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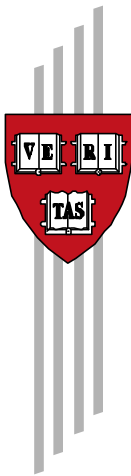
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at Harvard University

Is Grameen Lending Efficient?

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Abstract

Many believe that a key innovation by the Grameen Bank is to encourage its borrowers to help each other in hard times. To analyze this we study a novel mechanism design problem where borrowers share information about each other, but their limited side contracting ability prevents them from writing complete insurance contracts. We derive a lending mechanism which efficiently induces mutual insurance. It is necessary for borrowers to submit reports about each other to achieve efficiency. Such cross reporting increases the bargaining power of unsuccessful borrowers, and is robust to collusion against the bank.

1   Introduction

The Grameen Bank in Bangladesh has achieved high repayment rates on small uncollateralized loans. Its lending scheme is very popular among governments and international agencies, and has been replicated all over the world (Morduch [22]). Many believe that Grameen's lending has been successful because its *joint liability* loans have induced borrowers to provide mutual assistance in hard times (Besley and Coate [6], Yunus [28]). We argue that joint liability is not enough to efficiently induce borrowers to help each other; it is also necessary to ask borrowers to make reports about each other. Such *cross-reporting* is used by the Grameen Bank at village meetings where loan repayments are collected (Rahman [23]).

Cross-reporting mechanisms have been extensively studied in the implementation literature, but so far this literature has either assumed that agents have complete side contracting ability, or else that they are unable to side contract at all (see Maskin and Sjöström [20] for a recent survey).[1] The empirical evidence on village economies suggests that neither assumption is realistic (Townsend [26] and Udry [27]). Accordingly, we assume the borrowers can side contract but not perfectly. Our interest in Grameen lending therefore motivates the analysis of a novel implementation problem.

If borrowers are uninformed about each other, then simple individual loans will suffice. In village economies, however, borrowers often share information (about outputs, effort levels or types) that the bank does not possess. To study the incentives for mutual assistance, we abstract from moral hazard and adverse selection. We consider a strategic default model where agents observe each other's output realizations, while the bank does not. To induce repayment, the bank must punish borrowers who default (by denying future loans, for example). Since punishment implies a deadweight loss, the economic problem is to minimize the punishment imposed in equilibrium. The bank must induce successful borrowers (whose output is high) to help repay the loans of unsuccessful borrowers (whose output is low); this allows unsuccessful borrowers to avoid punishment. An inefficient way to induce mutual assistance is by a simple *joint liability* scheme without cross-reports. All the borrowers in a group are made liable for each other's repayment, i.e. the bank punishes the whole group if some group member fails to repay. If the collective punishment is sufficiently harsh, a successful group member will have an incentive to help repay the loan of an unsuccessful member. But

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[1]The implementation model closest to ours is Hurwicz et al [15]. They assume the agents have no side contracting ability at all.

harsh collective punishments would be imposed in equilibrium whenever the group cannot repay all the loans even by pooling its resources, and this is inefficient. By adding a cross-reporting component to the contract, harsh punishments need only be threatened *out of equilibrium.* If any group member defaults, then borrower j receives a harsh punishment only if borrower $i \neq j$ reports that borrower j is withholding some output from the bank. This allows an unsuccessful borrower i to threaten her successful partner: "Borrower j, help me repay my loan, or I will tell the bank that you refused to help me out and they will impose a harsh punishment on you (but not on me)." This threat induces the successful borrower j to help repay agent i's loan if she can. But suppose borrower j too is unsuccessful. Then agent i does not gain anything by threatening agent j in this way, and so in equilibrium no harsh punishments will be imposed. Cross-reporting therefore reduces the equilibrium punishment. Indeed, cross-reporting is a necessary feature of any efficient lending scheme when borrowers have limited side-contracting ability. Our cross-reporting scheme shifts the bargaining power in the favor of unsuccessful agents. Even if borrowers can collude on the reports they send, unsuccessful borrowers can still compel their successful partners to make repayments on their behalf. So unlike most mechanisms in the implementation literature, cross-reporting does not rely on agents being unable to collude on messages.

We distinguish between *ex ante* side contracting and *interim* side contracting. Ex ante side contracting is comprehensive: it involves complete state-contingent contracts. Interim side contracting is limited: it involves only agreements about what to say to the bank and how much to repay. If borrowers can side contract ex ante, then even with individual loans they will contract to provide mutual assistance in hard times (i.e., they will agree on state-contingent transfers from successful to unsuccessful agents). Neither joint liability nor cross-reporting is necessary for efficiency. If villagers can only side contract in the interim, however, then the design of the bank's lending scheme is crucial. The lending scheme must achieve two objectives: it must compensate for impediments to side contracting between borrowers (incomplete risk-sharing), yet it must also be robust to collusion against the bank. A cross-reporting mechanism efficiently achieves both these objectives. Further, it is efficient in both the ex ante and interim side contracting enviroments. If borrowers can only enforce interim side contracts, then individual and joint liability loans that do not use cross-reports are inefficient: joint liability loans can encourage risk-sharing only at the price of excessive punishments in equilibrium, while individual loans do not induce any risk-sharing at all.

Our model is based on an influential article by Besley and Coate [6]. While Besley and Coate argued that Grameen lending is innovative because it builds on the enforcement capabilities of villagers, we suggest that Grameen lending is innovative for just the opposite reason–it compensates for impediments to enforcement. They compared individual and joint liability loans, and argued that joint liability encourages borrowers to help each other make repayments. Besley and Coate did not solve for the efficient lending scheme and their treatment of side contracting was different from ours. More specifically, they considered two cases. In their first case borrowers cannot enforce any side contracts, and they found multiple equilibria associated with joint liability. In our Appendix we describe a cross-reporting mechanism with a unique equilibrium that strictly dominates all equilibria of any individual or joint liability contract that does not use cross-reports, assuming the agents are completely unable to side contract. Thus, both individual loans and joint liability loans without cross-reports are inefficient in this case. In Besley and Coate's second case, a borrower can "punish" her partner if she does not help repay a joint liability loan, but she cannot punish her partner if she does not help repay an individual loan. Joint liability therefore induces borrowers to help each other repay, while individual loans do not. There is nothing in our paper that corresponds to their second case, since we assume that villagers' side contracting ability is independent of the form of the lending scheme. Conversely, there is nothing in Besley and Coate's article that corresponds to our concept of limited (interim) side contracts.

In this paper we study how cross reporting is the efficient response to limitations in side contracting between borrowers. Other features of Grameen lending may indeed be efficient responses to different imperfections in credit markets. For instance, the widely studied joint liability feature can help overcome the adverse selection problem (Armendariz and Gollier [1], Ghatak [11], Laffont and N'Guessan [16] and Laffont [17]) and the moral hazard problem (Banerjee et al [4], Laffont and Rey [18] and Stiglitz [25]). This literature is surveyed by Ghatak and Guinnane [12]. Additional features of Grameen type lenders, such as direct monitoring, regular repayments and non-refinancing threats, have been studied by Armendariz and Morduch [2] and Bond and Krishnamurthy [8].

Independently of our work, a mechanism design approach to group lending is used by Laffont [17] and Laffont and Rey [18] (see also Besley and Jain [7] for an early contribution). They consider different informational imperfections, and like the articles in the implementation literature, they assume the agents' side contracting ability is either unlimited or non-existent. For

example, Laffont and Rey [18] consider a moral hazard model and find that joint liability loans are efficient if the bank knows that the agents can side contract perfectly, but if the bank knows that the agents cannot side contract at all then a message game is useful. They do not consider what the bank should do if it worries about collusion but is unsure whether or not side contracting is perfect.

Our article is divided into the following sections. The model is described in section 2. The benchmark case when villagers can side contract ex ante is discussed in section 3. The main results on efficient lending when villagers have limited side contracting ability appear in section 4. Section 5 concludes. For completeness, in the appendix we discuss the case where there are no side contracts at all.

