Monitoring by Delegates or by Peers? Joint Liability Loans under Moral Hazard[*]

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Abstract

This paper analyzes the conditions under which joint liability loans to encourage peer-monitoring would be offered and chosen ahead of monitored individual liability alternatives on a competitive loan market when production and monitoring activities are subject to moral hazard. In contrast to other analyses, the case for joint liability loans does not rest on an assumed monitoring or information advantage by borrowers but instead on a incentive diversification effect that cannot be replicated by outside delegates or intermediaries. Joint liability clauses are chosen to implement a preferred Nash equilibrium in a multi-agent, multi-task game, where each borrower must be given incentives to remain diligent as a financed entrepreneur and as a monitor of others.

Keywords: Joint-Liability; Delegated Monitoring; Microfinance; Financial Intermediation.

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1 Introduction

Joint-liability mechanisms such as those employed by the non–profit Grameen Bank of Bangladesh or the commercial Banco Solidario of Bolivia extend loans to members of a circle of borrowers on condition that each borrower should liability for some portion of the loan obligation of others should anyone in the group unable or unwilling to repay. Spurred on initial success and good press, microfinance programs built on the group lending model were replicated widely over the past two decades and today reach a client base that can be counted in the millions. Donors and international aid organization became intrigued and excited to back the further spread of a contractual innovation that seemed to allow previously marginalized borrowers to commit to repay lenders by substituting 'social collateral' for missing physical loan collateral.

Economists were also intrigued and a number of theoretical explanations have been proposed for how joint liability clauses might work in asymmetric information contexts to create incentives for borrowers to peer-select, peer-monitor, or peer-sanction each other.[1] Empirical studies have tried to measure the impact of such interventions (e.g. Pitt and Khandker, 1999; Morduch, 1998; Karlan, 2005) and some economists have even attempted to test between alternative theories of group loans (Ahlin and Townsend, 2005).

Yet despite the widespread attention and frequent celebration of the joint liability lending modality in academic papers and the popular press, the theoretical and empirical case for group loan projects remains far from settled. Microfinance practitioners are far from agreed about the merits of group loans themselves. Critics contend that the purported benefits of group loans have often been exaggerated and that the group methodology is often rigid and poorly adapted to borrowers' changing needs. They argue that simpler individual liability loans monitored by locally recruited loan officers can achieve results as good or better than group loans.[2]

Recent theoretical studies have also raised questions about the purported optimality of joint liability loans in different contexts, or have questioned the empirical validity of

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[1] The case for group loans in the context of ex-ante moral hazard problems has been argued under different assumptions for example by Arnott and Stiglitz (1990), Stiglitz (1990), Conning (1996, 1999), Madajewicz (1997) and Laffont and Rey (2000). The case for group loans to ameliorate the costs of ex-post moral hazard has been explored by Besley and Coate (1995), Diagne (1998), Che (1999) and others. The adverse selection case has been explored by Ghatak (1999, 2000), Sadoulet (1998), van Tassel (1999), Wydick (1999), Armendariz de Aghion and Gollier (2000) and N'Guessan and Laffont (2000). Literature surveys include Ghatak and Guinnane (1999) and Morduch (1999).

[2] Morduch (2000) and Conning (1999) summarize several important debates and disagreements in the field amongst practitioners and policymakers. Simplifying greatly, the so called 'institutionists' tend to favor individual liability lending and the development of 'sustainable' commercial microfinance, while a so called 'welfarist' camp is more likely to support group lending, and places more emphasis on targeted outreach and social mission.

some assumptions upon which earlier arguments were premised.[3] One obvious criticism is that several prior analyses of joint liability lending simply assumed that borrowers enjoyed an information or enforcement advantage relative to outsiders.[4] While such an information advantage may very well important in practice, joint liability loans cease to be quite as impressive or intriguing as a contractual innovation once it is made clear that 'closeness' amongst borrowers has been assumed rather than derived.

The main question addressed in this paper is whether and when there are advantages to assigning monitoring tasks to peers rather than to delegates, when peers and delegates have access to *the same* monitoring technology. The framework is cast in quite general terms, so as to be able to encompass and extend earlier theories of the role of joint-liability and point out how how these contracting models can be mapped onto the canonical principal-agent moral hazard problem (Holmstrom, 1979; Grossman and Hart, 1983) and in particular its application to problems with limited liability constraints (Innes, 1991; Laffont and Martimort, 2002). This points to fundamental connections to important earlier results on multi-task principal agent problems and results on financial intermediation that were derived under the assumption of individual liability lending (Diamond, 1983).

We consider the range of potential financial relationships between a risk neutral uninformed outside investor and an arbitrary number of risk-neutral potential borrowers who may operate projects subject to moral hazard and limited liability. Lenders may choose to lend to borrowers directly via collateral-based contracts, or via the intermediation of a borrowing group or a third-party delegated monitor, whose costly actions are also unobserved and therefore subject to moral hazard.

Limited liability constraints, which arise due to a borrower's lack of collateral or problems of enforcement, restrict the feasible level of repayment that a borrower can make following low project outcomes. Since these constraints place a limit on how much a borrower can be punished for project failures, monetary incentives to diligent choose actions that raise the probabilty that the project will succeed have to then be established via the prospect of 'bonuses' that leave the borrower with a large enough share of the surplus when the project succeeds. This however frequently means that the lender must cede *limited liability rents* to the borrower for incentives to be maintained. By directly reducing a borrowers temptation to moral hazard monitoring may reduce limited liability rents and the need to rely on collateral requirements or monetary bonuses, *delegation rents* may arise out of the need to provide a delegate with monitoring incentives. If the sum of limited liability and delegation rents becomes too large, there may not be enough surplus left over to attract the participation of the outside lender and the project will go unfinanced. We compare alternative con-

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[3] See for example Rai and Sjostrom (2004) or Chowdhury (2005).

[4] This is the main interpretation highlighted in Stiglitz (1990) and in recent literature surveys by Morduch (1999) and Ghatak and Guinnane (1999).

tractual arrangements in terms of how cost effectively they reduce these rents, and therefore how well they enable borrowers' access by reducing collateral requirements and/or borrowing costs.

The analysis begins by recasting the group loan problem with *costless* monitoring (side-contracting) studied by Stiglitz (1990), to highlight how this problem is isomorphic to a principal agent problem with a single agent with limited liability constraints in a multi-task setting (Holmstrom and Milgrom, 1990; Itoh, 1993) but facing limited liability. In the case of risk-neutral borrowers this multi-task problem can in turn be mapped onto the well-studied principal agent problem where a single agent (here a costlessly cooperating coalition) manages a multiple-outcome, single-task project under limited liability as in Innes (1990).

Under joint-liability the coalition and therefore also the representative borrower are made to manage a collection of imperfectly-correlated tasks or sub-projects. Limited liability rents that would have been large relative to the project had each borrower only held claims to her own production project, can now be reduced by having the representative borrower agree to pay for a failure on any one task out of the returns from other successful tasks. Since larger punishments can now be meted out following a signal indicating probable non-diligence on any one task, limited liability rents and collateral requirements can be reduced. Previously excluded borrowers may now gain loan access and joint liability loans can therefore help 'crowd-in' new forms of lending. Several extensions to this basic model are proposed, for instance to determine optimal group size as a tradeoff between greater diversification and rising opportunities for free riding when the social sanctions available to sustain action-contingent side-contracts are finite.

