The Economic Journal, **110** (*July*), 601–631. © Royal Economic Society 2000. Published by Blackwell Publishers, 108 Cowley Road, Oxford OX4 1JF, UK and 350 Main Street, Malden, MA 02148, USA.

SCREENING BY THE COMPANY YOU KEEP: JOINT LIABILITY LENDING AND THE PEER SELECTION EFFECT*

Maitreesh Ghatak

We look at an economic environment where borrowers have some information about the nature of each other's projects that lenders do not. We show that joint-liability lending contracts, similar to those used by credit cooperatives and group-lending schemes, will induce endogenous peer selection in the formation of groups in a way that the instrument of joint liability can be used as a screening device to exploit this local information. This can improve welfare and repayment rates if standard screening instruments such as collateral are unavailable.

This paper analyses a contractual mechanism through which lenders can utilise information borrowers may have about each other, thereby overcoming problems of adverse selection in credit markets. We show that by lending to self-selected groups of borrowers and making them jointly liable for each other's loan repayment, a lender can achieve high repayment rates even when these borrowers cannot offer any collateral.

Our work is motivated by contractual methods successfully used by real world lending institutions, such as group-lending programmes and credit cooperatives. These institutions lend to poor borrowers who are not considered creditworthy by conventional lenders. Of these, the dramatic success story of the Grameen Bank of Bangladesh in terms of loan recovery rates combined with a reasonable degree of financial self-sufficiency has received a lot of attention among economists and policymakers.[1] Indeed, it has become a role model for lending programmes to the poor used by government agencies and non-governmental organisations all over the world.[2] The practice of using joint liability to lend successfully to borrowers who cannot offer any conventional

* I am grateful to Abhijit V. Banerjee, Eric Maskin, and Jonathan Morduch for encouragement and helpful discussions, to the editors of this Journal, Timothy Besley and David De Meza, and two anonymous referees for very useful comments. I would also like to thank Michael Chwe, Jonathan Conning, Alain de Janvry, Gabriel Fuentes, Christian Gollier, Timothy Guinnane, Raja Kali, Fahad Khalil, Michael Kremer, Andrew Newman, Rohini Pande, Priyanka Pandey, Debraj Ray, Elizabeth Sadoulet, Loic Sadoulet, Ilya Segal, Tomas Sjostrom, Chris Udry, students and seminar participants at Berkeley, Chicago, Copenhagen, Dundee, Harvard, Iowa State, ITAM, LSE, Namur, Northwestern, Seattle, and the 1997 NEUDC meetings at Williams College for helpful feedback. The usual disclaimer applies.

[1] Beginning its operations on a very small scale in 1976, the membership of the Grameen Bank crossed 2 million borrowers by 1996, most of them poor women from rural areas (Morduch, 1999). Early estimates of the default rate under Grameen Bank's group-lending programme (Hossain, 1988) were around 2% as compared to 60–70% for comparable loans by conventional lending institutions. Recent estimates by Morduch (1999) puts the default rate to a slightly higher level of 7.8%.

[2] Today there are about 8-10 million households served by similar lending programmes all across the globe including the United States. However the evidence on the performance of these programmes in different countries is mixed. See Huppi and Feder (1990), Morduch (1999) and Ghatak and Guinnane (1999) for detailed discussions of how joint liability works in practice, the practical problems that arise in the design of these lending programmes.

collateral actually goes well back in history. In the middle of the nineteenth century a credit cooperative movement was successfully launched in Germany based on the idea of joint liability which too had a remarkable record of repayment and was widely imitated in different parts of Europe.[3]

The Grameen Bank's group-lending programme has several distinctive features. Small loans are given to poor people in rural areas for small scale non-agricultural enterprises. No collateral is required, and the interest rate is the same as rates charged by commercial banks. Borrowers are asked to form small self-selected groups from within the same village. Loans are given to individual group-members, but the whole group is jointly liable for the repayment of each member's loan.

We focus on two features of the contractual method used by the Grameen Bank and similar lending institutions to explain their excellent repayment record: the self selection of group members, and joint liability.[4] Under joint liability a borrower's payoff is higher the greater is the number of her group-members who repay their loans. If borrowers have some information about each other's projects and are allowed to select their own group members, then the deliberate creation of externalities through joint liability will induce them to select their peers based on this local information. We show that joint liability will induce positive assortative matching in group formation, i.e., safe borrowers will end up with safe borrowers as partners, and risky borrowers with risky partners. The reason is while every borrower prefers a safe partner, since safe borrowers repay more often, they value safe partners more than risky borrowers.

Given the selection of groups described above, we show how lenders can exploit the degree of joint liability to screen borrowers with different (unobservable) probabilities of repayment. Risky borrowers have risky partners and so are less willing to accept an increase in the degree of joint liability than safe borrowers for the same reduction in the interest rate. Since the bank does not know a borrower's type, if other screening instruments such as collateral are not available (say, due to the poverty of borrowers), it has to offer loans to all borrowers at the same nominal interest rate. Then it is possible to have situations where safe borrowers are driven out of the credit market because the presence of risky borrowers drives the break-even interest rate of the bank too high (Stiglitz and Weiss, 1981). Alternatively, it is possible to have situations where risky borrowers with unproductive projects are able to borrow because they are cross-subsidised by safe borrowers with productive projects (De Meza and Webb, 1987). We show that starting with the former situation, joint liability lending can be used to attract safe borrowers back into the market. Similarly, starting with the latter situation it can be used to drive risky borrowers away. The result would be an improvement in economic efficiency and a higher

[3] See Guinnane (1994). A credit cooperative differs from a group lending programme in that it also raises deposits from its members and hence has a greater resemblance with a bank.

[4] We ignore some dynamic aspects of joint-liability contracts which undoubtedly have an important effect on repayment behaviour. For example, joint-liability takes the form of denial of future loans, and also, the size of the loan to each member is conditioned on the past behaviour of all group-members. Besley and Coate (1990) address some of these issues.

average repayment rate. Hence joint liability lending can be viewed as a simple mechanism that exploits local information to alleviate credit market failures caused by asymmetric information.[5]

There is some informal as well as formal evidence indicating that microfinance programmes are successful in screening their borrowers as suggested in our model. According to Muhammad Yunus (1994), the founder of the Grameen Bank, 'Usually it takes quite a bit of time for the members to identify each other and consult each other before announcing they wish to form a group. Many times members screen each other out before they arrive at the final five.' Huppi and Feder (1990) observe that the most successful group lending programmes have been those where loans were made to homogenous self-selected groups of individuals belonging to the same village and with similar economic standing. Formal evidence is provided by McKernan (1998) in her evaluation of the Grameen Bank based on a large scale quasi-experimentally designed survey conducted in 87 villages in Bangladesh. She finds '... a positive correlation between unobservable borrower characteristics (such as entrepreneurial ability) that affect both profits and participation. This positive correlation provides evidence that the Grameen Bank may successfully screen bad credit risks (either because low profit households are turned away or because high profit households choose to join).' (p. 27). She concludes that not controlling for selection bias can lead to an overestimation of the effect of participation on profits by as much as 100%.

Since we show how a contractual method used by actual institutions can alleviate informational problems, it is of some interest to relate our results to the theoretical literature on contracts and mechanism design. Our main finding provides an interesting qualification to a well known result in the relative performance evaluation literature (see Hart and Holmstrom, 1987). It says, optimal contracts should not make the payoff of an agent dependent on the performance of other agents unless these performances are correlated. We show that because they exploit some private information agents might have about each other through the sorting process, such contracts may be optimal even if the performances of agents are uncorrelated. We also compare the joint liability mechanism with cross reporting schemes suggested by the mechanism design literature as well as other contractual solutions suggested for similar informational environments.

The existing literature, until very recently, has largely treated group formation under joint liability lending as exogenous.[6] It has focused instead on the role of joint liability in encouraging either *peer-monitoring*, which alleviates moral hazard problems, or *peer-pressure* which ensures better enforcement.[7]

[5] It should be noted, however, that while joint liability puts local information to use for the bank, it does not add to the bank's store of information in our model. I thank a referee for making this observation.

[6] An exception is Varian (1990). In his model joint liability takes a different form. The bank randomly selects and screens one group member which is assumed to reveal her type perfectly. If she turns out to be a bad risk, all group members are denied loans.

[7] Stiglitz (1990), Varian (1990), and Besley and Coate (1995) are some of the major contributions in the existing literature. See Ghatak and Guinnane (1999) for a detailed survey.

Our results suggest that the improvement in repayment rates over standard individual lending need not only reflect the change in the behaviour of borrowers as suggested by these theories, but also a pure selection effect in the form of different pools of borrowers under these two different lending arrangements.

A recent paper by Van Tassel (1999) looks at a model similar to the one in this paper, and finds similar results on its effect on the formation of groups and repayment rates. Apart from various modelling differences, our paper is distinguished by showing how joint liability lending can alleviate problems of *both* underinvestment and overinvestment, and by comparing it with other feasible mechanisms. 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. The main difference with the current paper is that it does not allow for side payments among participants at the group formation stage, or explore the possibility of using joint liability as a screening instrument. However, their paper addresses an interesting issue that we do not consider - whether joint liability can improve efficiency in environments with adverse selection where borrowers do not necessarily have better information about each other.[8]

1. The Model

We use a simple one-period model of a credit market under adverse selection.

Technology and Preferences All agents live in a village with a large population normalised to unity and are endowed with one unit of labour and a risky investment project. The project requires one unit of capital and one unit of labour. Agents lack sufficient personal wealth and need to borrow to launch their project. Once the capital is in place and the required unit of labour is put in, projects either yield a high or a low return. We refer to these *outcomes* as 'success' (S) and 'failure' (F), respectively. The outcome of a borrower's project will be denoted by the binary random variable, $\tilde{x} \in \{S, F\}$. There are two *types* of borrowers characterised by the probability of success of their projects, p_r and p_s, where

$$0 < p_r < p_s < 1.$$

Henceforth they will be referred to as 'risky' and 'safe' borrowers.[9] Risky and safe borrowers exist in proportions θ and $1 - \theta$ in the population. The outcomes of the projects are assumed to be independently distributed for the same types as well as across different types.

The *return* of a project of a borrower of type i, is a random variable $\tilde{y}_i$ which takes two values, R_i if successful and 0 if it fails where $R_i > 0$, $i = r, s$.

[8] See also the recent paper by Laffont and N'Guessan (1999) for a related contribution on this issue.

[9] Like in standard adverse selection models, we take the types of borrowers are exogenously given. We can think of them as derived from either tastes (e.g. attitude towards risk) or some non-marketable input affecting technology (e.g. managerial ability, quality of land, family labour etc.).

Borrowers are risk-neutral and maximise expected returns. Borrowers of both types have an exogenously given reservation payoff $\overline{u}$ which is the return from their endowment of labour from some alternative occupation.

The lending side is represented by risk neutral banks whose opportunity cost of capital is ρ per loan where $\rho \geqslant 1$. We assume that the village is small relative to the credit market, and so the supply of loans is perfectly elastic at the rate ρ.

Information and Contracting We assume that the type of a borrower is unknown to the lenders. However, borrowers know each other's types. It may be helpful to think of lenders as institutions 'external' to the village (e.g., city-based) and of borrowers as residents of the same village. There is no moral hazard and agents supply labour to the project inelastically.