2   The Model

There are two agents. They are risk-neutral above a minimum level of consumption, which we normalize to zero. Let c_i denote agent i's consumption and q_i the amount of punishment imposed on her by the bank. Agent i's utility is $u(c_i, q_i) = c_i - q_i$. Limited liability implies $c_i \geq 0$. The maximum feasible punishment is denoted Ψ. Thus, $0 \leq q_i \leq \Psi$. Each agent needs one dollar in order to carry out an investment project. We will restrict attention to contracts that treat the agents symmetrically at the investment stage. Agent i's output is denoted $y_i \in \{0, h\}$. Her project is either a success, $y_i = h > 0$, or a failure, $y_i = 0$. A *state of the world* is a pair $y = (y_1, y_2) \in Y \equiv \{0, h\} \times \{0, h\}$. The probability that state y occurs is denoted $p(y)$. The two random variables y_1 and y_2 may or may not be correlated. Agents are symmetric at the time of the investment, so $p(h, 0) = p(0, h)$.

There is a bank, which could be a subsidized non-profit organization, a part of a competitive banking sector, or operated by a benevolent government. Let r denote the bank's cost of capital. We assume

$$\sum_{y \in Y} p(y) (y_1 + y_2) > 2r \tag{1}$$

so that the projects are viable. Let $b_i(y)$ denote the payment from agent i to the bank in state y. The bank's break-even constraint if it finances both projects is

$$\sum_{y \in Y} p(y) (b_1(y) + b_2(y)) \geq 2r \tag{2}$$

4

The bank can impose a punishment $q_i(y) \in [0, \Psi]$ on agent i in state y. To simplify the discussion we assume $\Psi > h$. Just as in Besley and Coate [6], this non-pecuniary punishment can be interpreted as the denial of future loans, or as the cost of being "hassled" by the bank. Notice that the punishment is a continuous variable. For example, the next loan could be delayed for some time, or additional interest penalties could be imposed. Even if the underlying punishment is binary (a new loan is either made or denied), a continuously variable punishment could be induced by randomization. Punishments are a deadweight loss.[2] As long as loans are made to both agents, maximizing welfare is equivalent to minimizing equilibrium punishment subject to the bank's break-even constraint. Thus, the bank should impose the smallest punishment on default that will generate incentives to repay.

Suppose for the moment that the bank can observe y. In this case, the bank can break even just by threatening to punish, without actually punishing in equilibrium. Let the bank demand a repayment of R^* when a project succeeds, and threaten a punishment of Ψ if a project succeeds but no repayment is made. Let R^* be chosen so that the bank breaks even:

$$R^* \equiv \frac{r}{p(h,h) + p(0,h)} \tag{3}$$

Since $R^* \leq h < \Psi$ by (1), each agent prefers to repay her loan whenever her project succeeds. When the project fails, the bank observes it and does not punish the agent for defaulting. The outcome is *first best*: it is fully efficient since no punishments are imposed in equilibrium.

For the rest of the paper we assume that the bank cannot observe the state of the world y, but each agent observes $y = (y_1, y_2)$.[3] This yields an implementation problem similar to the one discussed by Hurwicz, Maskin and Postlewaite [15]. The timing is as follows.

Time 0. The bank commits to a lending mechanism Γ.

Time 1. Agents receive loans and invest.

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[2] The bank can credibly threaten to impose non-pecuniary punishments, even though they are inefficient ex post. This can be justified in different ways. For example, a long-lived bank may develop a reputation for toughness by refusing to renegotiate its loan contracts. In practice, Grameen does impose non-pecuniary punishments such as delays (Todd [24], Rahman [23]).

[3] Our main results would go through if some auditing technology gives the bank a noisy signal of the state of the world. With auditing, the bank can encourage repayment by severely punishing an agent who does not repay when the signal suggests that she was successful. But if the signal is noisy, then the severe punishment will sometimes be imposed on agents who actually were not successful. A cross-reporting scheme can be used to reduce the expected punishments.

Time 2. Outputs y_1 and y_2 are realized. The state of the world $y = (y_1, y_2)$ is observed by the agents, but not by the bank.

Time 3. Each agent i sends a message $m_i \in M_i$ to the bank and makes a repayment $b_i \geq 0$. (The choice of m_i and b_i is made simultaneously by each agent, without knowing what the other is doing). Here M_i denotes agent i's message space, i.e., the set of admissible messages. The bank can pay a "refund" $z_i = Z_i(m_1, m_2, b_1, b_2) \geq 0$ to agent i and impose a punishment $q_i = Q_i(m_1, m_2, b_1, b_2) \in [0, \Psi]$.

A mechanism Γ is formally defined as a specification of $(M_i, Z_i(\cdot), Q_i(\cdot))$ for each agent $i \in \{1, 2\}$, where M_i is the message space, the function $Z_i(\cdot)$ specifies the "refund" paid to agent i and the function $Q_i(\cdot)$ specifies the punishment imposed on agent i (the arguments of Z_i and Q_i are the messages sent and repayments made by the two agents). There is no need to consider more general mechanisms. For example, asking the agents to send messages before they know the output levels will not be helpful.

The above time line does not specify when and how the agents can side contract with each other. We will refer to side contracting between time 1 and time 2 as *ex ante* side contracting. Side contracting between time 2 and time 3 is *interim* side contracting. Notice that the uncertainty is resolved at time 2. Thus, ex ante side contracts can specify that in asymmetric states the successful agent will provide assistance to the unsuccessful one, but at the interim stage it is too late for such mutual insurance contracts to be written. Empirically, risk-sharing in village economies seems far from complete, so our main interest is in interim side contracting. However, it is necessary to first review the case of ex ante side contracts.

3 Ex Ante side contracts

Suppose the agents can sign binding side contracts at the ex ante stage, before outputs are realized. Ex ante side contracts can specify state-contingent side transfers among the borrowers, state-contingent repayments, and state-contingent messages to the bank. Such side contracts are "complete." The side contracts are assumed to be fully enforceable. In practice, they may be enforced by social sanctions, exclusion from informal insurance or physical violence. Thus, if agents i and j agree *ex ante* to help each other out in hard times, then each agent will be obliged to abide by this agreement.

Since the agents are risk-neutral, any efficient side contract will maximize the agents' expected joint surplus. That is, it will minimize the *sum* of the

agents' expected repayments (minus "refunds") and punishments.[4] The agents effectively act as they were one "composite agent." Therefore, the problem is equivalent to a problem where an artificial composite agent takes two loans, has income $y_1 + y_2$, and suffers a punishment $q = q_1 + q_2$. In this one-agent case, Diamond [9] showed that a mechanism is efficient if and only if, in each state $y = (y_1, y_2) \in Y$, the repayment is

$$b(y) = \min\left\{y_1 + y_2, 2\bar{R}\right\} \tag{4}$$

and the punishment is

$$q(y) = 2\bar{R} - b(y) = \max\left\{0,\ 2\bar{R} - (y_1 + y_2)\right\} \tag{5}$$

where $\bar{R}$ is uniquely determined by the bank's break even constraint

$$\sum_{y \in Y} p(y) \min\left\{y_1 + y_2, 2\bar{R}\right\} = 2r \tag{6}$$

Solving for $\bar{R}$ we obtain

$$\bar{R} = \begin{cases} \frac{r}{p(h,h) + 2p(0,h)} & \text{if } h \geq \frac{2r}{p(h,h) + 2p(0,h)} \\ \frac{r - p(0,h)h}{p(h,h)} & \text{otherwise} \end{cases} \tag{7}$$

It can be checked that (1) implies $h > \bar{R}$. The efficient contract in the artificial one-agent case resembles a standard debt contract where $2\bar{R}$ is the face value of the debt. To induce the artificial agent to repay when she has money, the bank must impose punishment when she does not repay. Since the agent will sometimes be unable to pay $2\bar{R}$, punishment occurs with positive probability in equilibrium, so the outcome is not first best.

Returning to the case of two borrowers who can write ex ante side contracts, and thus behave *as if* they were one composite agent, we can directly apply Diamond's result. A mechanism is *efficient subject to ex ante side contracting* if and only if there exists a joint surplus maximizing ex ante side contract such that in each state $y = (y_1, y_2) \in Y$, the *sum* of the repayments made by the two agents to the bank is given by (4) and the *sum* of the punishments is given by (5). Now $\bar{R}$ is the face value of each agent's debt.