This benchmark joint liability model rests however on the strong assumption that borrowers within a group can costlessly observe and enforce side-contracts on actions. Joint liability loans collapse under the weight of a free-riding problem if this assumption is relaxed, and provide no advantage, and in some contexts, disadvantages compared to individual liability loans.

The paper next turns to the more interesting and realistic scenario where monitoring is a costly and imperfect activity and monitoring actions are chosen non-cooperatively within the group. The analysis builds upon Holmstrom and Tirole's (1997) model of financial intermediation and costly delegated monitoring under individual liability and then further extends it to a joint liability setting. A delegate can help expand access via monitoring only if delegation costs do not rise too rapidly. Strategies to reduce such rents include asking the delegate to put some of their own capital at risk (i.e. to become a financial intermediary) and/or by placing the delegate in a multi-task setting by making them monitor several borrowers. The analysis is parallel to the earlier multi-task analysis and very similar in spirit to Diamond's (1984) model of financial intermediation. Delegation rents can be reduced, and leverage ratios increased, as the number of borrowers N in the delegates' portfolio increases.

Peer-monitors are assumed to have the *same* monitoring technology as a competing monitor. Joint liability contracts emerge as an optimal way to implement a preferred Nash equilibrium in a multi-agent, multi-task game, where each borrower must be given incentives to remain diligent as a financed entrepreneur and as a monitor of others.[5] The advantage of this setup is that whereas a delegate and a borrower face different incentive compatibility constraints, leading to the need to pay both limited liability rents and delegation rents (or at the very least minimum monitoring expenses), group lending places each borrower in a multi-task setting under a single incentive compatibility constraint and joint-liability provides, where incentive diversification arguments can again be applied: a borrower who fails on his own project can now be punished by also reducing their return as a monitor. Where the total cost of lending under a delegated arrangement would be the sum of limited liability and delegation rents, a single rent suffices to provide incentives in the joint-liability multi-task setting. Hence joint liability groups can out-perform delegated monitoring arrangements even when the delegate is a fully diversified financial intermediary and has the same or even a slightly better monitoring technology.

The paper highlights the important role of timing and commitment assumptions in shaping each of these results and discusses how this might relate to policy design choices.[6] The contract must also guard against collusion amongs borowers to reach different subgame perfect Nash Equilibria, and specifically the one where no borrower monitors or is diligent in production.

Putting all of the variants of the model together ends up providing a rich set of predictions regarding the shape of market structures that may emerge on a competitive loan market with heterogenous borrowers who differ in terms of initial collateral asset holdings and project characteristics and how financial intermediaries expand and transform the set of trades that can take place. Some borrowers are offered, and will choose, joint liability loans, other may prefer individual liability contracts with or withoug delegated monitors. Yet others will remain excluded from the loan market.

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[5] In independent work, Madajewicz (2002) examined a related arrangement and finds some related results. One difference between our approaches is that where I build on Holmstrom and Tirole's (1997) model in which monitoring affects the borrowers' opportunity cost of diligence (or the cost of effort), she instead extends Banerjee, Besley and Guinnane (1994) who have 'monitoring' affecting the probability of projects success.

[6] Aniket (2004) builds directly on the model of this paper by extending the time horizon further to analyze 'sequential group loans,' or arrangements where one borrower only receives a loan on the condition that the other borrower repays.

2 Model elements

Consider a population of risk-neutral entrepreneurs identical in every respect except for their initial holding of collateral assets A. Each has access to a risky production project that requires a non-recoverable lump-sum investment I to be initiated. If funded, a project generates verifiable return X_1 if it succeeds and $X_0 < X_1$ if it fails. The probability of success is affected by the entrepreneur's choice of diligence. If she chooses to be diligent, say by exerting effort and using all funds I to purchase required inputs then the project will succeed with probability $\overline{\pi}$ and fail with probability $(1-\overline{\pi})$. If the entrepreneur instead chooses to be non-diligent she is assumed to be able to capture private benefit B from diverting effort and/or funds to other private consumption or production activities but this lowers the probability of success to $\underline{\pi} < \overline{\pi}$. By assumption, outsiders cannot observe the agent's diligence choice nor can they observe or seize any part of B.

The analysis below will at several points be extended to allow a borrower or a delegate to operate or monitor a portfolio of N identical sub-projects or tasks. A simple notational adjustment will allow us to handle both the one-task and the multi-task cases together. If an entrepreneur operated $N = 2$ tasks there would be $2^N = 4$ possible joint outcomes depending on whether each task succeeds or fails. If task outcomes are independent and identically distributed it is sufficient to index joint outcomes by the total number of tasks that have succeeded since the sum of project outcomes will be the same. With $N = 2$ tasks there will be $N + 1 = 3$ contingencies or joint outcomes which can be labeled x_0, x_1 and x_2 corresponding to the total value of output when zero tasks succeed ($x_0 = X_0^1 + X_0^2$), where only one task succeeds ($x_1 = X_1^1 + X_0^2 = X_0^1 + X_1^2$), or when both succeed ($x_2 = X_1^1 + X_1^2$).

Expression $E[x|N,k]$ will indicate total expected project returns from the N different subtasks when the entrepreneur has choosen to be diligent on k out of N tasks. Since the outcome on each task is a Bernoulli trial, the probability of obtaining exactly j successes on N independent Bernoulli trials follows a Binomial distribution. For example, when the borrower is diligent on all N tasks the probability density function will be

$$f(x_j|N,N) = \frac{N!}{(N-j!)j!}\overline{\pi}^j(1-\overline{\pi})^{N-j}$$

and similar, appropriately modified, expressions can be found for $f(x_j|N,k)$ for any $k < N$. The total expected return $E[x|N,k]$ when the agent is diligent on k of N tasks can be written:

$$E[x|N,N] = \sum_{j=0}^{N} f(x_j|N,k)\ x_j \tag{1}$$

This notation encompasses the single task project, where $f(x_1|1,1) = \overline{\pi}$ and $f(x_1|1,0) = \underline{\pi}$. Expected returns to a diligent borrower who operates a simple one-task, two-outcome project are $E[x|1,1] = \overline{\pi}x_1 + (1-\overline{\pi})x_0$ and $E[x_i|1,0] = \underline{\pi}x_1 + (1-\underline{\pi})x_0$ when she is not diligent.

The top panel of Figure 1 depicts the binomial probability density function of joint outcomes when there are $N = 20$ tasks, each task yields a return of 1 or 0. The distribution on the left is the binomial distribution when the entrepreneur is diligent on *zero* tasks, while the distribution on the right corresponds to full diligence, where an entrepreneur is diligent on all N tasks, assuming that $\overline{\pi} = 0.8$ and $\underline{\pi}= 0.7$. The lower panel depicts (a partial view of) the *likelihood ratio*

$$\frac{f(x_j|N,N) - f(x_j|N,0)}{f(x_j|N,N)} \tag{2}$$

This measures the increased probability of observing exactly j task successes when the agent is diligent on all tasks compared to when she is diligent on zero tasks, normalized by the probability of actually observing that outcome under full diligence.