Following existing models of adverse selection in the credit market we will focus on debt contracts. In their classic paper Stiglitz and Weiss (1981) assume that only debt contracts can be used and then show how this could lead to underinvestment. De Meza and Webb (1987) have pointed out (see also footnote 13) that if lenders use equity instead of debt contracts, that would solve the problem of adverse selection in the Stiglitz and Weiss model. In order to justify our focus on debt contracts, which are contingent on outcomes, and ruling out contracts contingent on project returns, such as equity, we make the following informational assumption – the outcome of a project of a borrower, $\tilde{x}$, is observable by the bank at no cost and is verifiable; however the realised returns of a project of a borrower of type i, $\tilde{y}_i$, is very costly to observe for the bank. This particular informational environment can be derived from a costly-state verification model (e.g. Townsend, 1979) where multiple values of the return are allowed. In Section 5 we show that in this environment the bank *chooses* to observe the return only when the borrower does not repay.[10]

There is a limited liability constraint. So in case their projects fail, borrowers are liable up to the amount of collateralisable wealth they posses, w.[11] For the most part we take $w = 0$ for simplicity. However, when we consider some alternatives to joint liability as screening instruments in Section 6 we allow borrowers have some transferable wealth and look at the role of collateral. We assume that enforcement costs are negligible and hence rule out the problem of strategic default.

Given our assumptions about information and transaction costs the only contractible variable is $\mathbf{X}$, the vector of project outcomes of all borrowers. Therefore a lending contract can only specify a transfer from a borrower to the bank for every realisation of $\mathbf{X}$.

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

[10] Since in the De Meza and Webb model every borrower has the same return when their project is successful and also when they fail, if outcomes are verifiable, so are returns. To avoid this problem, another possibility is to assume that the only verifiable signal is whether a borrower has repaid her loan or not.

[11] That is, non-monetary punishments, such as imprisonment or physical punishment, are not feasible.

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, which we take to be two for convenience, and stipulating an individual liability component (i.e., interest rate) 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 r to the bank she has to pay an additional joint liability payment c per member of her group whose projects have failed.[12] Thus unlike standard debt contracts, repayment is not fixed in non-bankruptcy states : it is contingent on the project outcome of another pre-specified borrower.[13]

2. Individual Liability Lending

If the bank has full information about a borrower's type, optimal separating individual liability contracts are those that maximise the expected payoff of each borrower subject to a zero-profit constraint on each loan and a limited liability constraint that precludes any transfer from a borrower to the bank when her project fails. Since all parties are risk-neutral there are no risk-sharing considerations. So the optimal contracts are debt contracts under which the borrower pays nothing when her project fails, and the full-information interest rate when her project succeeds. These are solved from the bank's zero-profit constraint:

$$r_i^* = \frac{\rho}{p_i}, \qquad i = r,\ s.$$

Since safe borrowers pay back their debt more often they are charged a lower interest rate than risky types.

If the bank cannot identify a borrower's type then charging separate interest rates to the two types borrowers would not work. A risky borrower would have an incentive to pretend to be a safe borrower and pay the lower interest rate

[12] The form of joint-liability for defaults in actual group-lending programmes often takes the form of denying future credit to all group-members in case of default by a group-member until the loan is repaid. In most cases, intra-group loans are used to ensure timely repayment (Huppi and Feder, 1990). It may seem that our static interpretation of joint-liability is at odds with this particular form taken by it. But c can be interpreted as the net present discounted value of the cost of sacrificing present consumption in order to pay joint liability for a partner. Now if these loans from one group-member to the other are always repaid in the future, in cash or in kind, it may seem that in an intertemporal sense joint liability does not impose a cost on a borrower who has to pay it in a given period to cover for her partner. That would indeed be true if credit markets were perfect, but given that these borrowers face borrowing constraints to start with (which after all is the reason for introducing group-lending) such sacrifices of present consumption are costly.

[13] While there are some similarities between standard debt contracts with a *cosigner* and joint liability contracts, there are two important differences. Under joint liability contracts 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 cosigners on each other's loans at the same time. This is literally true in the case of group-lending programmes. Credit cooperatives may have non-borrowing members, such as those who only deposit money.

ρ/p_s. But the bank would not be able to break even if both types borrow at that rate. We therefore turn to pooling individual liability contracts.

The expected payoff to borrower of type i when the interest rate is r is

$$U_i(r) \equiv p_i R_i - r p_i,\ i = r,\ s.$$

The literature on the adverse selection problem in credit markets assumes that borrowers differ by a risk parameter which is not observed by the bank. In Stiglitz and Weiss (1981) risky and safe projects have the same mean return, but risky projects have a greater spread around the mean, i.e.,

$$p_s R_s = p_r R_r \equiv \overline{R}.$$

In contrast, De Meza and Webb (1987) assume that risky projects have a lower mean than safe projects, and in particular, both types of borrowers earn the same return when their project succeeds, i.e., $R_s = R_r = R$. In other words riskiness of a project is defined in terms of second-order and first-order stochastic dominance respectively. These two distinct notions of riskiness lead to very different equilibrium outcomes in the credit market.

2.1. *The Underinvestment Problem*

First consider the case where all projects have the same mean return. Assume that these projects are socially productive in terms of expected returns given the opportunity costs of labour and capital :

$$\overline{R} > \rho + \overline{u}. \tag{A1}$$

In the full information case, if the bank charges the interest rates $r_i^* = \rho/p_i$, the expected payoff of each type of borrower will be equal to the net surplus from the project, $\overline{R} - \rho - \overline{u}$. Hence by $A1$ both types of borrowers will choose to borrow at these rates. The average repayment rate will be equal to $\theta p_r + (1-\theta) p_s \equiv \overline{p}$, the average probability of success for the entire population.

Under asymmetric information, if the bank charges the same nominal interest rate r then safe borrowers will have a higher expected interest rate. Since expected revenues are the same, the expected payoff of safe borrowers will be lower than that of risky borrowers for any $r > 0$.

If the bank charges all borrowers the same interest rate r, and both types of borrowers borrow in equilibrium, from the zero profit constraint we get $r = \rho/\overline{p}$. As $U_s(r) < U_r(r)$, for $r = \rho/\overline{p}$ to be the optimal pooling individual liability contract, we have to check if it satisfies the participation constraint of safe borrowers, namely if $\rho/\overline{p} \leqslant (\overline{R} - \overline{u})/p_s$. If

$$\overline{R} < \frac{p_s}{\overline{p}} \rho + \overline{u} \tag{A2}$$

a pooling contract does not exist that attracts both types of borrowers. The unique optimal individual liability contract then is the one that attracts risky borrowers and satisfies the zero-profit condition of the bank, $r = \rho/p_r$. In this case the repayment rate is p_r, the expected payoff of a risky borrower is $(\overline{R} - \rho - \overline{u})$ and that of a safe borrower is 0.[14] Both the repayment rate and welfare are strictly less than that under full-information.[15] When $A2$ holds we have what is known as the lemons or the under-investment problem in credit markets with adverse selection (Stiglitz and Weiss, 1981).

2.2. *The Overinvestment Problem*

Next, consider the case where risky projects also have lower mean returns. Since risky borrowers succeed less often, their expected return $p_r R$ is lower than that of safe borrowers, $p_s R$. As before, charging different interest rates to risky and safe borrowers is not feasible. But now if the same interest rate r is charged we need to be concerned with the participation constraint of a risky borrower as $p_s(R - r) > p_r(R - r)$ for all $r < R$. If the expected surplus from risky projects is positive, i.e., $p_r R > \rho + u$, charging an interest rate at which the bank makes zero profits on the average borrower, $\rho/\overline{p}$, will attract both types of borrowers. In this case the repayment rate and expected social surplus are the same as in the full-information case.[16] Suppose that

$$p_r R < \rho + \overline{u}. \tag{A1'}$$

This implies risky projects are unproductive. Suppose that in addition the following condition holds:

$$p_r\left(R - \frac{\rho}{\overline{p}}\right) > \overline{u}. \tag{A2'}$$

Then risky borrowers will find it profitable to borrow as they are cross-subsidised by safe borrowers even though they make a negative contribution to social surplus. This is the overinvestment problem in credit markets with adverse selection (De Meza and Webb, 1987).

3. Joint Liability Lending

In this Section we show how starting with a situation where there is some form of inefficiency under individual liability lending due to adverse selection, joint liability lending can improve efficiency so long as borrowers have some private information about each other's projects.

3.1. *Group Formation: The Assortative Matching Property*

First we show that for any given joint liability contract (r, c), borrowers will always choose partners of the same type. That is, the equilibrium in the group-

[14] We are looking at payoffs net of opportunity cost of labour, $\overline{u}$.

[15] Notice that this inefficiency disappears if the bank could write contracts contingent on the project returns, such as by setting a share $\alpha = \rho/R$ of realised project returns for the bank.

[16] This claim is not necessarily true in terms of welfare as safe borrowers are cross-subsidising risky borrowers and are worse off compared to the full-information outcome.

formation game will satisfy the *optimal sorting property*, namely, borrowers not in the same group could not form a group without making at least one of them worse off. In our proof we explicitly allow borrowers to be able to make side payments to each other. So in principle, a risky borrower can make a transfer to a safe borrower to have her as a partner.[17] However, we show the maximum amount a risky borrower will be willing to pay as a side-transfer to a safe borrower to have her as a partner is strictly less than the minimum amount a safe borrower will need be paid to compensate her from having a risky partner. That is:

PROPOSITION 1. *Joint liability contracts lead to positive assortative matching in the formation of groups.*

Proof. The expected payoff of a borrower of type i when her partner is type j from a joint liability contract (r, c) is:

$$\begin{aligned} U_{ij}(r, c) &\equiv p_i p_j (R_i - r) + p_i(1 - p_j)(R_i - r - c) \\ &= p_i R_i - [p_i r + p_i(1 - p_j)c]. \end{aligned}$$

The net expected gain of a risky borrower from having a safe partner is $U_{rs}(r, c) - U_{rr}(r, c) = p_r(p_s - p_r)c$. Similarly, the net expected loss of a safe borrower from having a risky partner is $U_{ss}(r, c) - U_{sr}(r, c) = p_s(p_s - p_r)c$. If $c > 0$, as $p_s > p_r$, the latter expression is larger than the former. Hence, a risky borrower will not find it profitable to have a safe partner after making a side payment that fully compensates the latter for the expected loss she suffers from having a risky partner. So group formation will display positive assortative matching. Q.E.D.

Notice that the inequality $U_{ss}(r, c) - U_{sr}(r, c) > U_{rs}(r, c) - U_{rr}(r, c)$ can be rearranged to $U_{rs}(r, c) + U_{sr}(r, c) < U_{rr}(r, c) + U_{ss}(r, c)$. The latter implies assortative matching maximises aggregate expected payoff of all borrowers over different possible matches. Hence even if utility is transferable (i.e., side transfers are allowed), it is the only possible assignment that satisfies the optimal sorting condition. This is very close in spirit to Becker's assortative matching result in the context of the marriage market.[18]

The intuition behind this result is simple. Under joint liability lending the type of the partner matters only when the partner's project fails. Therefore, every borrower will prefer to have a safe partner because of lower expected joint liability payments. However, the benefit of having a safe rather than a risky partner is realised only when a borrower herself has succeeded. Hence a

[17] There are two reasons why such side payments may be feasible even though by assumption borrowers have no wealth that can be used as collateral. First, 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 labour services or services of agricultural implements. Second, a borrower can make promises to pay her partner from the return of her project. While such return-contingent transfers are not feasible between the bank and the borrower because it is costly for the former to verify project returns, they should be feasible between a borrower and her partner because by assumption they know each other's types and are members of a common social network.