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[4]Since we are restricting attention to symmetric mechanisms, there is no reason for ex ante side contracting agents (who are symmetric and risk neutral) to make side payments. Even without side payments, by the symmetry of the situation there always exists a surplus maximizing side contract with equal payoffs to the agents, and we may suppose this is what the two agents would agree on.

Notice that there are two possibilities, corresponding to the two lines of (7): either $h \geq 2\bar{R}$ or $h < 2\bar{R}$. Notice that $h \geq 2\bar{R}$ if and only if

$$h \geq \frac{2r}{p(h,h) + 2p(0,h)} \tag{8}$$

If $h \geq 2\bar{R}$ then a successful agent (with output h) can repay both loans in full even if the partner fails. In this case, in any efficient mechanism, in states $(h,0), (0,h)$ and (h,h) the joint repayment is $2\bar{R}$ and no punishment is imposed. (In the state $(0,0)$ there is no repayment, and a joint punishment of $2\bar{R}$ is imposed.) If instead $h < 2\bar{R}$ then a successful agent cannot repay both loans in full if the partner fails. In this case, in any efficient mechanism the bank collects $2\bar{R}$ in state (h,h), but in states $(0,h)$ and $(h,0)$ it accepts a partial repayment of $h < 2\bar{R}$. The punishment in states $(0,h)$ and $(h,0)$ will be positive but smaller than if the agents paid nothing. Intuitively, if the borrowers cannot pay back the full face value of the debt, it is efficient to make them pay what they have and to reduce the punishment proportionally.

We now define two simple mechanisms that are efficient subject to ex ante side contracting: individual and joint liability loans with no messages (and no "refunds"). Since there are no messages, we may abuse notation and write $Q_i(b_1, b_2)$ for the punishment imposed on agent i as a function of the repayments b_1 and b_2 made by the two agents. Each agent i gets a loan and is asked to repay $\bar{R}$ to the bank, where $\bar{R}$ is given by equation (7). With *individual liability loans*, for each agent i, if $b_i < \bar{R}$ then $Q_i(b_1, b_2) = \bar{R} - b_i$, and otherwise $Q_i(b_i) = 0$. Thus, with individual loans, agent i's punishment is independent of agent j's repayment. With *joint liability loans*, for each agent i, if $b_1 + b_2 < 2\bar{R}$ then $Q_i(b_1, b_2) = \left[2\bar{R} - (b_1 + b_2)\right]/2$, and otherwise $Q_i(b_i) = 0$. Thus, under a joint liability contract agent i's punishment depends on agent j's repayment.

Equation (4) implies that if $y_i = h$ and $y_j = 0$, then agent i should pay as much as she can up to $2\bar{R}$, that is, until both loans are repaid. With both individual and joint liability loans, the agents have an incentive to agree *ex ante* to behave in this way. That is, they will sign a mutual insurance agreement to help each other out in hard times, thereby reducing the chance of being punished by the bank (the agents are risk neutral, but they dislike punishment). Formally, faced with *either* individual loans *or* joint liability loans, the following ex ante side contract maximizes the agents' joint surplus. The agents agree that after the state is realized, they will pool their wealth. They repay both loans if they can, i.e., if $y_1 + y_2 \geq 2\bar{R}$ then each agent repays $\bar{R}$ to the bank. If $y_1 + y_2 < 2\bar{R}$ then each gives $(y_1 + y_2)/2$ to the

bank. The sum of the repayments and the sum of the punishments in each state would be as in equations (4) and (5), which is efficient. Thus, we have:

Proposition 1 *The individual loans and the joint liability loans are both efficient subject to ex ante side contracting.*

It is straightforward to extend Proposition 1 to the case where a project can have more than two possible output levels.

Clearly, the precise form of the lending mechanism is not very important when the agents can sign complete state-contingent side contracts ex ante. Ghatak and Guinnane [11] pointed out that if perfect risk-sharing is possible then individual liability and joint liability loans result in the same outcome. In fact, for a wide range of possible mechanisms, the agents will maximize joint surplus by signing mutual insurance contracts that minimize the expected punishment. Thus, the cross-reporting mechanism we will describe in section 4 is also efficient subject to ex ante side contracting.

The case of complete ex ante side contracting may not be relevant for many village economies. At the other extreme, if agents cannot enforce any side contracts at all, then implementation theory shows that the bank can achieve the *first best* outcome by extracting all information from the agents. This has been noted by Besley and Jain [7], Laffont and Rey [18], Ghatak [11] and Laffont [17]. For completeness, in the appendix we show how such a mechanism works in our environment. Since the mechanism in the appendix implements the first best outcome if agents cannot side contract at all, it strictly dominates both individual and joint liability loans in that case, but the proviso of no side contracting is crucial: the mechanism is highly vulnerable to collusion. In fact, if at the interim stage the villagers can collude with each other by sending false messages to the bank and limiting repayments, then the first best cannot be implemented by any mechanism. But, cross-reporting is still necessary for "second best" efficiency if the agents can collude interim. This second best problem is the topic of our next section.

4   Interim side contracts

In this section we suppose the agents cannot write state contingent side contracts ex ante, but they can write binding *interim* side contracts *after* they have observed the state of the world. These interim side contracts specify what the agents will say to the bank and what repayments they will make. These contracts are fully enforceable, perhaps by a threat of social sanctions against those who violate a side-agreement. However, interim side

contracts do not allow the agents to share risk efficiently, because at the interim stage the uncertainty has been resolved already. With individual loans, for example, a successful borrower who has not made any ex ante commitments has no reason to help an unsuccessful neighbor repay her loan.

Interim side contracting is a natural assumption for mechanism design in village economies because it captures two important aspects of the problem. First, the mechanism should not rely on the assumption that risk-sharing is perfect, since the empirical studies of village economies reject this assumption. The mechanism should compensate for whatever impediments to efficient risk-sharing exist by encouraging the agents to help each other in asymmetric states ($y_i \neq y_j$). Second, the mechanism should be immune to collusion against the bank. That is, it should not encourage the agents to conspire to lie to the bank, or hide their money from it. Our cross-reporting mechanism will be satisfy both these conditions. Furthermore, it will be efficient subject to ex ante (as well as interim) side contracting, so the bank can safely use it if it is not quite sure about the agents' side contracting ability.[5]

An *interim side contract* specifies, for each $i \in \{1, 2\}$, a (net) side payment τ_i made by agent i to agent j at the time the contract is signed, a (net) side payment τ_i' made *after* they have been to the bank, a message $m_i \in M_i$ that agent i sends to the bank, and a repayment $b_i \geq 0$ made by agent i to the bank. The time line is as follows.

Outputs y_1, y_2	Side contracting Transfers τ_1, τ_2	Messages m_1, m_2 Repayments b_1, b_2	Refunds z_1, z_2 Punishments q_1, q_2	Transfers τ_1', τ_2'

Side transfers must balance: $\tau_1 + \tau_2 = 0$ and $\tau_1' + \tau_2' = 0$. The total net[6] payment made by agent i (to agent j and to the bank) is $\beta_i \equiv b_i - z_i + \tau_i + \tau_i'$, and agent i's final payoff is $y_i - \beta_i - q_i$. The agents' *joint surplus*

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[5] Following the logic of Maskin and Tirole [21], sufficiently ingenious agents can replicate the outcome of an ex ante side contract by setting up their own cross-reporting scheme on the side. However, the Maskin-Tirole criticism of "incomplete contracts" does not apply to the cross-reporting mechanism Γ that we will define in this section. If the bank uses Γ then it does not pay for the agents to set up their own independent message game, because interim side contracting will anyway lead to the maximization of the agents' joint surplus in each state, and adding another message game on the side cannot improve on this. The mechanism Γ simply compensates for whatever deficiency in risk-sharing exists in the community, without relying too much on information about the precise form of side contracts that are written.

[6] It is a net payment since the refund is subtracted.

is $y_1 + y_2 - (\beta_1 + \beta_2) - (q_1 + q_2)$. Let $\beta_i(y)$ denote the total net payment made by agent i in state y, and $q_i(y)$ the punishment suffered by her in state y. It suffices to know $\beta_i(y)$ and $q_i(y)$ to determine agent i's payoff in state y. An interim side contract in state y can be formally represented as $C(y) = (\beta_1(y), \beta_2(y), q_1(y), q_2(y))$.