It will be useful to define $l = \underline{\pi}/\overline{\pi}$ as a convenient measure of the relative riskiness of non-diligence compared to diligence. The likelihood ratio associated with the 'all success' outcome where all projects succeed can then be written as

$$\frac{\overline{\pi}^N - \underline{\pi}^N}{\overline{\pi}^N} = 1 - l^N \tag{3}$$

As is suggesed by the lower panel of figure 1, the likelihood ratio associated with the Binomial distribution over joint outcomes is monotonically non-decreasing in the size of the joint outcome:

Claim 1 *For all N the ratio (2) satisfies the monotone likelihood ratio property (MLRP). Moreover, the likelihood ratio for the 'all success' outcome $(1 - l^N)$ is monotonically non-decreasing in N.*

The proof, which is straightforward, is in the appendix. As is well understood, the MLRP is an important property to have in moral hazard problems (Grossman and Hart, 1983) since it implies that higher outcomes are more likely associated with higher diligence than less than full diligence. In the classic one-task moral hazard problem this will generally imply that the optimal contract will be a monotonically non-decreasing function of the project outcome. Applied to the multi-task, delegated monitoring and group lending contexts below (which we show map onto the canonical principal-agent problem with limited liability constraints as in Innes, 1990) this property will imply that the optimal contract will involve a form of joint liability in many cases: by positively tying the reward to any one task on the outcome of another task in the single-agent multi-task case, or by positively tying each borrower's financial contract return to the size of joint outcome in certain group settings.

2.1 Individual liability loans

An individual liability loan contract for a one-task project establishes how project claims x_i,which are assumed verifiable, are to be divided between returns s_i to an entrepreneur/borrower and repayments $R_i = x_i - s_i$ to a lender. The loan market is assumed to be competitive so that borrowers are able to obtain their most preferred feasible loan contract. For the moment we also assume that a lender can stipulate and enforce an exclusive contract. The contract design problem for a borrower with collateral assets A can then be stated as finding contract terms s_i to implement diligence[7] and maximize borrower returns subject to the following constraints:

$$\underset{s}{Max} \quad E[s|1,1] \tag{4}$$

$$E[x|1,1] - E\left[s_i|1,1\right] \geq \gamma I \tag{5}$$

$$E[s|1,1] \geq E[s_i|1,0] + B \tag{6}$$

$$x_i - s_i \geq X_i + A \text{ for } i \in \{0,1\} \tag{7}$$

Constraint (5) is the investor's participation constraint which requires that expected repayments at least cover the lender's opportunity cost of funds. The borrower also has a participation constraint that they earn at least as much from the contract as in their next best activity (here normalized to zero), but this last constraint will typically be satisfied with slack since the lending market is assumed competitive. The borrower's incentive compatibility constraint (6) assures that any feasible contract will credibly commit the borrower to choosing diligence. Writing out and rearranging this constraint yields:

$$\begin{aligned} \overline{\pi} s_1 + (1-\overline{\pi}) s_0 \quad &\geq \quad \underline{\pi} s_1 + (1-\underline{\pi}) s_0 + B \\ s_1 \quad &\geq \quad s_0 + \frac{B}{(\overline{\pi} - \underline{\pi})} \end{aligned} \tag{8}$$

Intuitively, the borrower's return to success s_1 must be sufficiently greater than the return to failure s_0 to generate sufficient incentive for the borrower to want to raise the probability of success by choosing diligence. Limited liability constraints (7) restrict repayment in any given state to not exceed the value of the realized project outcome x_i plus available collateral A. Subtracting x_i from each side, these inequalities can be restated as a restriction on the minimum net return to the borrower, or $s_i \geq -A$ for $i \in \{0,1\}$.

Since by limited liability a borrower cannot be punished with a return any lower than $s_0 = -A$, the incentive constraint (6) can only be satisfied if the borrower is given

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[7] Throughout I assume that diligence is socially efficient while non-diligence implies at a social loss, or $E[x|1,1] - \gamma I > 0 > E[x|1,0] - \gamma I + B$.

an incentive 'bonus' in the success state that offers her at least $s_1 = -A + B/(\overline{\pi} - \underline{\pi})$. Hence, to satisfy both the limited liability and the incentive constraints, a borrower with assets A must earn a minimum expected return of at least

$$\begin{aligned} E\left[s|1,1\right] &= \frac{\overline{\pi}B}{(\overline{\pi} - \underline{\pi})} - A \\ &= \frac{B}{(1-l)} - A \end{aligned} \tag{9}$$

When expression (9) exceeds the borrower's reservation payoff (here assumed to be zero) the lender will have to yield a necessary economic rent to the borrower. Following Laffont and Martimort (2002), I label the term $B/(1-l)$ a *limited liability rent* since it measures the additional cost of providing indirect incentives due to the presence of limited liability constraints. If this rent becomes too large, expected project returns $EX = E\left[x|1,1\right]$ might no longer be sufficient to cover both this rent and the lender's opportunity cost of funds γI. The lender would then refuse to participate in the contract, even though the same project would be profitable in the hands of an entrepreneur who self-financed or who had more collateral wealth (Stiglitz and Weiss, 1981).

Substituting expression (9) into the lender's participation constraint (5) and solving for the level of collateral A at which it just binds yields a value for the *minimum collateral requirement*, or the lowest value of A that a borrower must be able to post if the lender is to be willingly enticed to provide an exclusive individual liability loan of size I:

$$\underline{A}_1 = \frac{B}{(1-l)} - \left[EX - \gamma I\right] \tag{10}$$

where the subscript on $\underline{A}_1$indicates that this is a one-task project. The minimum collateral requirement is equal to the limited liability rent less the expected value of net project returns, $EX = E[x|1,1]$. The individual liability contract with the least amount of collateral that can be offered on a competitive loan market will have $s_0 = -\underline{A}_1$ and $s_1 = B/(1-l) - \underline{A}_1$. Borrowers with assets A larger than or equal to $\underline{A}_1$ will obtain competively priced loans of size I and earn the full surplus $EX - \gamma I$ from the transaction. Entrepreneurs with assets less than $\underline{A}_1$ will be excluded from this particular loan market.

Note that the minimum collateral requirement $\underline{A}_1$ rises with the size of the requested loan I,with the lender's opportunity cost of funds γ,and with the scope for moral hazard as captured by the opportunity cost of diligence B. The minimum collateral requirement will be lower the higher are expected project returns EX and the 'safer' is the diligent project relative to the non-diligent project, as captured by a lower value of $l = \underline{\pi}/\overline{\pi}$. This last result suggests that lenders might prefer to steer asset poor borrowers toward safer sectors or borrowing activities[8]. This provides an early clue as to why grouping tasks under one borrower, or grouping borrowers into a group may help reduce collateral requirements, as will now be shown.