[18] See Becker (1993), Chapter 4.

safe borrower is much more concerned about the type of her partner than a risky borrower, although both would prefer a safe partner. To put it differently, *conditional* on her own project being successful the expected benefit of having a safe partner over a risky partner is the same and positive for all types of borrowers, but the *unconditional* expected benefit depends on the probability of her *own* project being successful and this is lower for risky borrowers. This implies that a risky borrower will never find it profitable to bribe a safe borrower to be in her group after compensating the latter for the loss of having a risky partner. Hence group formation under joint liability will display positive assortative matching.

Notice that our proof uses only the fact that borrowers have different probabilities of success and their types (i.e., probabilities of success) are complementary in the payoff function induced by a joint liability contract.[19] In particular, it does not depend on whether safe and risky borrowers have the same or different expected project returns.[20]

Proposition 1 implies that the expected payoff of borrower i under a joint liability contract (r, c) is :

$$U_{ii}(c, r) = p_i R_i - \{p_i r + p_i(1 - p_i)c\}. \tag{1}$$

From (1), an indifference curve of a borrower of type i in the (r, c) plane is represented by the line $rp_i + c(1 - p_i)p_i = k$ (where k is some constant) which also represents an iso-profit curve of the bank when lending to a borrower of type i. The only difference of course is that the higher is k the lower is the expected payoff of a borrower and higher is the expected profit of the bank. The slope of an indifference curve of a type i borrower in the (r, c) plane is:

$$\left.\frac{dc}{dr}\right|_{U_{ii}=const} = -\frac{1}{1 - p_i}.$$

Since $p_s > p_r$, this ensures that the absolute value of dc/dr is higher for safe borrowers than for risky borrowers. Consequently preferences of borrowers over joint liability contracts satisfy the *single-crossing property* (see Fudenberg and Tirole, 1991, Chapter 7 for a formal definition). This is a standard property needed to ensure incentive-compatibility in screening different types of agents in adverse selection models and is going to drive most of our results later.

Intuitively, under joint liability lending, conditional on success risky borrowers have higher expected costs than safe borrowers. The reason is they have a risky partner who is very likely to have failed and this means higher expected

[19] That is, $[\partial^2 U_{i,j}(r, c)]/(\partial p_i \partial p_j) = c > 0$.

[20] Even though we have proved this result in a simple set-up, the assortative matching result turns out to be quite general. Elsewhere (Ghatak, 1999) we have shown that it can be extended to situations where there are many types of borrowers, borrowers have some wealth and there is heterogeneity in wealth levels, the group-size exceeds two, and the population of borrowers is not necessarily balanced with respect to group size (i.e., in terms of the present set-up the total numbers of safe and risky borrowers in the population are not necessarily multiples of 2).

joint liability payments. It also follows that to receive a small reduction in the interest rate, safe borrowers would be willing to pay a higher amount of join-liability than risky borrowers because having safe partners they do not have to pay joint liability payments very often. We refer to the fact that risky and safe borrowers rank credit contracts with different combinations of individual and joint liability payments differently due to endogenous group formation as the *peer selection effect*.

So we have an immediate and useful corollary to Proposition 1:

COROLLARY 1. *Indifference curves of borrowers over joint liability contracts* (r, c) *satisfy the single-crossing property.*

Fig. 1 represents typical indifference curves of safe and risky borrowers satisfying the single-crossing property in the (r, c) plane. Notice that utility increases as one moves toward the origin.

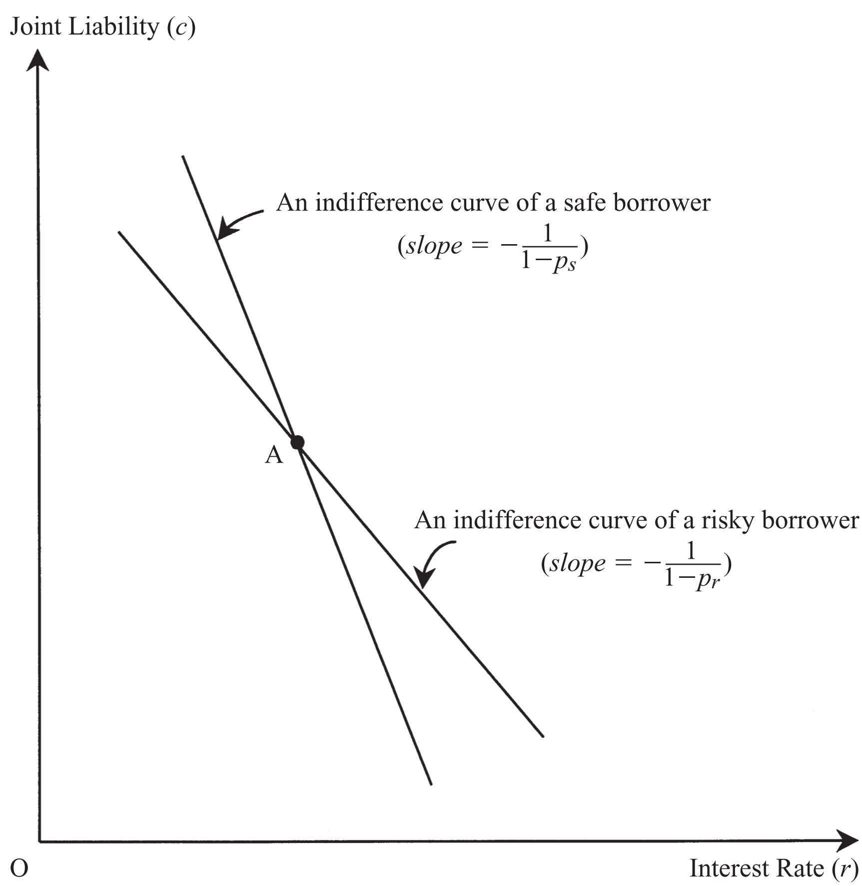

Fig. 1. *Indifference Curves of Safe and Risky Borrowers Under Joint Liability*

3.2. *Optimal Joint Liability Contracts: Joint Liability as a Screening Device*

In the previous Section we saw that faced with any joint liability contract (r, c) borrowers will choose partners of the same type. Here we derive the choice of joint liability credit contracts by the bank as an equilibrium of a standard optimal contracting problem. The contracting problem is the following sequential game: first, the bank offers a finite set of joint liability contracts $\{(r_1, c_1), (r_2, c_2), \ldots\}$; second, borrowers who wish to accept any one of these contracts select a partner and do so; 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 $\overline{u}$. Without loss of generality we restrict our attention to the set of contracts which have non-negative individual and joint liability payments, $\mathscr{C}^{JL} = \{(r, c): r \geqslant 0, c \geqslant 0\}$.

A joint liability contract $(r, c) \in \mathscr{C}^{JL}$ is optimal if there does not exist another contract $(r', c') \in \mathscr{C}^{JL}$ which will make at least one type of borrower strictly better off without making any other type of borrower worse off while continuing to satisfy incentive-compatibility and feasibility (namely, limited liability and budget-balance) constraints.[21] Given that there are two types of borrowers and any joint liability contract $(r, c) \in \mathscr{C}^{JL}$ induces assortative matching in the formation of groups, we will restrict the bank's choice of optimal contracts to a pair (r_r, c_r) and (r_s, c_s) designed for groups consisting of risky and safe borrowers respectively.

We pose the optimal contracting problem as follows. The bank's objective is to choose (r_r, c_r) and (r_s, c_s) to maximise a weighted average of the expected utilities of a representative borrower of each of the two possible types:

$$V = \lambda U_{rr}(r_r, c_r) + (1 - \lambda) U_{ss}(r_s, c_s) \tag{2}$$

where $\lambda \in (0, 1)$.[22]

The bank faces the following constraints:

(i) The *zero-profit constraint* of the bank requires that the expected repayment from each loan is at least as large as the opportunity cost of capital, ρ. For separating contracts (r_r, c_r) and (r_s, c_s), we require the bank to break even for each type of loan contract separately:

$$r_r p_r + c_r(1 - p_r) p_r \geqslant \rho \tag{3a}$$

$$r_s p_s + c_s(1 - p_s) p_s \geqslant \rho. \tag{3b}$$

Let ZPC_i denote the set of joint liability contracts that satisfy the zero-profit constraint for a borrower of type i $(i = r, s)$ with equality. For a pooling contract (r, c) the zero-profit constraint requires the bank to break even on the average loan:

$$\theta[r + c(1 - p_r)] p_r + (1 - \theta)[r + c(1 - p_s)] p_s \geqslant \rho. \tag{3c}$$

[21] That is, these contracts are *interim* incentive efficient in the sense of Holmstrom and Myerson (1983).

[22] λ may or may not depend on the size of a particular type of borrower in the population, θ.

Let $ZPC_{r,s}$ denote the set of joint liability contracts that satisfy the pooled zero-profit constraint with equality.

(ii) The *participation constraint* of each borrower requires that the expected payoff of a borrower from the contract is at least as large as the value of her outside option, $\overline{u}$.

$$U_{ii}(r_i,\ c_i) \geqslant \overline{u},\ i = r,\ s. \tag{4}$$

Let PC_i denote the set of joint liability contracts that satisfy the participation constraint of a borrower of type i ($i = r,\ s$) with equality.

(iii) The *limited liability constraint* requires that a borrower cannot make any transfers to the lender when her project fails, and that the sum of individual and joint liability payments, $r + c$, cannot exceed the realised revenue from the project when it succeeds:

$$r_i + c_i \leqslant R_i,\ i = r,\ s. \tag{5}$$

Let LLC_i denote the set of joint liability contracts that satisfy the limited-liability constraint of a borrower of type i ($i = r,\ s$) with equality.

(iv) The *incentive-compatibility constraint* for each type of borrower requires that it is in the self-interest of a borrower to choose a contract that is designed for her type since that is private information:

$$U_{rr}(r_r,\ c_r) \geqslant U_{rr}(r_s,\ c_s) \tag{6a}$$

$$U_{ss}(r_s,\ c_s) \geqslant U_{ss}(r_r,\ c_r). \tag{6b}$$

For a pooling contract the same contract $(r,\ c)$ is offered to all borrowers who wish to borrow and hence these constraints are not relevant. Let ICC_i denote the set of joint liability contracts that satisfy the incentive-compatibility constraint of a borrower of type i ($i = r,\ s$) with equality.