The interim side contract $C(y)$ is *feasible in state y* if there exists transfers $(\tau_1, \tau_2, \tau'_1, \tau'_2)$, where $\tau_2 = -\tau_1$ and $\tau'_2 = -\tau'_1$, messages $(m_1, m_2) \in M_1 \times M_2$ and repayments $(b_1, b_2) \geq 0$, such that for each $i \in \{1, 2\}$ the following three conditions hold: (i) total net payment made by agent i is no greater than her output y_i:

$$\beta_i(y) = b_i - Z_i(m_1, m_2, b_1, b_2) + \tau_i + \tau'_i \leq y_i, \tag{9}$$

(ii) agent i's repayment to the bank does not exceed her output less the side payment she already made to the other agent:

$$b_i \leq y_i - \tau_i, \tag{10}$$

(iii) the bank's punishment rule is respected:

$$q_i(y) = Q_i(m_1, m_2, b_1, b_2). \tag{11}$$

A side contract $C(y)$ is *efficient in state y* if it is feasible in state y, and there is no other side contract which is feasible in state y and gives a strictly higher payoff to both agents.

Efficient interim side contracting between wealth-constrained agents does not in general imply joint surplus maximization. If $y_i = 0$ and $y_j = h$, then the two agents may sign a side contract C even though another contract C' yields a strictly greater joint surplus for them. For C' might be better for agent i and worse for agent j, and i's gain from switching to C' might be bigger than j's loss, but if agent i has no wealth to transfer to agent j then agent i might be unable to convince agent j to replace C by C'. This kind of consideration is especially important in village economies where unsuccessful agents may be destitute.[7] Baliga and Sjöström [3] discuss a principal-agent model where a monopolistic principal wants the agents to choose an outcome that does *not* maximize the agents' joint surplus (joint

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[7]If agents could freely transfer utility at the interim stage by doing "favors" for each other, then they would be able to maximize their joint surplus. A successful villager could help a destitute neighbor repay her loan, even though she is not contractually bound to do so, in exchange for a "favor." This would lead to perfect risk-sharing which, empirically, seems implausible. In the light of this, it is reasonable to assume that utility is not perfectly transferable at the interim stage: there are no "favors."

surplus maximization involves too little effort). In their model, the principal benefits from the agents' limited side contracting ability. In our model, however, the problem is to maximize the agents' ex ante expected welfare, subject to the bank's break-even constraint. The solution to this problem does imply the maximization of the agents' joint surplus in each state of the world. Thus, the bank does *not* benefit from the agents' limited side contracting ability. Instead, the bank wants to *encourage* the agents to provide mutual assistance to each other.[8] Consequently, the mechanism which is efficient subject to interim side contracting will mimic the outcome of the mechanism that would be efficient subject to ex ante contracting (discussed in section 3). However, while with ex ante side contracting simple individual and joint liability loans are efficient, we will show that a cross-reporting scheme is needed for efficiency with interim side contracting.

The mechanism Γ and the state of the world $y = (y_1, y_2)$ define a game (Γ, y). If the agents do not sign any side contract in the interim stage (so that in particular there will not be any side payments), then they go on to play a non-cooperative Nash equilibrium of (Γ, y) at the bank. Let $u_i(\Gamma, y)$ denote agent i's Nash equilibrium payoff.[9] This is agent i's reservation utility in her interim negotiations with agent j. The side contract $C(y)$ is *individually rational in state* y if $y_i - \beta_i(y) - q_i(y) \geq u_i(\Gamma, y)$ for each $i \in \{1, 2\}$.

Given a set $\{C(y)\}_{y \in Y}$ of interim side contracts, one for each state of the world, the amount of money received by the bank in state y is $\beta(y) \equiv \beta_1(y) + \beta_2(y)$ and the joint punishment suffered by the agents is $q(y) \equiv q_1(y) + q_2(y)$. By the feasibility constraint (9), $\beta(y) \leq y_1 + y_2$ for each $y \in Y$. The break-even constraint for the bank is

$$p(h,h)\beta(h,h) + p(h,0)\beta(h,0) + p(0,h)\beta(0,h) + p(0,0)\beta(0,0) \geq 2r \quad (12)$$

A mechanism Γ is *efficient subject to interim side contracting* if there exists a set of interim side contracts $\{C(y)\}_{y \in Y}$ that are efficient and individually rational and satisfy the break-even constraint (12), and there is

---

[8] The bank wants the agents to help each other repay in asymmetric states, since that increases repayments and reduces punishments. If the bank suspects that complete ex ante side contracting might not exist in the village, it should design a lending scheme that replicates the perfect insurance of an ex ante side contract. Collusion on messages to the bank, on the other hand, is something the bank would like to prevent if it could, since absent such collusion the first best is implementable (see the appendix). However, collusion on messages is possible with interim as well as ex ante side contracting. Thus, the bank cannot do better with interim than with ex ante side contracting.

[9] If there were multiple Nash equilibria of (Γ, y) then we would assume the agents make some selection from the set of Pareto efficient Nash equilibria. The mechanism we construct will have a unique Nash equilibrium, however.

no other mechanism Γ' which has a set of efficient and individually rational interim side contracts that satisfy the break-even constraint with a strictly lower expected punishment.[10]

Proposition 2 *A mechanism Γ is efficient subject to interim side contracting if in each state $y \in Y$, there exists an efficient and individually rational side contract with joint repayment*

$$\beta(y_1, y_2) = \min\left\{y_1 + y_2, 2\bar{R}\right\} \tag{13}$$

and joint punishment

$$q(y_1, y_2) = \max\left\{0, 2\bar{R} - (y_1 + y_2)\right\} \tag{14}$$

where $\bar{R}$ is defined in equation (7).

Proof. See the Appendix. ∎

Notice that the repayments and punishments given in Proposition 2 are the same as those derived for the case of ex ante side contracting. In particular, the efficient outcome is not first best since $q(0,0) > 0$ and, if $h < 2\bar{R}$, $q(0,h) = q(h,0) > 0$ as well (the first best involves $q(y) = 0$ for all y). Next we describe a mechanism which is efficient subject to interim side contracting. In what follows, let $\bar{R}$ be defined in equation (7), let $A \equiv \min\left\{h, 2\bar{R}\right\}$, and let ε be a very small number, $0 < \varepsilon < \Psi - h$. Recall that $h > \bar{R}$ so $A > \bar{R}$.

Consider the following cross-reporting mechanism Γ. After the state is realized each agent i brings an amount $b_i \in \{0, \bar{R}, A\}$ to the bank. If agent i brings nothing, $b_i = 0$, then she can also choose to send a message to the bank, interpreted as a statement that agent $j \neq i$ was successful. Let ϕ denote this message. Thus, there are four possible strategies that agent i could use: 0 denotes the strategy of bringing nothing to the bank and saying nothing, $(0, \phi)$ denotes the strategy of bringing nothing but saying "the other agent was successful," $\bar{R}$ denotes the strategy of repaying ones own loan, and A denotes the strategy of doing as much as possible to repay both loans. Actually, agent i's feasible strategy set may be a strict subset of $\{0, (0, \phi), \bar{R}, A\}$, since repayment may not be feasible for her. If agent i has no money, she can only choose 0 or $(0, \phi)$. Punishments and "refunds" in Γ are described next.

---

[10]Notice that we have defined two notions of efficiency in this section: efficiency of a mechanism and efficiency of a side contract. Hopefully this will not cause confusion.

Agent i's punishment is given by the following matrix, where each row corresponds to a strategy for agent i and each column to a strategy for agent j.

$$
\begin{array}{c|cccc}
 & 0 & (0,\phi) & \bar{R} & A \\
\hline
0 & \bar{R} & A+\varepsilon & A & \Psi \\
(0,\phi) & \Psi & \Psi & \Psi & 2\bar{R}-A \\
\bar{R} & 0 & \Psi & 0 & 0 \\
A & 0 & 0 & \Psi & 0
\end{array}
$$

Thus, for example, if agent i chooses 0 and agent j chooses $(0,\phi)$ then $q_i = A + \varepsilon$.

