest rate. This implies that the degree of joint liability can be used as a screening instrument to induce borrowers to self select loans that differ in terms of individual and joint liability. Elsewhere (Ghatak, 1999) we have examined this screening problem, and compared optimal joint liability contracts with other schemes suggested for similar informational environments by the mechanism design literature (e.g., cross reporting) in terms of efficiency and collusion-proofness.

A related question is what is the nature of equilibrium in the credit market when lenders can compete by offering loans with varying amounts of individual and joint liability. For example, starting with a competitive equilibrium where lenders offer loans using only individual liability, can lenders offering joint-liability contracts can break the initial equilibrium? In this paper we have abstracted from these problems by assuming that the bank is like a planner who maximizes expected aggregate surplus subject to a break even constraint in order to focus on the effect of joint liability on repayment rates and welfare. In the aforementioned paper, we have addressed these questions as well.

To conclude, the theoretical literature on group lending to which this paper contributes, has proposed many different ways in which it may have informational and enforcement advantages over conventional forms of lending to borrowers who cannot offer collateral. However, empirical work testing the effect of the specific instrument of joint liability on repayment rates in group lending programs, and the relative importance of peel monitoring, peer pressure and peer selection effects, has lagged behind theoretical work on the topic. [21] Apart from pure academic interest, such evidence could tell us whether joint-liability-based mechanisms can work only in very cohesive 'rural' environments, or whether they can work in more 'urban' environments where even though social enforcement mechanisms are weaker, people still might have a lot of information about their neighbors or co-workers.

Acknowledgements

I am grateful to my thesis advisors Abhijit V. Banerjee, Eric Maskin and Jonathan Morduch for encouragement and guidance, and to Debraj Ray and two anonymous referees of this journal for helpful suggestions. I would like to specially acknowledge the help of one anonymous referee for critical comments on successive drafts of this paper from which it benefitted greatly. The usual disclaimer applies.

Appendix A

In this appendix we show that one of the main results of the paper concerning the composition of borrowing groups under group lending programs that use joint liability, Proposition 1, continues to hold if we relax some of the simplifying assumptions.

A.1. Groups of arbitrary size

First we consider groups of size n and prove by induction that the positive assortative matching result goes through. The unconditional expected payoff of a

[21] Wenner (1995) and Wydick (1999) are some recent papers that pursue this line of research.

borrower with probability of success p in a group consisting of n members of type p from a given joint-liability contract (r, c) is:

$$\mathrm{EU}_{p,p}(r,c,n) = pR(p) - rp - cp\left[\sum_{x=1}^{n-1} {}^{n-1}C_x (1-p)^x p^{n-1-x} x\right].$$

Since the random variable x representing the number of group members of type p who failed is binomially distributed with mean $(1-p)(n-1)$ we can rewrite this expression as:

$$\mathrm{EU}_{p,p}(r,c,n) = pR(p) - rp - cp(1-p)(n-1).$$

Suppose that positive assortative matching holds for groups of size n. We want to show that, if the group size is $n+1$ then this property still holds. The expected payoff of a member of type p of a group consisting of n members of type p from having an additional member of type p' is:

$$pR(p) - rp - cp\{(1-p)(n-1) + (1-p')\}.$$

Hence, the difference in the expected payoff of a member of a group with n members of type p from having an additional member of type p' over having an additional member of type p is $cp(p'-p)$. Suppose $p' > p$. Then the maximum total bribe that a group consisting of n borrowers of type p will be able to offer to a borrower of type p' to join their group is $ncp(p'-p)$. The expected loss of a borrower of type p' to leave a group of n borrowers of type p' and join a group of n borrowers of type p is:

$$\{p'R(p') - rp' - cp'n(1-p')\} - \{p'R(p') - rp' - cp'n(1-p)\}$$
$$= ncp'(p'-p).$$

Since $ncp(p'\text{-}p) < ncp'(p'\text{-}p)$, Lemma 1 applies and hence there does not exist a mutually profitable transfer from a group consisting of risky borrowers to a safe borrower in order to persuade the latter to leave a group consisting of safe borrowers and join the former group. [22]

[22] It turns out that group size and joint liability cannot be used as independent screening instruments. Rather, they are perfect substitutes as a candidate for a screening instrument that can be used with the interest rate. Starting with a given group size n and amount of joint liability c, an increase in c must be accompanied by a decrease in n to keep the expected payoff of a borrower of any type constant. However, only if the rate at which n must be decreased for a given increase in c varies across types, it will be possible to screen borrowers by varying group size and joint liability. This is not the case as $(\mathrm{d}c/\mathrm{d}n) = -c/(n-1)$ (where we hold the expected payoff of a borrower of type p constant) is independent of p. In contrast $(\mathrm{d}c/\mathrm{d}r) = -(1/((n-1)(1-p)))$ and $(\mathrm{d}n/\mathrm{d}r) = -(1/c(1-p))$ (again, holding the expected payoff of a borrower of type p constant) which suggests that either joint liability or group size can be used as a screening instrument with the interest rate.