According to this formulation of the contracting problem, the bank is like a planner. It can be thought of as a public lending institution or a non-governmental organisation (NGO) which is most often the case for observed group-lending schemes.[23]

Notice that by Proposition 1, for any *one* given joint liability contract $(r,\ c) \in \mathscr{C}^{JL}$ offered by the bank in stage 1, assortative matching will result in stage 2 of this game. However now we must ensure that even if the bank offers a *menu* of joint liability contracts in stage 1, assortative matching will still result in stage 2 of the game. The following result confirms this:

LEMMA 1. *If* $(r_r,\ c_r)$ *and* $(r_s,\ c_s)$ *satisfy the incentive-compatibility constraints then they will induce assortative matching in the group formation stage.*

Proof. Suppose not. Then a risky borrower must prefer having a safe partner and borrowing under the contract $(r_s,\ c_s)$ rather than having risky partner and

[23] If the bank was a monopolist maximising its expected profits then the optimal contracts will be similar to those derived in this section but they will lie on the respective participation constraints of the borrowers as opposed the zero-profit constraints of the bank.

borrowing under the contract (r_r, c_r) even after making a side payment that compensates the safe borrower from having a risky partner rather than a safe partner while borrowing under the contract (r_s, c_s). Hence their total expected payoff after switching partners in this manner must exceed their total expected payoff in the initial situation. That is,

$$U_{rs}(r_s, c_s) + U_{sr}(r_s, c_s) > U_{rr}(r_r, c_r) + U_{ss}(r_s, c_s).$$

By Proposition 1, if the contract (r_s, c_s) was the only one offered by the bank in stage 1, assortative matching would have resulted in stage 2. That is,

$$U_{rr}(r_s, c_s) + U_{ss}(r_s, c_s) > U_{rs}(r_s, c_s) + U_{sr}(r_s, c_s).$$

Together these inequalities imply $U_{rr}(r_s, c_s) > U_{rr}(r_r, c_r)$. But that violates the incentive compatibility constraint for risky borrowers, $(6a)$, a contradiction. Q.E.D.

Now we proceed to characterise optimal joint liability contracts. Since the bank is maximising a weighted average of the borrowers' expected utility subject to its own zero-profit constraint, and all parties are risk-neutral, we can focus on contracts for which the respective zero-profit constraints are satisfied with equality. Let $(\hat{r}, \hat{c})$ denote the contract that satisfies the zero-profit constraints for both risky and safe borrowers, $(3a)$ and $(3b)$, with equality. Explicitly solving these two equations we get $\hat{r} = \rho(p_r + p_s - 1)/(p_r p_s)$ and $\hat{c} = \rho/(p_r p_s)$. We assume:

$$p_r + p_s \geqslant 1. \tag{A3}$$

This assumption is not substantive. It merely rules out charging a *negative* interest rate and a *positive* joint liability rate to safe borrowers. Though perfectly sensible in theoretical terms, such a contract is hard to relate to anything observed in the real world.

Now we are ready to show how joint liability lending can solve both the underinvestment and the overinvestment problems.

3.2.1. *Joint liability lending and the underinvestment problem*

Recall that the mean returns are the same for all types of borrowers in this case. The following result, which follows from the single-crossing property, helps to identify the set of incentive-compatible contracts:

LEMMA 2. *For any joint liability contract* $(r, c) \in \mathscr{C}^{JL}$, *if* $r < \hat{r}$ *and* $c > \hat{c}$ *then* $U_{ss}(r, c) > U_{rr}(r, c)$, *and if* $r > \hat{r}$ *and* $c < \hat{c}$ *then* $U_{ss}(r, c) < U_{rr}(r, c)$.

Proof. See the Appendix.

The result has a simple intuition. Risky borrowers succeed less often but have risky partners. Hence they are hurt relatively more by an increase in joint liability than an increase in the interest rate. For safe borrowers it is just the opposite. The following assumption is needed to ensure that $(\hat{r}, \hat{c})$ satisfies the limited liability constraint, (5):

$$\overline{R} > \rho\left(1 + \frac{p_s}{p_r}\right). \qquad (A4)$$

Now we are ready to prove:

PROPOSITION 2. *Suppose that assumptions A1, A2, A3 and A4 hold. Then optimal separating joint liability contracts* (r_s, c_s) *and* (r_r, c_r) *exist which have the property* $r_s < r_r$ *and* $c_s > c_r$. *The average repayment rate and welfare under these contracts are equal to their full-information levels and strictly higher than those under individual liability contracts.*

Proof. See the Appendix.

The assumption $A4$ is important. It is needed to ensure that the realised returns from the projects when they succeed are high enough to meet both individual and joint liability payments. This is another guise in which the problem of limited liability, the main source of inefficiency under individual liability contracts in this environment, appears in the joint liability scheme as well. If it is not satisfied, then optimal separating joint liability contracts do not exist. This means that there exist joint liability contracts that satisfy limited liability and incentive compatibility and will raise repayment rates compared to standard debt contracts. However, the bank will not be able to break even on its loans and will require subsidies. This shows that joint liability is not guaranteed to work under all circumstances, and is consistent with the mixed performance of various group-lending programmes in terms of financial self sufficiency and repayment rates in practice.

The solution to the optimal separating problem will not be unique in general: any pair of contracts lying on the zero-profit equations such that $r_s < \hat{r}$, $c_s > \hat{c}$ and $r_r > \hat{r}$, $c_r < \hat{c}$ is a candidate so long as $r_s + c_s \leqslant R_s$. The non-uniqueness of optimal joint liability contracts is really a consequence of risk-neutrality of borrowers. In Section 5 where we consider the implications of risk-aversion on the part of borrowers, we show that there is a unique pair of optimal separating contracts. Another consequence of the assumption of risk-neutrality is that we can achieve the first-best using joint liability contracts. In Section 5 we show that when borrowers are risk averse, while joint liability still implements the full-information outcome, welfare is lower because some risk is imposed on safe borrowers to ensure incentive compatibility.

In Fig. 2 the set of contracts that satisfy the zero-profit constraints for risky and safe borrowers with equality are denoted by the lines ZPC_r and ZPC_s respectively. The set of incentive-compatible contracts for safe and risky borrowers are shown by the line segments DA and AC respectively. The set of contracts that satisfy the limited liability constraint with equality is denoted by LLC. Notice that the absolute value of its slope is 1, and hence it is flatter than the two zero-profit lines. In the Fig. $(\hat{r}, \hat{c})$ (indicated by point A) is shown to

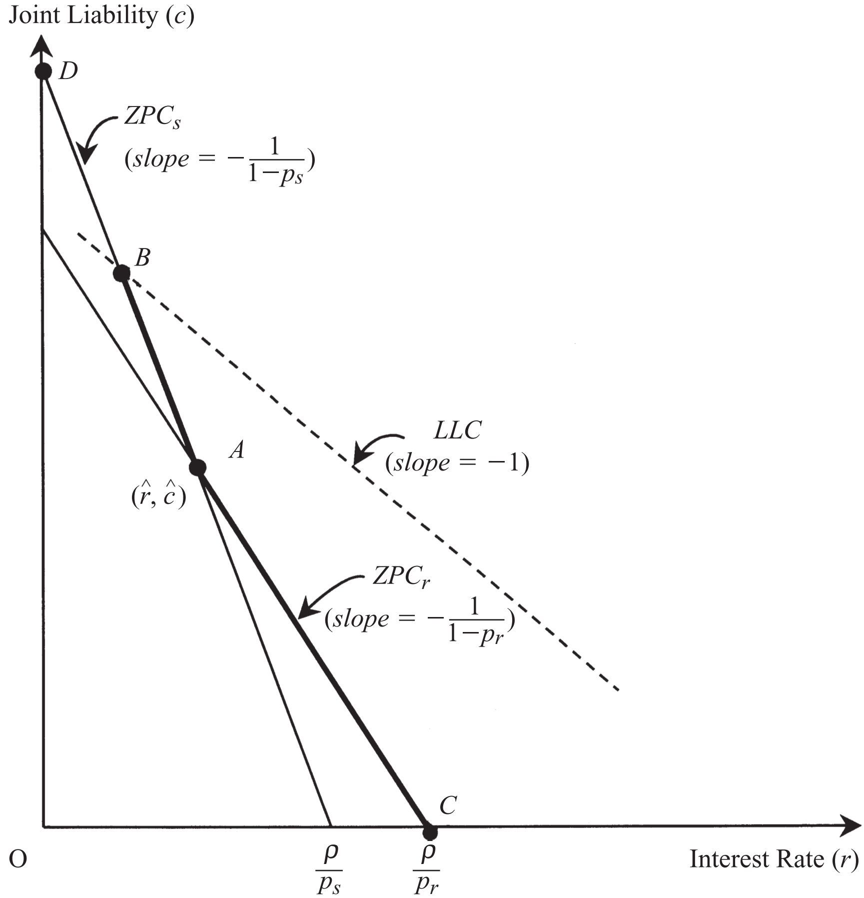

Fig. 2. *Optimal Separating Joint Liability Contracts*

satisfy the *LLC*. The line segments *BA* and *AC* shown in bold depicts the respective sets of optimal contracts for safe and risky borrowers.

Turning next to *pooling* contracts, we show that they exist and achieve higher repayment rates and welfare than individual liability contracts under more general conditions than separating contracts. Assume :

$$\overline{R} > \rho \frac{p_s}{\overline{p}} + \beta \overline{u}. \qquad (A5)$$

where $\beta \equiv [\theta p_r^2 + (1-\theta) p_s^2]/p_s \overline{p} \in (0, 1)$. Then we show:

PROPOSITION 3. *If assumptions A1, A2, A3 and A4 hold then a unique optimal pooling joint liability contract exists and is equal to $(\hat{r}, \hat{c})$. Even if A4 is not satisfied so that optimal separating joint liability contracts do not exist, so long as A5 is satisfied together with A1, A2, and A3, optimal pooling joint liability contracts exist and achieve higher repayment rates and welfare than individual liability contracts.*

Proof. See the Appendix.

In the Appendix we show that even when $A4$ is not satisfied it is possible for $A5$ to be satisfied for low values of $\overline{u}$. Hence optimal pooling contracts exist for a wider range of parameter values than optimal separating contracts. Assumption $A5$ is the counterpart to assumption $A4$ for the pooling equilibrium case. It ensures that the limited liability constraint is satisfied. If $A5$ is not satisfied, then optimal pooling contracts do not exist. Starting with standard debt contracts, a switch to joint liability lending can still improve repayment rates, but it will require subsidies.

If an optimal pooling contract exists, then joint liability payments permit a reduction in the equilibrium interest rate compared to a pure individual-lending contracts. Also, because of endogenous group-formation, even if the contract is the same to all types in nominal terms, the joint liability component entails different expected costs to different types of borrowers. These two factors lead to the participation of safe types under this scheme and an improvement in repayment rates and welfare.

In the (r, c) plane the line $r[\theta p_r + (1-\theta) p_s] + c[\theta p_r(1-p_r) + (1-\theta) p_s(1-p_s)] = k$ (where k is some constant) represents an indifference curve of an *average* borrower as well as an iso-profit curve of the bank when offering a pooling contract. In Fig. 3 we have drawn the set of contracts that satisfy the pooled zero-profit line denoted by the line $ZPC_{r,s}$ together with ZPC_r, ZPC_s and LLC. The slopes of these lines are explained in the proof of the Proposition. In the figure, the way LLC is drawn, $A4$ is seen to be violated. But a set of optimal pooling contracts nevertheless exists as illustrated by the line segment BC. Notice that the intercept of $ZPC_{r,s}$ on the r-axis, $\rho/\overline{p}$, is shown to be greater than that of PC_s, $(\overline{R} - u)/p_s$, which reflects assumption $A2$: under individual liability contracts safe borrowers do not find it profitable to borrow.