Agent i's refund is given by the following matrix, where again each row corresponds to a strategy for agent i and each column to a strategy for agent j.

$$
\begin{array}{c|cccc}
 & 0 & (0,\phi) & \bar{R} & A \\
\hline
0 & 0 & 0 & 0 & 0 \\
(0,\phi) & 0 & 0 & 0 & 0 \\
\bar{R} & 0 & 0 & 0 & \bar{R}+\varepsilon \\
A & A-\bar{R}+\varepsilon & 0 & 0 & 0
\end{array}
$$

For example, suppose agent 1 chooses A and agent 2 chooses 0. That is, agent 2 brings no money and keeps quiet (she does not say that agent 1 was successful), while agent 1 in fact tries to repay both loans. In this situation, agent 1 is "rewarded" with a refund and agent 2 is punished (for not reporting that agent 1 was successful). More precisely, agent 1's punishment is $q_1 = 0$ and her refund is $z_1 = A - \bar{R} + \varepsilon$. Since $b_1 = A$, her total repayment (net of the refund) plus punishment is $b_1 - z_1 + q_1 = \bar{R} - \varepsilon$. Agent 2's punishment is $q_2 = \Psi$ and her refund is $z_2 = 0$, so her total repayment plus punishment is $b_2 - z_2 + q_2 = \Psi$. Notice that agent i wants to *minimize* $b_i - z_i + q_i$.

Each cell of the following matrix represents the pair $(b_1 - z_1 + q_1, b_2 - z_2 + q_2)$ for each strategy combination.

$$
\begin{array}{c|cccc}
 & 0 & 0,\phi & \bar{R} & A \\
\hline
0 & \bar{R},\bar{R} & A+\varepsilon,\Psi & A,\bar{R} & \Psi,\bar{R}-\varepsilon \\
0,\phi & \Psi,A+\varepsilon & \Psi,\Psi & \Psi,\bar{R}+\Psi & 2\bar{R}-A,A \\
\bar{R} & \bar{R},A & \bar{R}+\Psi,\Psi & \bar{R},\bar{R} & -\varepsilon,A+\Psi \\
A & \bar{R}-\varepsilon,\Psi & A,2\bar{R}-A & A+\Psi,-\varepsilon & A,A
\end{array}
\tag{15}
$$

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Our next proposition establishes that in each state there is a unique Nash equilibrium: in state $(0,0)$ each agent pays nothing and says nothing; in the states $(h,0)$ and $(0,h)$ the successful agent pays A and the unsuccessful agent pays nothing and says ϕ; and in the state (h,h) each agent repays $\bar{R}$. The Nash equilibrium repayments and punishments agree with those derived in Proposition 2. Notice that if agent i is unsuccessful and agent j is successful, then in the Nash equilibrium, agent j does her best to repay both loans, while agent i truthfully reports ϕ ("agent j was successful"). If $h \geq 2\bar{R}$ then the successful agent j repays both loans (she pays $2\bar{R}$) and there is no punishment, while if $h < 2\bar{R}$ then agent j brings all she has, h, to the bank and there is a fairly mild punishment $q_i = 2\bar{R} - h > 0$ imposed on agent i. This is a Nash equilibrium in this state because if agent j pays any less then, given that agent i says ϕ, agent j receives a severe punishment (either $A + \varepsilon$ or Ψ). But if neither agent is successful, then in the Nash equilibrium each agent i receives a smaller punishment $q_i = \bar{R}$. Severe punishments never occur in equilibrium.

To show the Nash equilibrium is unique, we need to eliminate the possibility where both agents pay nothing and say nothing in the states where at least one agent has been successful. Such strategies are not Nash because a successful agent who makes a repayment A is rewarded with a refund. Moreover, in the state (h,h) we need to eliminate the possibility that agent i pays A and agent j pays nothing but sends the message ϕ. Such strategies are not Nash because agent j could bring $\bar{R}$ to the bank and receive a refund. So the refunds are used to guarantee that in each state there is only one Nash equilibrium. No refunds are given in equilibrium.

Proposition 3 *Let Γ be the cross-reporting mechanism described above. In each state $y = (y_1, y_2)$, the game (Γ, y) has a unique Nash equilibrium, with joint repayment*

$$\beta(y_1, y_2) = \min\left\{y_1 + y_2, 2\bar{R}\right\}$$

and joint punishment

$$q(y_1, y_2) = \max\left\{0, 2\bar{R} - (y_1 + y_2)\right\}.$$

Proof. Consider the game (Γ, y) that the agents play in state y if they do not sign any side contract. There are four possible states of the world.

Case 1: the true state is $(y_1, y_2) = (h, h)$. Each agent i can choose any of the four strategies $\{0, (0, \phi), \bar{R}, A\}$. It can be seen from matrix (15) that A is agent i's best response against 0 and $(0, \phi)$, while $\bar{R}$ is her best response

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against $\bar{R}$ and A . Thus, the unique Nash equilibrium is for each agent to choose $\bar{R}$. There are no refunds. The combined repayment is $\beta(h,h) = 2\bar{R} = \min\left\{2h, 2\bar{R}\right\}$ and the joint punishment is $q(h,h) = 0 = \max\left\{0, 2\bar{R} - 2h\right\}$.

Case 2: the true state is $(y_1, y_2) = (0, 0)$. Since neither agent can pay anything, the only feasible strategies are 0 and $(0, \phi)$. When the infeasible strategies $\bar{R}$ and A are eliminated from the matrix (15), we obtain the matrix

$$
\begin{array}{c|cc}
 & 0 & (0, \phi) \\
\hline
0 & \bar{R}, \bar{R} & A + \varepsilon, \Psi \\
(0, \phi) & \Psi, A + \varepsilon & \Psi, \Psi
\end{array}
$$

Here 0 is the dominant strategy. Thus, the unique Nash equilibrium is for each agent to pay nothing and say nothing. Each agent suffers a punishment of $\bar{R}$. There are no "refunds." The total repayment is $\beta(0, 0) = 0 = \min\left\{0, 2\bar{R}\right\}$ and the total punishment is $q(0, 0) = 2\bar{R} = \max\left\{0, 2\bar{R}\right\}$.

Case 3: the true state is $(y_1, y_2) = (h, 0)$. The successful agent 1 has four possible strategies: $\{0, (0, \phi), \bar{R}, A\}$. Agent 2, who has produced no output, can only choose 0 or $(0, \phi)$. When agent 2's infeasible strategies $\bar{R}$ and A are eliminated from the matrix (15), we obtain the matrix

$$
\begin{array}{c|cc}
 & 0 & (0, \phi) \\
\hline
0 & \bar{R}, \bar{R} & A + \varepsilon, \Psi \\
(0, \phi) & \Psi, A + \varepsilon & \Psi, \Psi \\
\bar{R} & \bar{R}, A & \bar{R} + \Psi, \Psi \\
A & \bar{R} - \varepsilon, \Psi & A, 2\bar{R} - A
\end{array}
$$

Here A strictly dominates all other strategies for agent 1. Agent 2's best response against A is $(0, \phi)$. Thus, the unique Nash equilibrium is for agent 1 to choose A and for agent 2 to choose $(0, \phi)$. Agent 2's punishment is $q_2 = 2\bar{R} - A$. There are no refunds. The joint repayment is $\beta(h, 0) = A = \min\left\{h, 2\bar{R}\right\}$ and the joint punishment is $q(h, 0) = 2\bar{R} - A = \max\left\{0, 2\bar{R} - h\right\}$.

Case 4: the true state is $(y_1, y_2) = (0, h)$. This is similar to case 3. ∎

In Nash equilibrium, the joint repayment plus the joint punishment equals $2\bar{R}$ in each state of the world. That is, $\beta(y) + q(y) = 2\bar{R}$ for all y. Moreover, there is no cell in the matrix (15) where the sum of the entries is strictly less than $2\bar{R}$. Thus, the Nash equilibrium outcome maximizes the agents' joint surplus, so there is nothing else they could do that would make both better off. Therefore, in each state y, agreeing to play according to the (unique) Nash equilibrium of (Γ, y) is an efficient and individually rational interim side contract. Propositions 2 and 3 then imply that Γ is efficient subject to interim side contracting. Thus, we have shown:

Proposition 4 *The cross-reporting mechanism Γ described above is efficient subject to interim side contracting.*

The next question is whether simpler mechanisms, in which agents make repayments but do not send any messages to the bank, can be efficient as well. The answer is no. The conditions derived in Proposition 2 are necessary as well as sufficient for efficiency (this is shown in the Appendix), but no mechanism without cross-reports can satisfy (13) and (14).