A.2. Borrowers have some wealth

Next, suppose a borrower of type p has some positive level of wealth, w. So irrespective of the outcome of her project she receives a payoff of w. The expected payoff of this borrower when her partner is of type p' is

$$\begin{aligned}\mathrm{EU}_{p,p'}(r,c;w) &= pp'(R(p)+w-r)\\ &\quad + p(1-p')(R(p)+w-r-c)+(1-p)w\\ &= pR(p)+w-\{rp+cp(1-p')\}.\end{aligned}$$

If her partner is of type p'' instead, her expected payoff is $\mathrm{EU}_{p,p''}(r,c;\ w)= pR(p)+w-\{rp+cp(1-p'')\}$. The difference in her expected payoff between these two cases is $cp(p'-p'')$ which is the only determinant of her choice of partner. Since this does not depend on her wealth w Proposition 1 goes through even when borrowers have some wealth and there is heterogeneity in initial wealth levels.

Of course if borrowers have enough initial wealth which can be offered as collateral then the adverse selection disappears. The bank can then offer contracts that differ in the amounts of interest charged and collateral demanded with safer borrowers preferring loans with low interest and high collateral, and risky borrowers the opposite. The importance of joint liability stems precisely from the fact that it allows a way of lending to the poor who cannot offer enough collateral. As mentioned above, elsewhere (Ghatak, 1999) we have examined the possibility of joint liability as a screening device. In that context a question arises about the relative efficiency of joint liability and collateral as screening instruments. We show that if borrowers are risk neutral, it does not matter whether in any given state of the world (depending on project outcome) the transfer to the bank takes place in the form of individual liability, joint liability or collateral payment. On the other hand, when borrowers are risk-averse, while both joint liability and conventional collateral involves less than full insurance in order to ensure incentive compatibility, joint liability involves a smaller departure from efficient insurance. The reason is, collateral involves a transfer from the risk-averse borrower to a risk-neutral bank in a state of the world when her marginal utility of money is the highest, namely when her project fails. But joint liability merely taxes her when her project succeeds and that of her partner fails.

A.3. Borrower population unbalanced with respect to group size

If we relax the assumption that the supply of partners of each type is balanced with respect to the required group size, then some borrowers will not be able to borrow under joint-liability contracts. Since, in equilibrium, identical borrowers should receive the same payoff under optimal sorting regardless of whom they get as a partner or whether they choose not to borrow given positive assortative matching, it will be the borrower of the lowest type who will fail to obtain a loan through group lending. [23]

Suppose borrowers are arranged in terms of their type by descending order: $p_1 > p_2 > \dots > p_N$. Suppose there are two borrowers of each type to begin with. Then from Lemma 1 we know that group formation will display homogenous groups. Suppose now one borrower of type p_1 is removed from the group of borrowers. In that case by Lemma 1 the remaining borrower of type p_1 will always be able attract any borrower of type p_i (where $i > 1$) away from the latter's current partner. Hence she will match with a borrower whose type is closest to her own type (from below), namely p_2. But this means there will be a borrower of type p_2 who will now fail to find a partner of her own type. Repeating the above argument, she will be able to find a partner of type p_3. In order for a borrower of any type to be indifferent between matching with a borrower of a safer type and a riskier type, there should be a corresponding set of transfers from a borrower of type p_i to a borrower of type p_{i-1}, $t_{i,i-1}$, which can be solved from the following set of equations:

$$\mathrm{EU}_{i,i-1}(r,c) - t_{i,i-1} = \mathrm{EU}_{i,i+1}(r,c) + t_{i+1,i}, \qquad i = 2,\dots,N-1$$
$$\mathrm{EU}_{N,N-1}(r,c) - t_{N,N-1} = u.$$

There is one potential complication. Suppose there are more than two borrowers of some types to start with. If p_i is such a type then in equilibrium there may still be some homogenous groups consisting of borrowers of type p_i. In this case, a borrower of type p_i must be indifferent in equilibrium between forming a group with three types of partners: a borrower of a safer type, a borrower of a riskier type and a borrower of the same type. Suppose there were $2N_i$ borrowers of type p_i to start with.Then we need to determine a transfer $t_{i,i}$ from each borrower of type p_i who gets to form a group with a borrower of the same type to the borrower of type p_i who gets to form a group with a borrower of type p_{i+1}:

$$\begin{aligned}\mathrm{EU}_{i,i-1}(r,c) - t_{i,i-1} &= \mathrm{EU}_{i,i+1}(r,c) + t_{i+1,i} + 2(N_i - 1)t_{i,i}\\ &= \mathrm{EU}_{i,i}(r,c) - t_{i,i}.\end{aligned}$$

Hence, for general distributions of the borrower population, there are two departures from Proposition 1. First, now side payments will take place in equilibrium to ensure borrowers of the same type receive the same expected payoff. Second, while there will be some heterogeneous groups in equilibrium, the following weaker version of the assortative matching result presented in Proposition 1 will continue to hold — the partner of a given type of borrower will have a probability of success at least as large as the partner of a borrower with a lower probability of success.

[23] This is similar to the case of sorting with unequal number of partners as in Becker's model of the marriage market.

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