3.2.2. *Joint liability lending and the overinvestment problem*

Here we show that joint liability contracts can discourage unproductive risky borrowers from borrowing. Since the proof of the assortative matching property in group-formation, and consequently, the single-crossing property of indifference curves do not depend on the distribution of the revenues of the projects, Proposition 1 and Corollary 1 apply in this case. As the incentive-compatibility and zero-profit constraints are the same as before, the set of incentive-compatible contracts that satisfy the zero-profit constraints for risky and safe borrowers are the same well. But as $rp_r + cp_r(1-p_r) = \rho > p_r R - \overline{u}$ by the assumption that risky projects are unproductive, any contract (r, c) that lies on the zero-profit line of a lender when lending to risky borrowers, cannot satisfy the participation constraint of risky borrowers. Therefore, so long as $(\hat{r}, \hat{c})$ satisfies the limited-liability constraint there exist joint liability contracts with $c > 0$ that ensure risky borrowers do not borrow. The required condition is obtained by substituting $\overline{R}$ by $p_s R$ to obtain the following counterpart of $A4$ in this case:

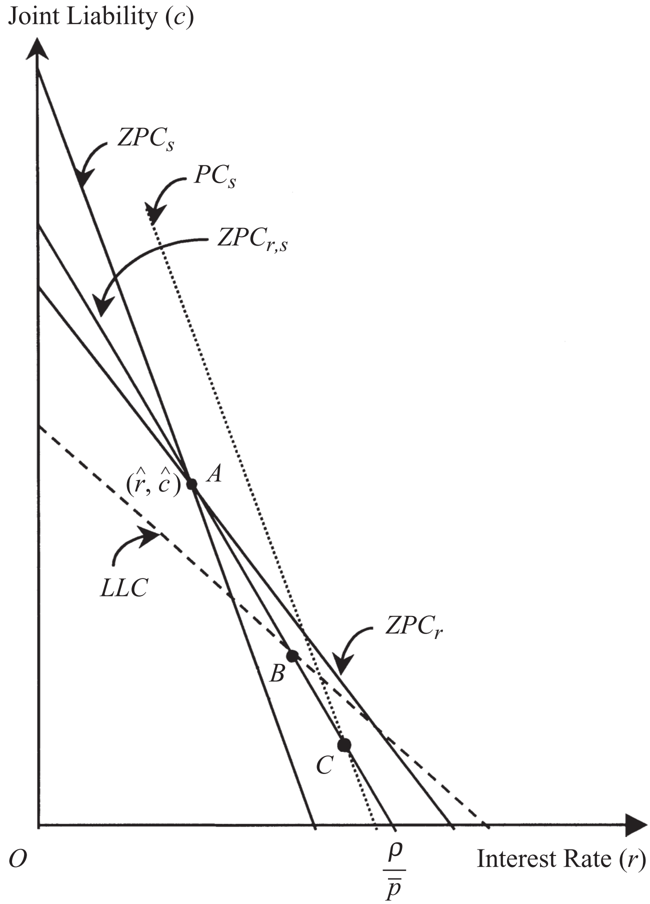

Fig. 3. *Optimal Pooling Joint Liability Contracts*

$$R > \rho\left(\frac{1}{p_s} + \frac{1}{p_r}\right). \qquad (A4')$$

Hence we have:

PROPOSITION 4. *Suppose that the assumptions A1′, A2′, A3 and A4′ hold. If projects have different mean returns and risky projects are unproductive in terms of expected returns, joint liability contracts will discourage risky borrowers from borrowing and thereby achieve a strictly higher average repayment rate and expected social surplus compared to individual liability contracts.*

The economic impact of joint liability contracts is very different in these two environments: in the former, the peer selection effect works to improve the repayment rate and raise welfare by attracting safe borrowers back into the market, while in the latter it drives socially unproductive risky projects out of the market. Saddled with a risky partner and high expected joint liability payments, risky borrowers decide not to borrow. This raises the repayment rate and aggregate social surplus, but not necessarily welfare, as risky borrowers are worse off.

4. Competitive Equilibrium with Joint Liability Contracts

In the previous Section we characterised optimal joint liability contracts in a setting where the bank maximised a weighted average of the expected utility of borrowers subject to feasibility and informational constraints, like a planner. Here we characterise how they can be implemented in a decentralised setting as competitive equilibria. To keep things brief, for the rest of the paper we restrict our attention to the Stiglitz-Weiss model only. Extending the results to the De Meza-Webb model is straightforward. Following Rothschild and Stiglitz (1976) we can define a competitive equilibrium as a finite set of joint liability contracts $\{(r_j, c_j)\}_{j=1}^{N}$ where N is some integer and a selection rule for each type of borrower that satisfies the following conditions:

(i) Borrowers choose a contract that maximises their expected payoff from the set of available contracts.

(ii) Lenders offer contracts that maximise their expected profits and must make non-negative profits on a contract from the menu which some borrowers select.

(iii) No contract can be created that if offered in addition to those in the menu would make strictly positive profits for the seller offering assuming that consumers choose contracts in a manner consistent with (i) above and that the existing contracts are left unmodified.

(iv) All contracts must satisfy the limited liability constraints (3).[24]

We show:

PROPOSITION 5. *Suppose that assumptions A1, A2, A3 and A4 hold so that optimal separating joint liability contracts exist. Then any pair of contracts* (r_s, c_s) *and* (r_r, c_r) *that solves the optimal contracting problem constitutes a separating equilibrium in a competitive credit market where lenders can offer a menu of joint liability contracts. However, a pooling equilibrium does not exist.*

Proof. See the Appendix.

There are a few examples of competition among alternative lending institutions using different amounts of joint liability, such as between Banco Sol and

[24] It is well-known that the game theoretic formulation of competition in contracts in the presence of asymmetric information is not satisfactory (see Freixas and Rochet, 1997). Under the specific extensive form game studied here which is based on Rothschild and Stigltiz (1976) an equilibrium, if it exists, will always be separating. But if one uses slightly different games in which banks are allowed to withdraw contracts that have become unprofitable due to the introduction of a new contract or reject some applicants after observing their choices it is possible for pooling equilibria to exist.

Caja Los Andes in Bolivia. Banco Sol offers loans to self-formed borrowing groups with joint liability, while Caja Los Andes uses individual loans (Conning *et al.*, 1998).[25] Also, among the German cooperatives of the nineteenth century, the Schutze-Delitzsch cooperatives had limited liability, whereas the Raiffeisen-style cooperatives had unlimited liability – any unsatisfied creditor could sue any cooperative member for up to the full amount owed to that creditor (Banerjee *et al.*, 1994).

Proposition 5 has two important implications. First, if one started with a situation where safe borrowers were not borrowing under individual liability contracts, in a competitive equilibrium with joint liability contracts risky borrowers are as well off and safe borrowers are strictly better off. Therefore a competitive equilibrium with individual liability contracts is not constrained Pareto efficient. This is because the former exploits one useful resource which the latter does not, namely the information borrowers have about each other. Second, if a pooling equilibrium with individual liability does exist (i.e., $A2$ does not hold) then the introduction of joint liability will break it.[26] Given that an individual liability contract is a joint liability contract with $c = 0$, this follows from our proof that a pooling equilibrium does not exist with joint liability lending. This means if a group lending programme is introduced in an area, it will have a negative effect on the borrower pools of existing programmes based on individual liability.

5. Some Extensions

Our main results were proved within the framework of a simple model based on many simplifying assumptions. In this section we consider the implications of relaxing some of these assumptions.

5.1. *Risk Averse Borrowers*

First consider the case where everything else is as before, but borrowers are risk averse and their utility of income is a strictly increasing and concave function of income y and is denoted by $u(y)$. We normalise $u(0)$ to 0. It turns out that assortative matching still occurs in the group-formation stage. Now there are two reasons why a risky borrower does not find it profitable to bribe a safe borrower to be her partner. First, like before, the opportunity to benefit from having a safe partner arises less often for a risky borrower. Second, conditional on one's own success a borrower will have two possible income levels depending on whether the partner has failed or not and the non-smoothness of the implied consumption profile is costly when borrowers are risk-averse. And this cost is relatively higher for safe borrowers because they earn less when they succeed than risky borrowers.

[25] I thank Jonathan Conning for suggesting this example.
[26] I thank Debraj Ray for suggesting this question.

Given assortative matching, the expected utility of a type i borrower under a joint liability contract (r, c) is:

$$U_{ii}(c, r) = p_i^2 u(R_i - r) + p_i(1 - p_i) u(R_i - r - c).$$

The slope of an indifference curve of a type i borrower in the (r, c) plane is

$$\left.\frac{dc}{dr}\right|_{U_{ii}=const} = -\left[1 + \frac{p_i}{1 - p_i} \frac{u'(R_i - r)}{u'(R_i - r - c)}\right].$$

So long as $u(.)$ displays constant or decreasing absolute risk-aversion, indifference curve of borrowers over group-lending contracts satisfy the single-crossing property. If a borrower is risk-averse, an increase in the interest rate by a given amount would require a greater cut in the joint liability payment to keep her on the same indifference curve the higher is the initial interest rate and hence higher is the marginal utility of income. Therefore, in the (r, c) plane an indifference curve of a risk-averse type i borrower is negatively sloped and strictly concave (see Fig. 4).

Joint liability has an important property when borrowers are risk averse. By making the success payoff contingent on the performance of the partner, joint liability imposes extra risk on borrowers compared to an individual liability contract that yields the same expected payoff. Intuitively, a joint liability contract (r, c) can be viewed as a lottery from the point of view of a borrower under which there are three relevant states of the world: both she and her partner succeeds, she succeeds and her partner fails, and she fails. These states occur with probabilities p_i^2, $p_i(1 - p_i)$ and $(1 - p_i)$ and the corresponding monetary returns to the borrower are $R_i - r$, $R_i - r - c$ and 0 respectively. Consider two contracts (r_0, c_0) and (r_1, c_1) with $r_0 > r_1$ and $c_0 < c_1$ that have the same expected returns to a type i borrower. Under both contracts the probability of the three relevant states is the same and the borrower receives the same payoff 0 in the third state. But the lower is c the closer the returns in the first two states, $R_i - r$ and $R_i - r - c$, are to each other. Hence the expected utility of a risk-averse borrower is higher under (r_0, c_0) than (r_1, c_1).

This property implies that under full-information the risk-neutral bank would set $c_r = c_s = 0$ and choose $r_r = \rho/p_r$ and $r_s = \rho/p_s$ Let $u_i^* \equiv p_i u[R_i - (\rho/p_i)]$, $i = r, s$. Even though the mean return of both types of borrowers are the same under the full-information contract, safe borrowers have a lower spread between high and low returns and so $u_s^* > u_r^*$. Assume that both types of borrowers choose to borrow at the full-information interest rates, i.e., $u_s^* > u_r^* > \overline{u}$. Under asymmetric information, in the absence of any other screening instrument only pooling individual liability contracts are feasible. Similar to $A2$, if $p_s u[R_s - (\rho/\overline{p})] < \overline{u}$ safe borrowers will pull out of the market.[27] To restore incentive compatibility using a joint liability scheme

[27] Under pooling contracts safe borrowers have lower mean returns as well as lower spread between success and failure returns compared to risky borrowers. If the pooled interest rate $\rho/\overline{p}$ exceeds some critical level the first effect would dominate over the second effect, i.e., there exists $\tilde{r} \in (0, R_s)$ such that for $r > \tilde{r}$, $p_r u(R_r - r) > p_s u(R_s - r)$.