2.2 Loans for multiple tasks

Suppose that instead of working on a single production project the entrepreneur could operate N smaller independent projects each $1/N^{th}$the size of the original. If the original project yielded X_0 or X_1, each subproject or task n now yields X_0/n or X_1/N, and requires I/N investment funds. The opportunity cost of diligence on each task is now also B/N. If the entrepreneur is diligent on all tasks, this portfolio of subprojects will generate the same expected return EX as the original larger single-task project and at the same total opportunity cost of diligence B. For example, rather than work a single agricultural plot, a farmer might scatter her plots around the village, or they might scale back on farming activities in order to diversify into non-farm activities. Diversified production strategies of this sort are widely used by poor households in developing countries although this has usually been interpreted as a consumption smoothing strategy by risk-averse households (McCloskey, 1976). The analysis here suggests why diversification activities might also be part of a strategy to expand access to financial contracts.

If this entrepreneur were to seek outside funding from a single lender for this portfolio of N subprojects the problem would have to be analyzed as a multi-task principal agent problem (Holmstrom and Milgrom, 1991) with limited liability constraints. Since there are two outcomes per task, there are in principle 2^N possible joint outcomes or contingencies. Each contingency can be indexed by an N-element vector $I = (i_1, ...i_N)$ where $i_n \in \{0, 1\}$ indicates success or failure for each task n. However, when subprojects are identically distributed binary outcomes there will be in effect only $N + 1$ possible *aggregate* project outcomes in which case it will be convenient to economize on notation and index joint outcomes by the total number of successful outcomes $j = 0, 1, N$ as described earlier.[9]

There are now also $N + 1$ action choices or different ways that the borrower can affect *overall* expected returns, ranging from choosing to be diligent on zero to all N subprojects. The contract design problem is now to maximize expected borrower returns $E[s|N, N]$ subject to the lender's participation constraint, limited liability, and the following $N + 1$ incentive compatibility constraints to assure that the borrower prefers to choose diligence on all N projects rather than on any smaller k number of

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[8] For example, asset-poor farmers might have access to loans for safer traditional crops but not for riskier but possibly higher-yielding non-traditional crops.

[9] The parties are assumed to observe individual outcomes and not only the aggregate ones, and they would use this information in the contract if it served a useful purpose.

projects :

$$E[s|N,N] \geq E[s|N,k] + (N-k)B/N \quad \text{for all } k \in \{1,N\} \tag{11}$$

The key advantage of multi-tasking and diversification is that this set of incentive constraints is more relaxed than the earlier incentive constraint on a single larger project (6). Subdividing the original project into smaller independent tasks and financing all tasks together under a single contract expands access by lowering the overall minimum collateral requirement relative to the individual liability alternatives of either 'unlinked' individual liability contracts for each separate task, or the original undivided larger project:

Proposition 2 *On a competitive loan market, the optimal loan contract for an N-task project impliments diligence on all tasks at minimum collateral requirement*

$$\underline{A}_N = \frac{B}{(1-l^N)} - (EX - \gamma I) \tag{12}$$

The contract rewards the borrower when all projects succeed, $\widetilde{s}_N = Z_N - \underline{A}_N$, and punishes fully under all other contingencies, $\widetilde{s}_j = -\underline{A}_N$ for $j \neq N$ where

$$Z_N = \frac{B}{(\overline{\pi}^N - \underline{\pi}^N)} \tag{13}$$

The collateral requirement $\underline{A}_N$ is monotonically decreasing in the number of independent subprojects N.

Details of the proof are in the appendix. The advantage of a multi-task contract derives from the fact that it allows a borrower to pledge to pay for failure on any one task out of the returns from other successful tasks. By increasing the expected 'punishment' to the borrower for failure on any one task compared to separate individual liability contracts without such 'joint-liability' or interdependencies across tasks, the contract is able to economize on the costly incentive bonuses that would have otherwise had to have been paid out to any one task that succeeds. This reduces the size of the limited liability rent and hence opens up room to expand loan access by lowering the minimum collateral requirement.[10]

Another way to see this, and to understand the shape of the optimal contract, is to notice that this multi-task principal-agent problem maps onto the more canonical contracting problem studied by Innes (1990) of a risk-neutral principal (lender) contracting with a risk-neutral agent who manages a *single*-task but multiple outcome project subject to moral hazard and limited liability. To see this recall that the $N+1$

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[10] Laux (2001) has a discussion of similar results in the context of task allocation within firms.

possible aggregate returns that can result from N identical subprojects with outcome X_0 or X_1 can be indexed by the number of subprojects $j \in \{0, N\}$ that succeed, as in $x_j = jX_1/N + (N-j)X_0/N$. The borrower can now be thought of as having a choice between $N+1$ distinct 'effort levels' on this single task indexed by k according to the number of underlying component tasks operated with diligence. As previously described in (1) and illustrated in figure 1, x_j will be distributed as a binomial conditioned by the chosen effort level.

As is well understood in the single-task moral hazard setting when the agent is *not* subject to limited liability constraints a first-best solution to with a risk neutral agent is to make the agent a full residual claimant. A fixed debt contract (FDC) that obligates the borrower to repay fixed level γI regardless of project outcome, or $s_j = x_j - \gamma I$ would generate such incentives. This however may not be feasible due to limited liability if the fixed repayment γI exceeds total project returns x_j plus available collateral A in any state(s). As shown by Innes (1990; Proposition 2) given that the distribution of x_j has the MLRP, the optimal contract in such a context will be a *live-or-die* contract (LDC) that places all of the reward on the highest (and most informative) project outcome x_N. Adapted to the multi-task setting this implies the entreprenneur receives a strictly positive transfer when all projects succeed and earns a fixed return $-\underline{A}_N$ (i.e. hands over repayment $R_j = x_j + \underline{A}_N$ equal to output plus collateral) under all other outcomes.

The highly fine-tuned nature of the LDC reward structureemerges because the most cost-efficient way to provide incentives to a risk-neutral agent is to concentrate all reward on the single outcome that is most informative that the agent has chosen diligence. This will be the joint outcome with the highest likelihood ratio, which by the MLRP property of Claim 1 is 'all success' where all N tasks succeed.[11] Innes (1990) also demonstated however that if one imposes a few additional reasonable monotonicity constraints on the contracting environment and assume MLRP (which is guaranteed by our assumptions) then the optimal contract solution becomes a more familiarly ubiquitous Standard Debt Contract (SDC) which has the borrower pay a fixed repayment $\overline{R}$ for all joint outcomes above a given threshold and all output plus required collateral otherwise.

'Monotonicity constraints' simply impose the requirement that any repayment schedule $R_j = x_j - s_j$ must be non-decreasing in x_j, or that $R_j \geq R_{j'}$for all $x_j \geq x_{j'}$. There are good reasons to justify such constraints in practice. First, if the optimal contract did not satisfy monotonicity then a lender might be tempted to try to sabotage or mis-measure the borrower's project outcomes in an effort to avoid the low repayment or borrower 'bonus' outcomes. Also, under non-monotonic contracts entrepreneurs might be tempted to secretly borrow output from other agents to pretend to have

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[11] Laffont and Martimort (2002, 164) refer to this type of contract as a *bang bang* reward structure.

higher output in order and get away with a low repayment to the lender in ways that could undermine the contract (Innes,1990). If any of the monotonicity constraints bind an standard debt contract solution will emerge. Obviously, since new constraints have been imposed, a standard debt contract cannot improve on the unconstrained LDC and may provide weaker incentives. This implies a somewhat higher minimum collateral requirement with a SDC than the $\underline{A}_N$ in the Proposition above.