Proposition 5 *Any mechanism which is efficient subject to interim side contracting must rely on cross-reports.*

Proof. Proposition 7 in the Appendix shows that (13) and (14) are necessary for efficiency. Suppose the bank does not ask for any reports. We claim that (13) and (14) cannot be satisfied in all states of the world.

Suppose $y = (h, 0)$. To satisfy (13), agent 1 should pay $\beta(h, 0) = A$, which gives her a payoff $h - A$. Suppose however that agent 1 instead decides to bring nothing to the bank. Agent 2 cannot bring anything to the bank either, since she has nothing. Now since the bank does not ask for any messages, all the bank observes is that neither agent is making any repayment. So, while the true state is $(h, 0)$, to the bank it will look like the state is $(0, 0)$, and the bank will punish each agent i by the amount $q_i(0, 0)$. To ensure that agent 1 prefers to pay $\beta(h, 0) = A$ rather than paying nothing and taking the punishment $q_1(0, 0)$, we must have $q_1(0, 0) \geq A$. By symmetry, $q_2(0, 0) \geq A$. So, without cross-reports, the joint punishment in state $(0, 0)$ is $q(0, 0) \geq 2A > 2\bar{R}$. But this violates (14) so the mechanism is inefficient. (The joint punishment in state $(0, 0)$ should only be $q(0, 0) = 2\bar{R}$, as in the Nash equilibrium of the efficient cross-reporting scheme). ∎

Efficiency with interim side contracting leads to the same outcome in each state as efficiency with ex ante side contracting. The important point is that with interim side contracting the efficient outcome cannot be implemented using simple individual or joint liability loans. The intuition is clear. To achieve efficiency, the face value of the debt must be $\bar{R}$, and in the asymmetric states the successful agent must do what she can to repay both loans, i.e., she should pay $A = \min\{h, 2\bar{R}\} > \bar{R}$. Clearly this rules out individual loans. Consider instead a joint liability loan. To motivate the successful agent to pay A in the asymmetric state, she must be punished by at least A if she doesn't pay. But without cross-reports, if only one agent was successful but that agent refuses to pay anything, it looks to the bank as if the state is $(0, 0)$. Consequently, each agent must suffer a punishment of at least A

in state $(0,0)$. This is inefficient. With the efficient cross-reporting scheme each agent's punishment is only $\bar{R}$ in state $(0,0)$. Simple joint liability loans can encourage agents to provide mutual assistance, but only at the price of excessively harsh punishments. Notice that the usefulness of cross-reports is not due to a requirement that mechanisms have a unique equilibrium. Even if we allow multiple equilibria, we cannot support any efficient equilibrium without cross-reports. Nevertheless, our cross-reporting scheme does have a unique Nash equilibrium, hence avoiding some difficulties discussed by Besley and Coate [6].

If, contrary to what we assume in this section, agents *can* side contract *ex ante,* then our cross-reporting scheme is still efficient. Indeed, faced with the cross-reporting mechanism the agents can do no better than to play the unique Nash equilibrium in each state, since it maximizes their joint surplus. Thus, the outcome will be the same whether agents side contract ex ante or in the interim. Since the efficient outcome is also the same with interim side contracts as with ex ante side contracts, the cross-reporting mechanism achieves (second best) efficiency regardless of the precise side contracting ability of the agents. The point is that, without imposing severe penalties in equilibrium, the cross-reporting scheme encourages agents to share risk *even if* they for some reason fail to write ex ante contracts.

5 Conclusion

Previous literature has shown how different features of Grameen-type lending schemes can alleviate various imperfections in credit markets. Besley and Coate [6] and others have emphasized that joint liability can encourage borrowers to help each other repay. According to the Grameen Bank's founder, Grameen successfully encourages its members to "provide one another with peer support in the form of mutual assistance (Yunus [28])." But if borrowers can share risk perfectly, then they will agree to help each other out in hard times even when they have individual loans. Thus, any "peer support" justification for Grameen lending must rely on limitations in side contracting. In fact, empirical evidence suggests that though side contracts sometimes involve contingencies, full risk sharing is not achieved (Townsend [26], Udry [27]). Our paper is a first attempt to study efficient mechanism design with limited side contracting. We show that when villagers are unable to enforce state contingent side contracts, a *cross-reporting scheme* encourages the villagers to help each other out at the lowest possible cost. A joint liability loan without cross-reports can also encourage mutual

assistance, but at a higher cost in terms of the expected equilibrium punishments. Cross-reports are valuable even if borrowers can collude on the reports they send to the bank.

In practice, the Grameen Bank does collect cross-reports at village meetings where loan repayments are made. These reports seem to influence punishments (Rahman [23], p. 122). In addition, if a borrower wants to make a withdrawal from a joint savings account, Grameen asks for an approval (a message) from each member of the group (Gibbons [14], p. 142). We hope that future empirical work will further clarify the (largely implicit) rules that govern how the Grameen uses cross-reports. With regard to punishment, Grameen's joint liability rule specifies that if any group member defaults on her loan, then the entire group should be punished. A harsh punishment would be to completely cut the group members off from all future loans, but Grameen seldom does this. In practice, the punishment usually consists of *delays* of new loans, or "hassling" of borrowers (Hashemi and Schuler [13], Rahman [23], Todd [24]). Harsh punishments seem to be used only as a threat "off the equilibrium path."

Some evidence suggests that replications of the Grameen that do not allow cross-reports are less successful that the Grameen Bank itself. A Grameen replication in Kenya initially gave joint liability loans without any village meetings. Borrowers were simply told to make repayments directly into a bank account. The result was very high default rates, which the bank attributed to a lack of contact with the villagers. When a bank official began making visits to the villages to collect repayments at monthly meetings, and presumably also to collect reports, repayment rates improved (Espisu et al [10]). The bank could probably have improved repayment rates by increasing the punishment for default, but that would have been inefficient.

6   Appendix

6.1   No side contracts

For completeness, we briefly consider what happens if the agents cannot make any side agreements at all. In this case the principal can achieve the *first best* outcome by a simple cross-reporting mechanism. Each agent is asked to repay her loan and to make a statement about the other agent's repayment ability. Let R^* denote the face value of debt, defined by equation (3). After the state y is realized, each agent $i \in \{1, 2\}$ (simultaneously) makes a repayment $b_i \leq R^*$ and sends a message $m_i \leq R^*$ to the bank. The message is interpreted as a statement about how much the *other* agent (agent

$j \neq i$) should repay. Feasibility requires that in each state $y \in Y$, agent j $\in \{1, 2\}$ does not pay more than she has: $b_j \leq y_j$. Agent j's punishment is $q_j = \Psi$ if $m_j \neq b_i$; if $m_j = b_i$ then $q_j = \max\{0, m_i - b_j\}$. If $b_j > m_i$ then agent j gets a refund from the bank, $z_j = b_j + \varepsilon$, where $\varepsilon > 0$ can be arbitrarily small. Since the agents cannot write any binding agreement about how to play, they will play a Nash equilibrium of the game induced by this mechanism.