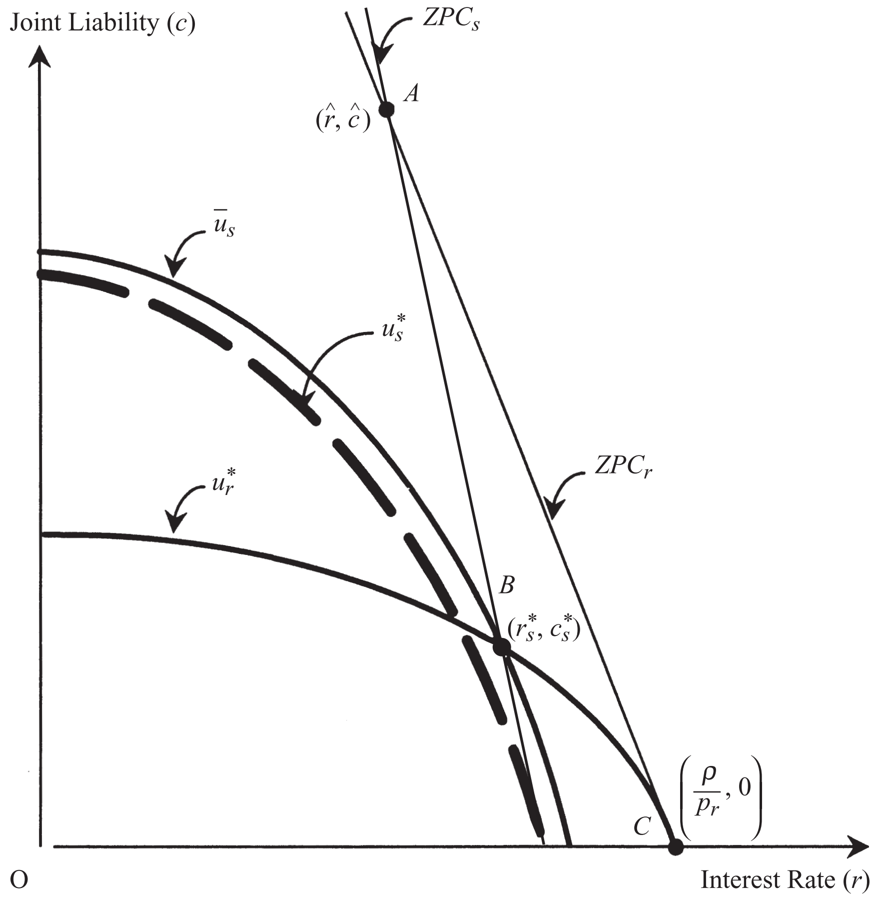

Fig. 4. *Optimal Joint Liability Contracts With Risk Averse Borrowers*

the bank would have to raise c_s from 0 to c_s^* and reduce r_s to r_s^* along the zero-profit line for safe borrowers up to the point risky borrowers are indifferent between $(r_r, c_r) = (\rho/p_r, 0)$ and (r_s^*, c_s^*). Any other pair of contracts that lie on the respective zero-profit lines will either violate the *ICC* or achieve lower expected utility for at least one type of borrower. Formally:

PROPOSITION 6. *If borrowers are risk averse while the bank is risk neutral, joint liability involves inefficient risk sharing. Hence optimal contracts involve the minimum possible use of joint liability necessary to ensure incentive-compatibility. In particular, the unique pair of optimal contracts involve offering loans at the full-information interest rate to risky borrowers and a joint liability contract to safe borrowers.*

We illustrate the optimal contracts in Fig. 4. Under this contract risky borrowers are as well-off as under full-information but safe borrowers are worse off, in order to maintain incentive-compatibility. So the repayment rate is the same under full information while welfare is strictly lower. But as before, joint liability solves the lemons problem and hence is a strict improvement over simple individual liability contracts.

5.2. *Multiple States of the World and Costly State Verification*

One of the informational assumptions of our model, that the bank can contract on the outcome of a project and not the amount of the return, can be derived by using a costly state verification argument. This also shows that our results go through if we allow returns to take more than two values. Assume that it costs the bank C to verify a borrower's project returns and that project returns ($\tilde{y}$) can take many values. The probability distribution of $\tilde{y}$ is given by its cumulative distribution function $F(\tilde{y})$. As before, borrowers have no wealth.

The main issues in the design of an optimal contract in such a setting are: first, the borrower can repay the bank only out of her project returns, second, she will always have an incentive to claim that her returns are at the lowest possible level, and third, to find out whether she is telling the truth the bank will have to incur a cost. The optimal contract turns out to be a debt contract (see Townsend, 1979). If the borrower does not announce bankruptcy, and pays her dues to the bank, it is not optimal for the bank to undertake costly output verification. If the borrower falsely announces bankruptcy under this contract (when $\tilde{y} > r$), the bank verifies the true state of the world and collects all the revenue, $\tilde{y}$, which is greater than the debt, r. Hence it is not optimal for the borrower to lie in such situations. The borrower announces bankruptcy only when her realised return is less than her debt to the bank in which case the bank collects all output net of verification costs. This shows that if verifying returns is costly, the optimal contract is a debt contract under which the borrower either receives 0 with probability $F(r)$ or is the full residual claimant with probability $1 - F(r)$, as in our simple model.[28]

5.3. *Correlated Project Returns*

Another assumption we have maintained throughout is that group members' project returns are uncorrelated. Joint liability contracts work by exploiting *ex post* heterogeneity among project outcomes of borrowers in a group. If project returns are positively correlated, then there is less heterogeneity and less room for the effects of joint liability to work. Take the extreme case of perfect correlation among project outcomes. If one borrower's project fails, then those of her group members fail as well and there is no one to repay the loan. In contrast, when one borrower's project succeeds, then all her group members are successful as well, and there is no need for joint liability. Joint liability works particularly well if project returns are negatively correlated.

[28] Interestingly, introducing costly state verification points to an added source of efficiency gain under joint liability contracts, namely the bank needs to undertake costly audits only when the whole group defaults. Elsewhere (Ghatak and Guinnane, 1999) we have explored this issue in greater detail.

5.4. *Optimal Size of the Group*

Group size has two countervailing effects. If project returns are uncorrelated, an increase in group size improves the effectiveness of joint liability because it increases the number of states of the world in which the group as a whole can repay its members' loans. On the other hand, joint liability works better than other financial contracts because group members have superior information on one another. This advantage is likely to be diluted in larger groups. These considerations would tend to imply small optimal group sizes.

6. Comparing Joint Liability with Alternative Solutions

We have showed how joint liability provides a screening instrument when borrowers know each other's types. In this section we consider some alternative solutions to the lemons problem and compare them with joint liability schemes.

6.1. *Other Screening Instruments and Tax-Subsidy Policies*

The source of the problem with individual liability contracts lies in the absence of another contracting instrument which can be used as a screening device. One set of suggestions offered in the literature involve various screening instruments such as the probability of granting loans and using collateral when borrowers have some collateralisable wealth.[29]

Consider first using the probability of granting loans as a screening device. The following pair of contracts will work. Loans are offered at two different interest rates, namely, the full information interest rates for risky and safe borrowers, but while the loan with the higher interest rate is always granted upon application, the cheaper loan is granted with some probability $\pi_s^* < 1$. Risky borrowers will then self-select the contract under which they receive credit at the interest rate ρ/p_r with certainty. All safe borrowers will apply for the contract under which they receive credit at the interest rate ρ/p_s, although only a fraction π_s^* will be successful in obtaining a loan. The advantage of such a contract over individual liability contracts is that *some* safe borrowers will obtain credit at the full-information interest rate. Hence both welfare and repayment rates will be higher. But they will still be strictly less than that under joint liability because all safe borrowers do not receive credit.

Next consider the case where borrowers have some collateralisable wealth $w > 0$. The bank could try to screen borrowers by offering a menu of contracts that differ in terms of the interest rate r and the collateral requirement, $\gamma \leqslant w$. The expected payoff of a borrower of type i under an individual liability contract with collateral (r, γ) is $U_i(r, \gamma) \equiv p_i R_i - [p_i r + (1 - p_i)\gamma]$. If borrowers have enough wealth to offer as collateral (in particular, $w \geqslant \rho$) it would be possible to attract safe borrowers in by offering two contracts: one with a

[29] See Besanko and Thakor (1987) and Bester (1985).

low interest rate and a high amount of collateral and the other just the opposite. Risky borrowers, who fail and hence lose their collateral relatively more often, would self-select the latter while safe borrowers would select the former. Even if $w < \rho$, so that such a pair of separating contracts does not exist, so long as $w \geqslant \overline{w}$ where $\overline{w} \in (0, \rho)$, a pooling contract (r, c) is shown to exist under which both types of borrowers choose to borrow. But if borrowers are poor (i.e., $w < \overline{w}$) collateral cannot solve the problem of adverse selection.

A policy that is often suggested in the present environment, namely, a balanced budget tax-subsidy scheme is exactly equivalent to an individual lending contract with collateral. Suppose the government offers a subsidy of s per loan to whoever wants to borrow such that safe borrowers find it profitable to borrow, and finances its expenditure through a lump-sum tax t on all members of the village. Since by construction safe borrowers borrow under this scheme, and the size of the population is normalised to 1, the budget-balance condition becomes: $s = t$. The expected cost of borrower i under this scheme is $(r - s)p_i + t = rp_i + (1 - p_i)t$. This is identical to a collateral-scheme of the previous subsection if we replace t by γ. Thus unless the government has the ability to impose lump-sum taxes on borrowers drawing on wealth which is unusable as collateral by private lenders, it cannot do anything to remove the inefficiency that private lenders cannot.[30]

We summarise the analysis in this section with the following proposition:

PROPOSITION 7. *Joint liability contracts strictly dominate contracts that use the probability of granting a loan as a screening device in terms of the average repayment rate and welfare. If borrowers do not have some minimum level of wealth, joint liability contracts also strictly dominate contracts using collateral as a screening device or standard tax-subsidy schemes.*

Proof. See the Appendix.

If borrowers are risk averse the above result has to be modified. Now schemes involving either joint liability or the probability of granting a loan as a screening instrument will make safe borrowers worse off compared to the full-information outcome. Hence they cannot be directly compared in terms of *welfare* without extra assumptions. Still, joint liability contracts involve lending to *all* safe borrowers while the other scheme denies credit to some safe borrowers. Hence the former yields higher *expected social surplus.* Also, while both joint liability and collateral involves inefficient insurance in order to ensure incentive compatibility, joint liability involves a smaller departure from efficient insurance. In particular, 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

[30] Compulsory contribution of labour for public projects may be one way of tapping non-collaterisable wealth.

joint liability merely taxes her when her project succeeds and that of her partner fails.