With or without monotonicity constraints the underlying logic of incentive diversification remains the same however: pledging returns from successful tasks to cover obligations arising from failures on other tasks can lower the size of needed limited liability rents and thereby increase loan access. Since this is the case the results that follow below are first derived using the more simple and intuitively explained LDC case, before discussing how monotonicity constraints may lead to (sometimes important) qualifications.

2.3 Joint Liability Loans with Costless Monitoring

Stiglitz (1990) provided an early treatment of group lending under the assumption of *costless* 'peer-monitoring' or what Tirole (1992) has labeled the *full side-contract assumption* that agents can costlessly observe each others action choices and enter into binding *action*-contingent side-contracts or cooperation. Borrowers' actions can now be analyzed as if they were decided by a single-minded collective or coalition. Each borrower's project is now a task or subproject managed by the coalition, and the contracting problem is then exactly like the multi-task case of the last section. This section briefly restates and extends Stiglitz' results to establish a relevant benchmark against which to compare the non-cooperative, costly-monitoring scenarios to follow. Stiglitz demonstrated that a two person joint-liability loan could be used to encourage costless side-contracting (or 'peer-monitoring') that increased the size of the loans that could be offered to borrowers with *zero* collateral. Here we adapt his model to the fixed loan size, variable-collateral setting analyzed above with groups of arbitrary size N.

The notation is as in the multi-task case with j indexing the total number of borrowers' whose projects that succeed. Let $\mathbf{X}_I = (X^1_{i_1}, ...X^n_{i_n}...X^N_{i_N})$ indicate a given realization of project returns across the group, where borrower $n \in \{1, N\}$ receives realization $i_n \in \{0, 1\}$. Let $x_j = (jX_1 + (N - j)X_0)/N$ now indicate the *average* return per borrower where j indexes the number of projects in the group that succeed. The outside lender will now establish a coalition contract that makes the entire group responsible for repayments on any given project. For simplicity we shall assume for now that members of the group simply divide up net project returns symmetrically amongst themselves. This is without loss of generality because, a side-contracting coalition of risk-neutral agents will always choose to maximize total expected group returns per borrower s_j and then efficiently redistribute returns amongst themselves via side transfers to match whatever redistributive preferences (or balance of bargaining power) exists within the group.

On a competitive lending market the coalition now chooses the group contract that maximizes expected net return *per borrower* $E[s|N, N]$ subject to the lender's and the agents participation constraints as well as to incentive constraints to commit the group to diligence on each of the N subprojects or tasks within the group. When all constraints of this problem are stated in per-borrower terms, and s_j is the average return per borrower, the setup of the problem becomes *exactly* as the multi-task problem of the last section. The following result, similar in spirit to Stiglitz (1990) follows immediately:

Proposition 3 *On a competitive loan market, the optimal N-borrower loan contract implements diligence on all borrowers' projects at minimum collateral requirement per borrower $\underline{A}_N < \underline{A}_1$. The contract involves a joint-liability structure that rewards the group when all projects succeed, $s_N = Z_N - \underline{A}_N$, and 'punishes' all borrowers for the failure of any one borrower, $s_j = -\underline{A}_N$ for all $j \neq N$ where $\underline{A}_N$ and Z_N are as defined in (12) and (13) above.*

The intuition is as before. When all projects can be consolidated under the management of a single-minded coalition the most efficient way to economize on the costly incentive 'bonuses' that lead to limited liability rents and exclusion under individual liability loans is to re-allocate rewards toward the single outcome with the highest likelihood ratio where all projects succeed. This solution immediately imposes a joint-liability structure that punishes each borrower for the failure of any one other borrower in the group.

With additional monotonicity constraints imposed, it may no longer be possible to concentrate all reward on the highest likelihood ratio, forcing the contract to redistribute rewards toward the next highest-likelihood ratios until all constraints are satisfied and borrowers' obtain access. The result would be a group-level standard debt contract which still implies a form of joint liability.

Unfortunately, this and Stiglitz' closely related result turns out to be somewhat of an embarrassment of riches as it suggests that collateral requirements can be driven ever lower simply by increasing group size.

Corollary 4 *The minimum collateral requirement $\underline{A}_N$ is monotonically decreasing in group size N and can be brought to zero with finite N.*

With a very large and diversified group the variance of average project returns, and the cost of providing incentives falls, allowing for greater outreach as the collateral requirement becomes vanishingly small. This follows simply from the fact that l^N

falls with N in (12). In the limit $\underline{A}_N$ converges to $B - (EX - \gamma I) < 0$ as N increases without bound, where the sign of the inequality follows from our earlier assumption that diligence is socially profitable but non-diligence is not. This implies negative collateral for very large groups, or in other words a guarantee of a positive net return of approximately $(EX - \gamma I) - B > 0$ in all states but for the one that all projects succeed, in which case the borrower receives a bonus. The minimum group size at which loan access becomes possible with zero collateral can be found by setting $\underline{A}_N = 0$ in (12) and solving for N.

Free Riding, Social Sanctions, and Optimal Group Size The result that barriers to access fall with group size seems unlikely. Although microfinance lenders such as FINCA International successfully work with 'village banks' of twenty or more jointly liable borrowers most microfinance providers tend to limit group size to between two and seven borrowers. One factor that might be expected to limit group size is the concern that borrowers could find it difficult to sustain cooperative arrangements and enforce side-contracts. Costless side-contracting implicitly *assumes* that group members not only observe each others' diligence choices but can enforce them by credibly threatening sanctions against any member who deviates from such a cooperative agreement.

One way of thinking of this is that borrower actions are observable but not verifiable but that the proposed cooperative equilibrium is sustained via a credible threat to impose a social sanction F_N on any borrower who chooses non-diligence. In other words sanctions F_N must be large enough to assure that *individual* incentive compatibility constraints for each and every borrower are now also satisfied, along with the coalition incentive compatibility constraints (11) to assure that borrowers do not collude to switch to a lower action equilibrium. Substituting the earlier optimal joint liability contract of Proposition 3 into the typical individual-level incentive compatibility constraint would look as follows:

$$\frac{\overline{\pi}^N B}{(\overline{\pi}^N - \underline{\pi}^N)} - \underline{A}_N \geq \frac{\underline{\pi}\overline{\pi}^{N-1} B}{(\overline{\pi}^N - \underline{\pi}^N)} - \underline{A}_N + B - F_N \tag{14}$$

When no social sanctions are available, so $F_N = 0$, it is easy to see that the above incentive constraint will *always* be violated. That is, in the absence of sufficient social sanctions borrowers acting non-cooperatively always have an incentive to free-ride or defect from the proposed joint-liability contract. Much stronger individual-level incentives must be provided to insure that every borrower chooses diligence in the non-cooperative case. If we are to insist on a joint liability contract of the LDC form then the contract will again be of the form $s_{I_s} = Z'_N - A$ where I_s indicates the state where all projects succeed and $s_I = -A$ for all $I \neq I_s$. With $F_N = 0$,individual incentive constraints (14) can then be met if we set Z'_N to at least

$$Z'_N = \frac{B}{(\overline{\pi}^N - \underline{\pi}\overline{\pi}^{N-1})}$$

The expected return under this joint liability contract would then be $\overline{\pi}^N Z'_N - A = B/(1-l) - A$. This, however, is exactly the same limited liability rent (9) that was obtained when we analyzed separate *individual* liability contracts for each borrower. From this we may conclude that:

Remark 5 *Without an assumed enforcement advantage that gives group members the ability to enforce action-contingent side-contracts, joint-liability contracts offer no advantage over individual liability loans.*

When costless side contracting cannot be assumed, a classic Prisoner's Dilemma problem arises as each borrower has an incentive to *free-ride* to capture a personal payoff at the expense of joint profits. Since in the non-cooperative case any joint liability loan must satisfy the same incentive constraint as an individual liability loan, joint liability replaces the borrower's success return s_s under an individual liability loan by an equivalent lottery that makes each borrower's reward depend on the outcomes of other borrowers' projects (which they are now powerless to affect). A risk-neutral borrower is indifferent between these two choices but a risk-averse borrower should strictly prefer an individual contract since joint liability adds risk without any incentive benefit. If monotonicity constraints are imposed to restrict feasible contract solutions to standard debt contracts then, depending on parameters, individual loans may actually dominate group loans for $N > 2$, even for risk-neutral borrowers as Che (2002) illustrates with a simple example.

The case for joint liability loans in Stiglitz' analysis therefore rests on the assumption that group members can threaten social sanctions to enforce action-contingent contracts in ways that outsider lenders cannot. To explore the role of such sanctions in sustaining the proposed costless side-contracting solutions, let F_N be the minimum required social sanction that *would* exactly deter a borrower in a group of size N from defecting from the contract of Proposition 1. In a indefinitely repeated game framework, F_N might be the present discounted value of the cash stream lost from being cut off from further access to loans.[12] F_N is defined to be the smallest value that just satisfies (14) above. Solving for F_N and examining its properties leads to the following observation:

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[12] Che and Yoo (2001) provide an insightful analysis of joint liability in a repeated moral hazard setting that endogenizes social sanctions. They argue that joint-liability may provide an important role in sustaining preferred equilibria in two-person groups, even in contexts where joint liability is not an optimal contract in the static case. Joint liability clauses provide a "built-in punishment device for peer sanction," by helping to sustain more effective punishment threats.

Claim 6 *The minimum social sanction* $F_N = \frac{(l-l^N)}{(1-l^N)}B$ *needed to sustain the minimum collateral peer-monitoring equilibrium of Proposition 3, is monotonically increasing with group size* N*,with* $\lim_{N\to\infty} F_N = B \cdot l$.

Hence, although a larger group size N increases diversification opportunities that can lower the collateral requirement, it also becomes more and more costly to contain free-riding as group size increases. The ability to impose social sanctions will in practice typically depends on the nature of the community and how well the borrowers know each other and interact in other spheres. Suppose that these circumstances place an exogenous cap $F < B \cdot l$ on the size of the social sanction that can be credibly threatened by the group against any borrower. The optimal joint-liability group size will then be determined by the largest integer number of borrowers N such that $F_N \leq F$. Since, as is often argued, rural agents are usually less mobile and live in more tightly-knit and tradition and social norms ruled communities than their urban counterparts, joint liability groups could be expected to be less frequent and/or smaller in size in urban areas. Hence larger joint liability groups such as village banks would tend to be found mostly in rural areas. On the other hand, project returns are more likely correlated in rural areas, and this would tend to work toward making the opposite prediction, as will be discussed later.

2.4 Costly delegated monitoring

We turn next to financial contracts with *non*-cooperative interactions and *costly* monitoring. First we look at contracts with costly delegated monitoring building on the individual liability lending contracts above and Holmstrom and Tirole's (1997) model of financial intermediation. In the next section we compare these results to an intermediary structure where monitoring is carried out by peers instead of delegates.

Consider again an uninformed lender seeking to finance a single borrower except that now the lender may also involve a delegated monitor in the contract who by exerting variable expense c, is able to exert monitoring and control activities that directly limit the borrower's scope for moral hazard by reducing the borrower's potential private benefits from non-diligence from $B = B(0)$ to $B(c) < B$. Although the borrowers' actual choice of diligence will remain unobserved by the delegate or lender, we assume that 'monitoring and control' activities can reduce the borrower's private returns to non-diligence. For example, microfinance loan officers may make frequent unexpected visits to an entrepreneur's business or place of residence to check that loan funds and effort commitments are being applied to the financed activity and not to other private projects. The return to non-diligence might then be reduced due to the borrower's increased cost of concealing and diverting funds or peraps simply because a borrower might feel guilt at deceiving a monitor who has shown a willingness to establish a personal stake in the project and has made very frequent visits. To fix ideas, let's assume, quite reasonably, that monitoring effort c lowers $B(c)$ but at a diminishing rate.[13]

Assumption 1: *$B(c) \geq 0, B_c < 0$ and $B_{cc} > 0$ for all $c \geq 0$.*

A financial contract will establish how the property claims x_i generated by the financed project are to be distributed between repayments to an uninformed lender R_i, payments to a delegated monitor w_i, and returns to the borrower $s_i = x_i - R_i - w_i$. Following Holmstrom and Tirole (1997), the timing of the contracting game is as follows: first a contract is proposed and accepted or rejected by the parties; Next loans are disbursed and, if a monitor is to be involved, she chooses her monitoring intensity c; Finally, project outcomes are realized and the verifiable returns are distributed according to the agreed-upon terms of the contract. Since the delegate's monitoring intensity cannot be verified by the outside lender, they will want to make sure that incentives to monitor are created by tying the delegate's renumeration w_i to the observable outcomes of the borrower's project.

Consider first the case where the delegate has sufficient 'intermediary capital' to put up $I^m \leq I$ of her own capital at risk in the borrower's project so as to either attract the funding participation of an outside investor or to provide the entire loan herself, whichever is smaller. The opportunity cost of the delegate's funds is γI^m. One interpretation of I^m is that it is the part of the total loan I financed by the delegate, leaving $I^u = I - I^m \geq 0$ to be leveraged from the outside lender. Alternatively, but equivalently, the delegate can be thought of as becoming a guarantor or co-signer on the loan, agreeing to be liable for up to γI^m of the loan obligation in the event that the borrower's project fails. Under either interpretation, the delegate's liability or loss in the event a failure in the borrower's project is $w_0 = -\gamma I^m$. Assuming competition in monitoring and lending activities, an optimal individual liability contract will maximize the borrower's expected return subject to the following constraints:

$$\max_{s_i,\, w_i} E[s_i|1,1]$$

$$EX - E[s_i|1,1] - E[w_i|1,1] \geq \gamma I \tag{15}$$

$$E[w_i|1,1] - c \geq 0 \tag{16}$$

$$E[s_i|1,1] \geq E[s_i|1,0] + B(c) \tag{17}$$

$$E[w_i|1,1] - c \geq E[w_i|1,0] \tag{18}$$

$$s_i \geq -A \qquad w_i \geq -\gamma I^m \tag{19}$$

Expected value $E[s_i|1,1]$ is conditioned on the borrower being diligent on his one task project, while $E[w_i|1,1]$ is conditioned on the delegate diligently monitoring this one

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[13] A simple function that satisfies this property is $B(c) = B/(c+1)$. It is straightforward to analyze other monitoring functions, for example by considering the effect of adding a fixed cost of monitoring.

borrower at the minimum required intensity (to be determined). Constraint (15) is the investor's participation constraint while (16) is the delegated monitor's break-even condition that their expected return covers the cost of monitoring and other costs (normalized to zero). Expression (17) is the borrower's incentive compatibility constraint, while (18) is the delegate's incentive compatibility constraint that she prefer to monitor each borrower to not monitoring at all, and (19) are limited liability constraints for the borrower and the monitor respectively.