Proposition 6 *In each state of the world, the cross-reporting mechanism has a unique Nash equilibrium. The Nash equilibrium outcome is* first best *efficient.*

Proof. Suppose the true state of the world is $y = (y_1, y_2)$. Clearly, there is a Nash equilibrium where $b_1 = m_2 = \min\{y_1, R^*\}$ and $b_2 = m_1 = \min\{y_2, R^*\}$. There are no punishments in equilibrium and the bank breaks even, so the outcome is first best. We claim there is no other Nash equilibrium. Since agent j is punished by $\Psi > R^*$ when $b_i \neq m_j$, any Nash equilibrium involves $b_1 = m_2$ and $b_2 = m_1$. If $m_i = b_j < \min\{y_j, R^*\}$, then agent j can increase her payoff by slightly increasing her repayment, since she will then get a refund of $b_j + \varepsilon$. Thus, any equilibrium involves $m_1 = b_2 \geq \min\{y_2, R^*\}$ and $m_2 = b_1 \geq \min\{y_1, R^*\}$. But neither inequality can be strict, so the Nash equilibrium is unique. ∎

The cross-reporting mechanism strictly dominates individual loans and joint liability loans (without cross-reports) since there are no punishments in equilibrium. Moreover, it follows from the definition of *coalition-proof* Nash equilibrium (Bernheim, Peleg and Whinston [5]) that the unique Nash equilibrium must be coalition-proof. Therefore, the equilibrium of the cross-reporting mechanism is resistant to collusion, *as long as the agents cannot sign binding side contracts about how to play.*

6.2   Proof of Proposition 2

An efficient mechanism will surely not punish the agents in state (h, h) or give them money in state $y = (0, 0)$, so from now on we set $q_1(h, h) = q_2(h, h) = 0$ and $\beta_1(0, 0) = \beta_2(0, 0) = 0$. Given the symmetry of the mechanism, there is no loss of generality in assuming side contracts $C(0, 0)$ and $C(h, h)$ treat the agents symmetrically. Thus, from now on we set $\beta_i(h, h) = \beta(h, h)/2$ and $q_i(0, 0) = q(0, 0)/2$ for $i \in \{1, 2\}$. Similarly, we can assume $C(0, h)$ is symmetric to $C(h, 0)$ (except that the roles of the agents have been interchanged) so the *sum* of their repayments is the same in the

two states: $\beta(0, h) = \beta(h, 0)$. Using these simplifications, and the fact that $p(0, h) = p(h, 0)$, the bank's break even constraint (12) can be rewritten as

$$p(h, h)\beta(h, h) + 2p(0, h)\beta(0, h) \geq 2r \tag{16}$$

Since wealth-constrained agents cannot freely transfer utility between themselves, efficient interim side contracting does not necessarily mean maximization of their joint surplus (i.e., the sum of their payoffs). Nevertheless, it is useful to prove a result about joint surplus maximization.

Lemma 1 *Consider a set of interim side contracts $\{C(y)\}_{y \in Y}$. Suppose in each state $y \in Y$, $C(y)$ is feasible and maximizes the agents' joint surplus in the class of all feasible interim side contracts. Then the following inequalities must hold:*

$$q(0, 0) \geq \beta(h, h) \tag{17}$$

$$\beta(0, h) + q(0, h) \geq \beta(h, h) \tag{18}$$

$$q(0, 0) \geq \beta(0, h) + q(0, h) \tag{19}$$

Proof. Since $q(h, h) = 0$, the joint surplus in state (h, h) is $2h - \beta(h, h)$. If instead they signed the side contract $C(0, 0)$ in state (h, h), their joint surplus would be $2h - q(0, 0)$ (this means they behave in state (h, h) just as they would in state $(0, 0)$, making no repayments but suffering punishment). By hypothesis, doing this cannot increase their joint surplus:

$$2h - \beta(h, h) \geq 2h - q(0, 0) \tag{20}$$

Similarly, they cannot increase their surplus in state (h, h) by signing $C(0, h)$ instead of $C(h, h)$, which yields the inequality

$$2h - \beta(h, h) \geq 2h - \beta(0, h) - q(0, h) \tag{21}$$

This proves (17) and (18).

In state $y = (0, h)$, by hypothesis they cannot increase their joint surplus by signing $C(0, 0)$ instead of $C(0, h)$, so the following inequality must be satisfied:

$$h - \beta(0, h) - q(0, h) \geq h - \beta(0, 0) - q(0, 0) \tag{22}$$

Since $\beta(0,0) = 0$, this proves (19). $\blacksquare$

With interim side contracting, an efficient side contract does *not* necessarily maximize the agents' joint surplus in asymmetric states of the world, so inequality (19) may actually be violated. It may happen that in state $(0,h)$ the *sum* of their payoffs would be strictly higher under the side contract $C(0,0)$ than under $C(0,h)$, but still they agree on $C(0,h)$. Indeed, if agent 2 prefers $C(0,h)$ to $C(0,0)$ in state $(0,h)$ then there is no way for agent 1 to convince her to switch to $C(0,0)$ even though it raises joint surplus, since agent 1 has no money to "bribe" agent 2. Hence, $C(0,h)$ may be efficient for the agents even though it is not joint surplus-maximizing.

Lemma 2 *Consider a set of interim side contracts $\{C(y)\}_{y \in Y}$ such that for each $y \in Y$, $C(y)$ is efficient in state y. Then, (17), (18) must hold, as well as the following inequality:*

$$q(0,0) \geq \min\{\beta(0,h) + q(0,h), 2q_2(0,h) + 2\beta(0,h)\} \qquad (23)$$

Proof. The reason why agents who contract interim may fail to maximize their joint surplus is that the ability to make side-transfers is limited by the amount of money an agent has. In state (h,h) this is not a problem, since both agents have money in that state. Thus, it should be clear that any efficient side contract satisfies (17) and (18).[11] Inequality (19), however, may be violated by an efficient contract. That is, signing $C(0,0)$ instead of $C(0,h)$ could raise the sum of the agents' payoffs in state $(0,h)$.

---

[11]For completeness, we prove (18) formally. Suppose $C(h,h)$ is efficient in state (h,h) but the agents' joint surplus is strictly higher with $C(0,h)$ than with $C(h,h)$. We will derive a contradiction. Signing $C(0,h)$ is certainly feasible in state (h,h), so for $C(h,h)$ to be efficient some agent, say agent 2, must be made worse off if $C(0,h)$ were signed in state (h,h). Since the joint surplus would be higher by hypothesis, agent 1 must be better off under $C(0,h)$, i.e., she would get

$$h - \beta_1(0,h) - q_1(0,h) > h - \beta_1(h,h)$$

where $h - \beta_1(h,h) \geq 0$ is agent 1's payoff when $C(h,h)$ is signed (there is no punishment in state (h,h)). Now let the agents sign $C(0,h)$ in state (h,h), but let agent 1 make an additional transfer of $\Delta\tau$ to agent 2 (in addition to whatever transfers she was supposed to make in $C(0,h)$). If we set $\Delta\tau = 0$, then by hypothesis agent 1 is made better off than with $C(h,h)$. If we set $\Delta\tau = h - \beta_1(0,h) > 0$ then agent 1's payoff from this new agreement is non-positive (her net payment will be $\beta_1(0,h) + \Delta\tau = h$, i.e., she will give up all his income), so she is worse off than with $C(h,h)$. But then, since $C(0,h)$ has a higher total surplus, there must exist a feasible $\Delta\tau \in [0, h - \beta_1(0,h)]$ such that both agents strictly prefer the new agreement to $C(h,h)$. So $C(h,h)$ is not efficient, a contradiction. The roles of agents 1 and 2 can be interchanged in this argument. This proves (18). We can prove (17) in a similar way.

If *both* agents prefer $C(0,0)$, then $C(0,h)$ is certainly not efficient in state $(0,h)$. If only agent 2 prefers $C(0,0)$, then since agent 2 has h, there exists some transfer that agent 2 can make to agent 1 to convince her to accept $C(0,0)$ plus the transfer (the argument is similar to the one described in the previous footnote). Then again $C(0,h)$ would not be efficient. So, if (19) is violated and $C(0,h)$ is efficient in state $(0,h)$, then it must be that the unsuccessful agent 1 is the only one who prefers $C(0,0)$ to $C(0,h)$ in state $(0,h)$. In this case, agent 1 cannot convince agent 2 to sign $C(0,0)$ instead of $C(0,h)$, since agent 1 cannot make any side transfer to agent 2 in state $(0,h)$. In state $(0,h)$ agent 2's payoff if $C(0,h)$ is signed is $h - q_2(0,h) - \beta_2(0,h)$ and her payoff if $C(0,0)$ is signed is $h - q_2(0,0) = h - q(0,0)/2$. So agent 2 prefers $C(0,h)$ if and only if

$$h - \frac{1}{2}q(0,0) \le h - q_2(0,h) - \beta_2(0,h) \tag{24}$$

Moreover, $\beta_1(0,h) \le 0$ from (9), so

$$\beta_2(0,h) = \beta(0,h) - \beta_1(0,h) \ge \beta(0,h) \tag{25}$$

But (24) and (24) together imply

$$\frac{1}{2}q(0,0) \ge q_2(0,h) + \beta(0,h) \tag{26}$$

Thus, if the side contract $C(0,h)$ is efficient in state $(0,h)$ and (19) is violated, then (26) must be satisfied. In other words, either (19) or (26) must be satisfied, which is equivalent to (23). ∎

Lemma 2 shows that, in addition to the break even constraint (16), the net repayments and punishments must satisfy (17), (18) and (23). Thus, if a mechanism Γ has a set of efficient and individually rational interim side contracts $\{C(y)\}_{y \in Y}$ that minimize expected punishment subject to these constraints, then Γ must be an efficient mechanism. To complete the proof of Proposition 2, it remains only to solve this minimization problem.