6.2. *Cross-Reporting Schemes*

The mechanism design literature on environments with complete information suggests a different approach to the problem in the form of a direct revelation scheme. It involves putting all agents together in one single group or a number of smaller groups, and asking each member of a group to announce each other's types simultaneously. If their announcements match, then they are given loans at full-information interest rates. Otherwise none of them are given loans because by limited liability this is the maximum punishment that can be inflicted on a borrower. Then, if all other group-members are making truthful announcements, it is in the best interest of the remaining agent to do so as well.

A well-known difficulty with a scheme like this is that there are many other equilibria, such as one where every agent announces the *same* incorrect vector of types. To avoid this problem sequential mechanisms have been suggested. We illustrate this approach by adapting a sequential mechanism proposed by Ma (1988) for a principal multi-agent model of moral hazard.

Suppose that the bank sorts all borrowers arbitrarily in groups of two. Consider a pair of borrowers A and B who are of types i and j. The bank asks A to announce her own type and that of her randomly assigned partner, B. Suppose that A announces a pair (k, l) of types. Next, the bank asks B whether she agrees with A or not. If A is not challenged by B, the bank offers loans at the respective full-information interest rates ρ/p_k and ρ/p_l to the borrowers. If B disagrees, the bank asks her to announce her own and A's types. Then the bank offers A a loan at an interest rate a little higher than the full-information rate given her type according to B's announcement. It offers B a loan whose terms depend on the outcome of her own and A's projects.

We can show that the planner can always find a lottery that would make it profitable for B to contradict A in case she lies.[31] For instance, suppose both A and B are risky. In that case by setting the transfer associated with the outcome that both borrowers fail very high, the truth can be elicited from B. Knowing that A would tell the truth and get a loan at the full-information interest rate for risky borrowers rather than lying and paying a higher interest rate. Even if there is a limited liability constraint with respect to transfers from the agents to the planner, so long as it does not operate the other way round (and in any case these transfers are made only off the equilibrium path), this scheme works.

A joint liability scheme is a sequential game as well. In the group-formation (second) stage of this game by choosing a partner of a specific type a borrower effectively chooses a specific lottery whose payoffs are contingent on the joint outcomes of her and her partner's projects in the final-stage. Faced with this choice, we showed that borrowers would always select partners of the same type. Anticipating this, in the first-stage we showed that the bank can find joint

[31] A formal proof is straightforward and is available upon request.

liability contracts that attract all types of borrowers and provide them with the same expected payoff as under the full-information outcome.

Hence both joint liability contracts and sequential cross-reporting mechanisms implement the full-information outcome as the unique subgame perfect equilibrium of the corresponding game. There is no loss of surplus – all socially productive projects are undertaken in equilibrium. However, in more general environments, they are not necessarily equally effective.

The joint liability mechanism actually uses lotteries. So the range of parameter values for which it can implement the first-best outcome is limited by the degree of risk-aversion of borrowers, and the tightness of a limited-liability constraint (namely, the revenue from the projects when they succeed should be enough to cover both individual and joint liability payments). In the cross-reporting mechanism, fines cannot be used to punish lying due to limited liability. So the bank has to commit to pay arbitrary amounts of bribes to 'whistleblowers.' which would be higher the more risk averse the agents. Since these bribes are offered in the form of truth-eliciting lotteries, they need to be used off of the equilibrium path only. Hence, the planner does not actually have to pay out anything. This is an advantage cross-reporting mechanisms have over all standard contracting solutions to principal multi-agent problems where agents have private information about each other's types or actions (Ma, 1988).[32]

Despite this advantage, the effectiveness of cross reporting schemes would depend on the planner's ability to commit to large amount of transfers. More importantly, they are vulnerable to collusion in the following way: given that the planner has limited sanctions against an agent who lies, agents might be able to collude by having one of them commit the crime (of lying about their types), the other one catching her and collecting the reward, and then finally both of them splitting it up among themselves at a later date.[33,34] Indeed, in the close-knit social environment that our model is based on, it is quite plausible that agents will also be able to write and enforce side-contracts (e.g. about splitting the bribe) with each other that are not feasible with 'outsiders'. The advantage of the joint liability mechanism is that it is collusion-proof in this environment: indeed, it works by anticipating that assortative matching would occur allowing borrowers to write side-contracts with each other in the group-formation stage.

[32] Cross-reporting schemes are not a purely theoretical artefact. There are frequent examples of uses of them by totalitarian states and they are not unusual in democratic states as well. Recently, a programme called Beat-A-Cheat was successfully introduced in the United Kingdom which established a toll-free line for people to report incidents of welfare fraud among their neighbours (see the *New York Times*, October 29, 1996.)

[33] One is reminded of the Charlie Chaplin movie *The Kid*, where the kid who is Charlie's assistant would break windows glasses and Charlie the window-repairer would accidentally happen to pass by. Andrew Newman suggested another analogy in the movie *The Good, The Bad and The Ugly* a bounty hunter played by Clint Eastwood would help arrest his pal a notorious criminal, collect the reward, rescue him while he is about to be hanged, and move on together to another town to repeat the trick. Notice that neither trick would work more than once in the same place.

[34] Besley and Jain (1994) have made a similar point about the risk of using cross-reporting schemes with arbitrarily large rewards in terms of the possibility of collusion in an environment where large punishments are not feasible

Moore (1992) in his survey the mechanism design literature noted that message games seem to be able to implement anything provided we have the right notion of equilibrium, but they seem to have little resemblance with real world institutions or contractual arrangements. He conjectured that mechanisms that are robust to small changes in the environment and the possibility of side-contracting will turn out to simple. Our analysis suggests that joint liability lending is a good example.

7. Conclusion

In this paper we have proposed a theory to explain how joint liability contracts 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, which is shown to economise on information costs by exploiting local information. The model is based on many simplifying assumptions, and it is of some interest to know how far the results on assortative matching and efficiency advantages of joint liability lending carry on to more general environments. Elsewhere (Ghatak, 1999) we have partly explored this question by allowing for a continuum of borrower types, general distributions of the borrower population, and arbitrary group sizes.

The main idea of the paper that local information among agents can be utilised to provide simple solutions to problems of asymmetric information can also be applied to other contexts. One example is group health insurance in the United States under which the premium paid by the members of a group, such as workers of a firm, depends on the size, demographic composition and to some degree on the average claims made by the whole group. This is referred to as partial (group) experience rating. Other potential applications include contracts for work teams, and preventing abuse of targeted programmes such as poverty alleviation or welfare.

University of Chicago

Date of receipt of first submission: October 1998
Date of receipt of final typescript: September 1999

Appendix

Proof of Lemma 2. For any contract (r, c),

$$U_{ss}(c, r) - U_{rr}(c, r) = (p_s - p_r)[r - c(p_r + p_s - 1)].$$

By $A5$, $p_r + p_s - 1 > 0$. For any contract $(r, c) \in \mathscr{C}^{JL}$ if $r/c \geqslant (p_r + p_s - 1)$, $U_{ss}(c, r) - U_{rr}(c, r) \geqslant 0$, and if $r/c \leqslant (p_r + p_s - 1)$ then $U_{ss}(c, r) - U_{rr}(c, r) \leqslant 0$. Also, by construction,

$$U_{ss}(\hat{r}, \hat{c}) - U_{rr}(\hat{r}, \hat{c}) \equiv 0.$$

Hence the proof follows. Q.E.D.

Proof of Proposition 2. By $A1$, $(\hat{r}, \hat{c})$ satisfies the participation constraint of both safe and risky borrowers. Consider a pair of joint liability contracts (r_r, c_r) and (r_s, c_s) which lie on the zero-profit equations of the bank for risky and safe borrowers respectively. Suppose in addition, $r_s < \hat{r}$, $c_s > \hat{c}$ and $r_r > \hat{r}$, $c_r < \hat{c}$. Then by Lemma 2 these contracts are incentive-compatible. For $(\hat{r}, \hat{c})$ to satisfy the limited-liability constraint, we need $\hat{r} + \hat{c} \leqslant \overline{R}/p_i$ for $i = r, s$. Since $p_s > p_r$, it is sufficient to check the limited liability constraint of safe borrowers, $\hat{r} + \hat{c} \leqslant (\overline{R}/p_s)$. This is satisfied with strict inequality given *A*4. Because of this and since *LLC* is flatter than both ZPC_s and ZPC_s, there exists a compact and convex set of incentive-compatible joint liability contracts (r_s, c_s) on ZPC_s and a similar set of contracts (r_r, c_r) on ZPC_r, that satisfy the limited-liability constraint. Since these contracts lie on the respective zero-profit equations, the payoff of each type of borrower is equal to $(\overline{R} - \overline{u} - \rho)$ and as both types of borrowers choose to participate, the repayment rate is equal to $\overline{p}$. Q.E.D.

Proof of Proposition 3. By construction $(\hat{r}, \hat{c})$ satisfies the zero-profit constraint for a pooling contract with equality. Therefore if *A*4 is satisfied, then $(\hat{r}, \hat{c})$ will satisfy the *LLC* as well. In that case a pooling solution to the optimal contracting problem will exist.

Suppose *A*4 is not satisfied (as depicted in Fig. 3). The absolute value of the slope of $ZPC_{r,s}$ is $1/\{1 - [\theta p_r^2 + (1-\theta) p_s^2]/\overline{p}\}$ where $\overline{p} \equiv \theta p_r + (1-\theta) p_s$. Since $[\theta p_r^2 + (1-\theta) p_s^2]/\overline{p} - p_i = [\theta p_r(p_r - p_i) + (1-\theta)(p_s - p_i)]/\overline{p}$ is negative for $p_i = p_s$ and positive for $p_i = p_r$, in the (r, c) plane $ZPC_{r,s}$ is steeper than ZPC_r but flatter than ZPC_s as shown in Fig. 3. Since the *LLC* is flatter than both ZPC_r and ZPC_s, it is therefore flatter than $ZPC_{r,s}$. Then the contract (r, c) that lies on both $ZPC_{r,s}$ and *LLC*, must satisfy $r > \hat{r}$ and $c < \hat{c}$. By Lemma 2, for such a contract $U_{rr}(r, c) > U_{ss}(r, c)$. Hence, of the two participation constraints, we only need to check that of safe borrowers. The condition under which this contract satisfies PC_s turns out to be *A*5. Notice that $\rho(1 + (p_r/p_s)) > \rho(p_s/\overline{p})$. Therefore even when *A*4 is not satisfied and hence optimal separating contracts do not exist, it is possible for *A*5 to be satisfied and pooling joint liability contracts to exist for low values of $\overline{u}$. Moreover, as $\beta < 1$, *A*2 and *A*5 are consistent with each other. Therefore there is a range of parameter values for which optimal pooling contracts exist while separating contracts do not, and which achieve higher repayment rates than individual liability contracts (by *A*2). Since under this contract safe borrowers are indifferent between borrowing and not (and the bank earns zero-profits) risky borrowers are cross-subsidised by safe borrowers and are strictly better off than under individual liability contracts. Q.E.D.