A range of different optimal financial contracts and intermediary structures can be analyzed by varying the amount of borrower collateral A and the amount of available 'intermediary capital' I^m.

2.4.1 Delegated monitoring with intermediary capital

If any funds at all are to be raised from outside investors (i.e. if $I^u > 0$), those investors will want to be assured that the delegate has contractual incentives to monitor sufficiently such that the borrower remains diligent. Contracts should aim to reward a delegate when the monitored borrower's project succeeds and 'punish' them for failures. Similar to how we rewrote the borrowers' incentive constraint in (8), the monitor's incentive constraint (18) can be re-written:

$$w_s \geq w_f + c/(\overline{\pi} - \underline{\pi}) \tag{20}$$

The least costly way for a contract to provide a delegate with incentives to monitor at intensity c is to set $w_f = -\gamma I^m$ and $w_s = c/(\overline{\pi} - \underline{\pi}) - \gamma I^m$ so that (20) binds exactly. The expected return to a monitor net of the cost of monitoring c must therefore be set to be at least

$$\begin{aligned} E[w|1,1] - c &= \frac{\overline{\pi}c}{(\overline{\pi} - \underline{\pi})} - \gamma I^m - c \\ &= \frac{lc}{(1-l)} - \gamma I^m \end{aligned} \tag{21}$$

This is a *delegation rent* very much like the limited liability rent in (9) because it measures the cost of providing incentives. Notice that the delegate can commit to reducing the size of the rent by increasing the amount of funds γI^m that she is able and willing to put at risk in the project, much like a borrower can reduce the size of a limited liability rent if they possess collateral. From (21) it is clear that the delegation rent must be strictly positive unless the delegate can commit to assume a personal liability of at least

$$\underline{I}_1^m(c) = \frac{lc}{\gamma(1-l)} \tag{22}$$

Suppose first that the delegate is able to put up this amount of intermediary capital. The delegation rent (21) is then pushed to zero and the total cost of delegation will simply be the expense of covering the delegate's monitoring costs $E[w|1,1] = c$.[14] How much monitoring and intermediary capital, and what minimum collateral requirement per borrower will be required? To find out note that the uninformed lender will only participate if expected project returns are sufficient to cover the uninformed lenders' opportunity cost of funds, or if

$$\begin{aligned} EX - E[s|1,1] - E[w|1,1] &\geq \gamma I \\ EX - \left[\frac{B(c)}{(1-l)} - A\right] - c &\geq \gamma I \end{aligned}$$

Solving for the minimum level of collateral A at which this lender is just willing to participate yields a new expression for the minimum collateral requirement, which is now written as a function of the monitoring intensity c:

$$\underline{A}^m(c) = \frac{B(c)}{(1-l)} - [Ex - \gamma I] + c \tag{23}$$

By reducing the borrowers' potential return from moral hazard $B(c)$, monitoring lowers the size of the limited liability rent $B(c)/(1-l)$ and hence potentially also the collateral requirement. On the other hand, the monitoring costs must be paid for and this reduces the remaining proceeds with which to make repayments. If $B'(0) < -1$, then the first dollar of monitoring reduces rents faster than it increases costs and monitoring will lower collateral requirements $\underline{A}^m(c)$ and expand loan access. The assumption of diminishing returns to monitoring means however that delegation costs may eventually rise more rapidly than limited liability rents fall, and so there may be a cutoff monitoring level $\overline{c_m}$ beyond which further monitoring becomes counterproductive.[15] Figure 2a illustrates how the minimum collateral requirements $\underline{A}^m(c)$ might at first fall and then rise with monitoring intensity c.

Figure 2 about here

Since monitoring costs must be paid for out of expected project returns, monitored finance must by definition always be more expensive than non-monitored lending. Therefore only borrowers who do not have sufficient collateral assets to gain access to

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[14] Recall that the monitor's reservation wage was normalized to zero.

[15] We assume the borrower's own participation constraint does not bind before this cutoff has been reached.

unmonitored loans (i.e. those with assets A below $\underline{A}_1 = \underline{A}^m(0)$) would ever turn to monitored finance, and even those that do will only agree to a loan with just enough monitoring to reduce the collateral requirement to their available assets A. As illustrated in Figure 2a, a borrower with collateral A would choose a loan with monitoring intensity $c_m = c_m(A)$ given by $\underline{A}^m(c_m) = A$. This borrower would pay an implicit cost of funds of $\gamma + c_m(A)/I$. The contract involves the delegated monitor putting up $\underline{I}_1^m(c_m) = c_m l/\gamma(1-l)$ worth of funds and leveraging an additional $I^u = I - \underline{I}_1^m(c_m)$ from the outside lender. Since monitoring substitutes for collateral, borrowers with fewer assets pay higher borrowing costs and will have a higher share of monitored versus unmonitored finance $\underline{I}_1^m(c_m)/I$. The following summarizes the relationship between the target borrower's collateral asset A and the the minimum cost loan type to which they will be matched:

Proposition 7 *If delegated monitors have abundant intermediary capital and* $B'(0)/(1-l) > -1$, *then borrowers on a competitive loan market will be matched to monitored individual liability loans according to their initial collateral* A *as follows:*

Loan Type	***Collateral Assets***	***Monitoring***	***Cost funds*** γ
Non-monitored Loans	$A \geq \underline{A}_1$	0	γ
Monitored Loans	$\underline{A}_1 > A \geq \underline{A}^m(\overline{c_m})$	$c_m(A)$	$\gamma + c_m(A)/I$
Excluded	$A < \underline{A}_1^m(\overline{c_m})$	*n.a.*	*n.a.*

where $\overline{c_m}$ *is given by* $B_c(\overline{c_m})/(1-l) = -1$ *and* $c_m = c_m(A)$ *is given by* $\underline{A}_1^m(c_m) = A$.

Borrowers with collateral assets $A \geq \underline{A}_1$ will find it cheapest to post collateral $\underline{A}_1 = \underline{A}^m(0)$ and borrow through the previously analyzed non-monitored individual liability loans. Monitored lending expands access to borrowers with assets A in the range $\underline{A}_1 > A \geq \underline{A}^m(\overline{c_m})$. Since costly monitoring substitutes for collateral, and monitoring incentives must be maintained, the necessary share of intermediary capital I^m/I and the borrowers' cost of funds will increase as the market tries to reach borrowers with fewer and fewer collateral resources to offer.