Lemma 3 *Consider the problem of minimizing the sum of the two agents' expected punishment, subject to (16), (17), (18), and (23). The unique solution is $\beta(0,h) = \min(h, 2\bar{R})$, $q(0,0) = \beta(h,h) = 2\bar{R}$, and $q(0,h) = \beta(h,h) - \beta(0,h)$ (where $\bar{R}$ is defined by (7)).*

Proof. Consider two possibilities for a solution to the minimization problem.

Case 1: $q(0, h) = 0$. In this case, (23) reduces to $q(0, 0) \geq \beta(0, h)$ and (18) reduces to $\beta(0, h) \geq \beta(h, h)$. These inequalities imply (17). Hence we may drop (17). Now, $q(0, 0)$ should certainly be reduced until $q(0, 0) = \beta(0, h)$, and $\beta(0, h)$ should be reduced until $\beta(0, h) = \beta(h, h)$ (in order to minimize $q(0, 0)$). The zero profit condition then yields

$$\beta(0, h) = \beta(h, h) = \frac{2r}{p(h, h) + 2p(0, h)} \tag{27}$$

Feasibility requires this to be less than h, which is true if and only if (8) holds. In this case (27) implies $\beta(0, h) = \beta(h, h) = 2\bar{R}$.

Case 2: $q(0, h) > 0$. In this case, (18) must hold with equality, or else $q(0, h)$ could be reduced without violating any constraints. Hence,

$$\beta(0, h) + q(0, h) = \beta(h, h) \tag{28}$$

But (28) and (17) imply (23), so we can disregard (23). There must then be equality in (17), or else $q(0, 0)$ could be reduced. Hence, $q(0, 0) = \beta(h, h)$. Now, increasing $\beta(0, h)$ makes it possible to decrease $q(0, h)$. Therefore, $\beta(0, h)$ must be increased as much as possible: $\beta(0, h) = h$. We determine $\beta(h, h)$ from (16):

$$\beta(h, h) = 2\frac{r - p(0, h)h}{p(h, h)} \tag{29}$$

Now,

$$q(0, h) = \beta(h, h) - \beta(0, h) = 2\frac{r - p(0, h)h}{p(h, h)} - h$$

We need this expression to be strictly positive, which is true if and only if (8) is violated. Notice that in this case (29) implies $\beta(h, h) = 2\bar{R}$.

To summarize, the only possible solution if (8) holds falls under case 1. The only possible solution if (8) is violated falls under case 2. Inspection of the solutions for the two cases completes the proof. ∎

Lemma 3 shows that (13) and (14) is the unique solution to the problem of minimizing the agents' expected punishment subject to the relevant constraints. Since this establishes a lower bound on the expected punishments, (13) and (14) are sufficient for efficiency. This proves Proposition 2.

The following result is needed to prove Proposition 5 in the text.

Proposition 7 *The conditions given in Proposition 2 are necessary as well as sufficient for efficiency subject to interim side contracts.*

Proof. Lemma 2 gives *necessary* conditions that net repayments and punishments must satisfy. Lemma 3 shows that the problem of minimizing the expected punishment subject to these necessary conditions has the *unique* solution given by (13) and (14). Now in fact there exists a feasible mechanism which attains the lower bound on the expected punishment, namely the cross-reporting mechanism Γ defined in section 4 (Proposition 4). Since (13) and (14) is the *unique* solution to the problem of minimizing the expected punishment, we conclude that efficiency *requires* that (13) and (14) are satisfied. ∎

References

[1] Armendariz de Aghion, B. and C. Gollier. 2000. "Peer Group Formation in an Adverse Selection Model," *Economic Journal,* 110:1-12.

[2] Armendariz de Aghion, B. and J. Morduch. 2000. "Microfinance Beyond Group Lending," *Economics of Transition.*

[3] Baliga, S and T Sjöström. 1997. "Decentralization and Collusion," *Journal of Economic Theory,* 83: 196-232

[4] Banerjee, A., T. Besley, and T. Guinnane. 1992. "Thy Neighbor's Keeper: The Design of a Credit Cooperative with Theory and a Test," *Quarterly Journal of Economics.* 84, May, pp. 491-515.

[5] Bernheim, B.D., B. Peleg and M.D. Whinston. 1989. "Coalition Proof Nash Equilibria I: Concepts," *Journal of Economic Theory,* 42:1-12.

[6] Besley, T. and S. Coate. 1995. "Group Lending, Repayment Incentives, and Social Collateral," *Journal of Development Economics*, 46.

[7] Besley, T. and S. Jain 1994. "Collusion and the Design of Credit Cooperatives," George Washington University, draft.

[8] Bond, A. and A. Krishnamurthy 2001. "Credit Denial as a Threat." Northwestern University, draft.

[9] Diamond, D. 1984. "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies,* 51: 393-414.

[10] Espisu, E., G. Nasubo, M. Obuya and K. Kioko 1995. *Lending Through Chikola Groups: Four Years of Experience.* Kenya Rural Enterprise Evaluation Report No. 28, Nairobi, Kenya.

[11] Ghatak, M. 2000. "Screening by the company you keep: Joint Liability Credit and the Peer Selection effect," *Economic Journal,* 110.

[12] Ghatak, M. and T. Guinnane. 1999. "The Economics of Lending with Joint Liability: A Review of Theory and Practice," *Journal of Development Economics*, 60:1.

[13] Hashemi, S. and S. Schuler. 1997. "Sustainable Banking with the Poor: A Case Study of Grameen Bank." John Snow International Working Paper No. 10.

[14] Gibbons, D. 1994. *The Grameen Reader.* Grameen Bank Publications, Dhaka, Bangladesh.

[15] Hurwicz, L., E. Maskin and A. Postlewaite. 1995. "Feasible Nash Implementation of Social Choice Rules When the Designer Does Not Know Endowments or Production Sets," *The Economics of Informational Decentralization: Complexity, Efficiency, and Stability.* John O. Ledyard, ed. Kluwer Academic Publishers. pp. 367-433.

[16] Laffont, J.-J. and T. N'Guessan 2000. "Group Lending with Adverse Selection," *European Economic Review,* 44: 4-6.

[17] Laffont, J.-J. 2000. "Collusion and Group Lending with Adverse Selection," draft, IDEI, Toulouse.

[18] Laffont, J.-J. and P. Rey 2000. "Collusion and Group Lending with Moral Hazard," draft, IDEI, Toulouse.

[19] Maskin, E. 2001 "On Indescribable Contingencies and Incomplete Contracts," draft, Princeton

[20] Maskin, E. and T. Sjöström 2001. "Implementation Theory," *Handbook of Social Choice Theory Vol. 1*, K. Arrow, A. Sen, and K. Suzumura, eds. North-Holland, forthcoming.

[21] Maskin, E. and J. Tirole 1999, "Unforeseen Contingencies and Incomplete Contracts," *Review of Economic Studies* 66:83-114.

[22] Morduch, J. 1999. "The Microfinance Promise," *Journal of Economic Literature* 37 : 4.

[23] Rahman, A. 1999. *Women and Microcredit in Rural Bangladesh.* Westview Press.

[24] Todd, H. 1996. *Women at the Center,* Westview Press.

[25] Stiglitz, J. 1990. "Peer Monitoring and Credit Markets," *World Bank Economic Review.* $43 : 351 - 366.$

[26] Townsend, R. 1994. "Risk and Insurance in Village India," *Econometrica,* $62 : 3, 539 - 91.$

[27] Udry, C. 1994. "Risk and Insurance in a Rural Credit Market: An Empirical Investigation in Northern Nigeria," *Review of Economic Studies,* $61 : 495 - 526.$

[28] Yunus, M. 1999. "The Grameen Bank," *Scientific American,* November, $114 - 119$.