Proof of Proposition 5. First we show that in equilibrium lenders must earn precisely zero-profits per borrower on any contract that is selected by borrowers. Let (r_r, c_r) and (r_s, c_s) be incentive-compatible contracts chosen by risky and safe borrowers and suppose that firms offering these contracts are making strictly positive profits. If a firm offers the contract $(r_r - \varepsilon, c_r)$ and $(r_s - \varepsilon, c_s)$ where $\varepsilon > 0$ is small it will attract both type of borrowers while continuing to make positive profits. Also, by construction both the incentive-compatibility constraints will be satisfied, as will be the limited liability constraints. But this is not consistent with equilibrium by (iii). Hence lenders cannot make strictly positive profits in equilibrium. By (ii) they must be earning non-negative profits. So lenders must be earning exactly zero profits in equilibrium. This proof goes through if we start with a pooling contract (r, c). It is simpler because by definition of a pooling contract, the *ICC*s are not relevant.

Second, we show that there cannot exist a pooling equilibrium. Suppose not. Let us take the pooling contract $(\hat{r}, \hat{c})$ that yields zero-profits to lenders. Since by Corollary 1 joint liability contracts satisfy the single-crossing property, there exists a contract $(\hat{r} - \varepsilon, \hat{c} + \delta)$ that lies below the zero-profit line for safe borrowers such that all safe borrowers and no risky borrowers are attracted. Also, since $A4$ is satisfied the limited liability constraints are not violated. Consider next the case where a pooling equilibrium exists under individual liability lending, i.e., $A2$ is not satisfied. Instead of $(\hat{r}, \hat{c})$ if we take the pooling individual liability contract $(\rho/\overline{p}, 0)$, by a similar argument it can be broken by a joint liability contract.

These two steps allow us to focus on separating contracts (r_r, c_r) and (r_s, c_s) that satisfy the respective zero-profit, incentive-compatibility and limited liability constraints of the two types of borrowers (contracts that lie on line segments AC and AB respectively of Fig. 2) as candidates for a competitive equilibrium. But by construction these contracts solve the optimal contracting problem. Q.E.D.

Proof of Proposition 7. Let π_i denote the probability of obtaining a loan at the full-information interest rate $r_i^* = \rho/p_i$ to a type i borrower. We show that a unique pair of optimal incentive-compatible contracts exists under which $\pi_r^* = 1$ and $\pi_s^* = (\overline{R} - \rho - \overline{u})/[\overline{R} - p_r(\rho/p_s) - \overline{u}] \in (0, 1)$. Since borrowers are risk-neutral we can focus on contracts that either offer loans at the full-information interest rate, or reject a loan application. The ICCs of risky and safe borrowers can be written as $\pi_r(\overline{R} - \rho - \overline{u}) \geqslant \pi_s[\overline{R} - p_r(\rho/p_s) - \overline{u}]$ and $\pi_s(\overline{R} - \rho - \overline{u}) \geqslant \pi_r[\overline{R} - p_s(\rho/p_r) - \overline{u}]$.

As $p_s > p_r$, $[\overline{R} - p_r(\rho/p_s) - \overline{u}] > (\overline{R} - \rho - \overline{u})$ and so we must have $\pi_r \geqslant \pi_s$ to satisfy ICC_r. Notice that even if $A2$ holds so that a pooling equilibrium does not exist under the non-random scheme, we can never have $\pi_r = \pi_s = 0$ as an optimal contract because by setting $\pi_r = 1$, $\pi_s = 0$ we can always ensure a positive surplus. So $\pi_r > 0$. Then the two ICCs imply:

$$\frac{\overline{R} - p_s(\rho/p_r) - \overline{u}}{\overline{R} - \rho - \overline{u}} \leqslant \frac{\pi_s}{\pi_r} \leqslant \frac{\overline{R} - \rho - \overline{u}}{\overline{R} - p_r(\rho/p_s) - \overline{u}}.$$

Notice that $[(\overline{R} - \rho - \overline{u})/(\overline{R} - p_r(\rho/p_s) - \overline{u})] - [(\overline{R} - p_s(\rho/p_r) - \overline{u})/(\overline{R} - \rho - \overline{u})] = [(\overline{R} - \overline{u})\rho(p_r - p_s)^2]/\{(p_r p_s)/[\overline{R} - p_r(\rho/p_s) - \overline{u}](\overline{R} - \rho - \overline{u})\} > 0$ so an incentive-compatible contract exists. Since the bank maximises the expected utility of a borrower, we want to set π_r and π_s as high as possible, and this yields $\pi_r^* = 1$ and $\pi_s^* = (\overline{R} - \rho - \overline{u})/[\overline{R} - p_r(\rho/p_s) - \overline{u}]$. Safe borrowers are better off applying for a loan in expected terms as by $A1$, $\pi_s^*(\overline{R} - \rho) + (1 - \pi_s^*)\overline{u} > \overline{u}$, but a fraction $1 - \pi_s^*$ of the population of safe borrowers are credit-rationed. In this case, the repayment rate is $\theta p_r + \pi_s(1 - \theta)p_s < \overline{p}$ and the expected payoffs of risky and safe borrowers are $(\overline{R} - \rho - \overline{u})$, and $\pi_s^*(\overline{R} - \rho - \overline{u})$.

Next consider the case of collateral. The contract which satisfies the zero-profit constraint for both borrowers with equality is $r = \gamma = \rho$. Since the slope of her indifference curve in the (r, γ) plane is: $d\gamma/dr = -p_i/(1 - p_i)$, the single-crossing property is satisfied. Hence any contract with $r < \rho$ and $\gamma > \rho$ that satisfies the zero-profit constraint of safe borrowers with equality is incentive-compatible. Similarly, any contract with $r > \rho$ and $\gamma < \rho$ that satisfies the zero-profit constraint of risky borrowers with equality is incentive-compatible. Thus if $w \geqslant \rho$, there exist optimal separating individual liability contracts with collateral. Now consider pooling contracts. The pooled zero-profit equation is $r\overline{p} + \gamma(1 - \overline{p}) = 1$ from which we can solve $r = [1 - \gamma(1 - \overline{p})]/\overline{p}$. Notice that for $\gamma < \rho$, it is the PC of safe borrowers that we have to be concerned with. Substituting this value of r in the PC of safe borrowers we get the minimum collateral needed to attract safe borrowers: $\overline{w} \equiv [\rho p_s - (\overline{R} - \overline{u})\overline{p}]/(p_s - \overline{p})$. Notice that $\overline{w} > 0$ by $A2$ and $\overline{w} < \rho$ by $A1$. Thus even if $w < \rho$, so long as $w \geqslant \overline{w}$, a pooling contract (r, γ) will exist under which both types of borrowers choose to borrow. Q.E.D.

References

Armendariz de Aghion, B. and Gollier, C. (1998). 'Peer group formation in an adverse selection model'. Mimeo. University College, London, and IDEI, Toulouse.

Banerjee, A. V., Besley, T. and Guinnane, T. W. (1994). 'Thy neighbor's keeper: the design of credit cooperative with theory and a test.' *Quarterly Journal of Economics*, vol. 109, no. 2, pp. 491–515.

Becker, G. (1993). *A Treatise on the Family*. Cambridge: Harvard University Press.

Besanko, D. and Thakor, A. (1987). 'Collateral and rationing: sorting equilibria in monopolistic and competitive credit markets.' *International Economic Review*, vol. 28, no. 3, pp. 671–89.

Bester, H. (1985). 'Screening vs. rationing in credit markets with imperfect information.' *American Economic Review*, vol. 75, no. 4, pp. 850–5.

Besley, T. and Coate, S. (1990). 'Group lending and repayment incentives.' Mimeo. Princeton University and University of Pennsylvania.

Besley, T. and Coate, S. (1995). 'Group lending, repayment incentives and social collateral.' *Journal of Development Economics*, vol. 46, no. 1, pp. 1–18.

Besley, T. and Jain, S. (1994). 'Collusion and the design of credit cooperatives.' Mimeo. Princeton University.

Conning, J., Navajas, S. and Gonzalez-Vega, C. (1999) 'Lending technologies, competition, and consolidation in the market for microfinance in Bolivia.' Mimeo. Williams College.

De Meza, D. and Webb, D. (1987). 'Too much investment : a problem of asymmetric information.' *Quarterly Journal of Economics*, vol. 102, no. 2, pp. 281–92.

Freixas, X. and Rochet, J.-C. (1997). *Microeconomics of Banking*, Cambridge: M.I.T. Press.

Fudenberg, D. and Tirole, J. (1991). *Game Theory*, Cambridge: M.I.T. Press.

Ghatak, M. (1999). 'Group lending, local information, and peer selection.', *Journal of Development Economics*, vol. 60, no. 1, pp. 27–50.

Ghatak, M. and Guinnane, T. (1999). 'The economics of lending with joint liability: theory and practice.' *Journal of Development Economics*, vol. 10, no. 1, pp. 195–228.

Guinnane, T. (1994). 'A failed institutional transplant: Raiffeisen's credit cooperatives in Ireland, 1894–1914.' *Explorations in Economic History*, vol. 31, no. 1, pp. 38–61.

Hart, O. and Holmstrom, B. (1987). 'The theory of contracts.' In (T. Bewley, ed.) *Advances in Economic Theory*, pp. 71–155. Cambridge: Cambridge University Press.

Holmstrom, B. and Myerson, R. (1983). 'Efficient and durable decision rules with incomplete information', *Econometrica*, vol. 1, no. 6, pp. 1799–820.

Hossain, M. (1988). *Credit for Alleviation of Rural Poverty. The Grameen bank in Bangladesh*. Research Report 65, IFPRI, February.

Huppi, M. and Feder, G. (1990). 'The role of groups and credit cooperatives in rural lending.' *The World Bank Research Observer*, vol. 5, no. 2, pp. 187–204.

Laffont, J.-J. and N'Guessan, T. (1999). 'Group lending with adverse selection.' Mimeo. IDEI Toulouse.

Ma, C. (1988). 'Unique implementation of incentive contracts with many agents.' *Review of Economic Studies*, vol. 55, no. 4, pp. 555–72.

McKernan, S.-M. (1998). 'The impact of micro-credit programs on self-employment profits: do non-credit program aspects matter?' Mimeo. Federal Trade Commission.

Moore, J. (1992). 'Implementation, contracts and renegotiation in environments with complete information.' in (J.-J. Laffont, ed.) *Advances in Economic Theory*, Volume 1, pp. 182–282. Cambridge: Cambridge University Press.

Morduch, J. (1999). 'The microfinance promise.' *Journal of Economic Literature*. vol. 37, no. 4, pp. 1564–1614.

Rothschild, M. and Stiglitz, J. (1976). 'Equilibrium in competitive insurance markets: an essay in the economics of imperfect information.' *Quarterly Journal of Economics*, vol. 90, no. 4, pp. 630–49.

Stiglitz, J. (1990). 'Peer monitoring and credit markets.' *World Bank Economic Review*, vol. 4.

Stiglitz, J. and Weiss, A. (1981). 'Credit rationing in markets with imperfect information.' *American Economic Review*, vol. 71, no. 3, pp. 393–410.

Townsend, R. (1979). 'Optimal contracts and competitive markets with costly state verification.' *Journal of Economic Theory*, vol. 21, no. 2, pp. 265–93.

Van Tassel, E. (1999). 'Group lending under asymmetric information.', *Journal of Development Economics*, vol. 60, no. 1, pp. 3–25

Varian, H. (1990). 'Monitoring agents with other agents' *Journal of Institutional and Theoretical Economics*, vol. 146, no. 1, pp. 153–74.

Yunus, M. (1994). *Grameen Bank As I See It*. Dhaka: Grameen Bank.