The analysis also points to a possible further distinction between two types of monitoring lender: those who can leverage outside funds and can therefore act as *financial intermediaries* and those who are unable to leverage outside funds and therefore must provide finance entirely out of their own equity. The issue is that the delegate's required share of total funds I^m/I increases as monitoring substitutes for collateral. Depending on parameters, the most collateral poor borrowers in the range $\underline{A}_1 > A \geq \underline{A}^m(\overline{c_m})$ may require so much monitoring that the delegate's required stake rises to $I^m = I$. At this point the monitor is lending entirely out of their own equity (or providing a 100 percent loan guarantee) and cannot therefore leverage any net new outside funds.

Corollary 8 *Monitored loans may be further sub-divided into*

$$\begin{array}{lll} \textbf{\textit{Intermediated Loans}} & \underline{A}_1 > A \geq \underline{A}^m(\widehat{c}) & (I^u > 0\,,\, I^m_N > 0) \\ \textbf{\textit{Non-Intermediated Loans}} & \underline{A}^m(\widehat{c}) > A \geq \underline{A}^m(\overline{c}) & (I^u = 0\,,\, I^m_N\ = I) \end{array}$$

where $\widehat{c}$ *is defined by* $\gamma I = \widehat{c}l^N/(1-l^N)$ *and* $I^m_1 = I^m_1(c^m(A))$.

Several studies of rural credit markets have characterized informal moneylenders in precisely terms of such non-intermediated loans: moneylenders monitor their borrowers very heavily, they charge very high interest rates, but the scale of their operations is small because they lend primarily out of own equity (Aleem, 1994; Bell, 1994). This may also help explain why leverage ratios in microlending appears to have remained so low despite many efforts, or why it has proven so difficult to securitize bank's small business lending portfolios even in advanced industrial economies. In essence, unsecured and heavily monitored small business loans cannot be easily sold without diluting the bank's incentive to monitor and protect the quality of its loan portfolio.

2.4.2 Delegated monitoring without intermediary capital

Consider next the case of a non-invested delegated monitor who has *no* intermediary capital, or $I^m = 0$. A good example would be a loan officer at a bank or at a microfinance lending institution. Loan officers act as delegated monitors for the financial institution and can be placed on high-powered incentive contracts, typically a salary plus bonuses proportional to how well their portfolio of monitored loan projects performs, but their personal liability will be limited. We can then think of the delegate receiving a base wage $w_0 = 0$ and a bonus of $w_s = c/(\overline{\pi} - \underline{\pi})$ when the borrower repays. This requires a minimum delegation cost of $E[w|1,1] = c/(1-l)$. Substituting this instead of into the outside lenders' participation constraint and solving for the new minimum collateral requirement when the delegate has no intermediary capital:

$$\underline{A}^d_1(c) = \underline{A}^m(c) + \frac{lc}{(1-l)} \tag{24}$$

At any level of monitoring, $\underline{A}^d_1(c)$ exceeds $\underline{A}^m(c)$ by the size of the delegation rent needed to sustain monitoring incentives, as illustrated on figure 2b. Since $\underline{A}^d_1(c) > \underline{A}^m(c)$ for all $c > 0$, delegated monitors with intermediary capital can always offer loans at lower cost (i.e. $c_m(A) < c_d(A)$ for all $A \in \{\underline{A}_1, \underline{A}^d_1(\overline{c}_d)\}$) compared to loans using non-invested delegated monitors. Delegates with intermediary capital can also offer access to more collateral-poor borrowers (i.e. they can reach borrowers with $A \in \{\underline{A}^d_1(\overline{c}_d), \underline{A}^m(\overline{c}_m)\}$ which would otherwise not have been served.

2.4.3 Loan diversification strategies

Locally recruited lending agents are potentially good monitors because they understand, and participate in, the social and economic life of the community of borrowers. But precisely because they are locally recruited from poor areas they may not have the intermediary capital to bring down delegation costs, attract outside investors, expand outreach, and lower the costs of lending to the poor. The situation would seem in theory difficult to break past except that in a seminal paper Diamond (1984) argued that is an important additional way to bring down delegation costs. Diamond's argument was built around a model with ex-post moral hazard and costly state verification, but his insights are readily adapted to fit the ex-ante moral hazard context examined here.

Put simply the argument is that if a delegate is put to monitor not just one but a portfolio of borrowers then delegation costs per borrower may be brought down by taking advantage of the the kind of incentive diversification mechanisms that can be applied to such multi-task settings. Specifically, consider the case where an outside lender contracts with a delegated monitor who in turn monitors N different individual-liability borrowers each with available collateral A. The typical microfinance organization or bank in fact hires a loan officer to monitor anywhere from a few dozen to several hundred loans. The delegated monitor's return w_I will now be made explicitly contingent on the joint outcome $(x^1_{i_1}, .., x^N_{i_N})$ of all N borrowers in his portfolio. Consider first the simplest case where the total cost to monitoring is a simple linear function of the number of borrowers monitored, so that if it takes c to reduce the opportunity cost of funds of a single borrower from $B(0)$ to $B(c)$ then it takes Nc to reduce N borrowers to $B(c)$.

Each borrower is offered an individual liability contract of the form $s_{i_n}$where $i_n \in \{0, 1\}$ indexes output on borrower n's project but since borrowers are identical we analyze the representative borrower's contract s_i. Contract terms $\{s_i, w_I\}$ will now be chosen to maximize expected returns to the representative borrower at minimum monitoring cost:

$$
\begin{aligned}
&\max_{s_i,\, w_I} E[s_i|1,1] \\
&N \cdot EX - N \cdot E[s_i|1,1] - E[w_I|1,1] \geq N \cdot \gamma I \\
&E[w_I|N,N] - N \cdot c \geq 0 \\
&E[s_i|1,1] \geq E[s_i|1,0] + B(c) \\
&E[w_i|N,N] - c \geq E[w_i|1,0] \\
&s_i \geq -A \qquad w_I \geq -\gamma I^m
\end{aligned}
$$

The problem is just like the earlier defined single borrower case in (15)-(19) except that now the outside investor's participation constraint is written to reflect that he contracts with N borrowers and a delegated monitor. The delegate's incentive constraint reflect that she now multi-tasks across N different loan monitoring projects. The limited liability has been written to allow for intermediary capital, or in the case of a simple loan officer $I^m = 0$.

The logic of optimal multi-task contracts now applies to the delegated monitor: optimal contracts will punish the monitor for failure by any one monitored borrower by collecting away any proceeds from a successful monitored loan in the portfolio. The optimal contract for a risk-neutral delegate who competes to offer her services at minimum delegation cost will again be a live-or-die type contract that pays the monitor a bonus $c/(\overline{\pi}^N - \underline{\pi}^N)$ when all monitored loans succeed and a zero wage for all other outcomes. The delegation cost

$$\begin{aligned} E[w|N,N] - c &= \frac{\overline{\pi}^N c}{(\overline{\pi}^N - \underline{\pi}^N)} - \gamma I^m - c \\ &= \frac{l^N c}{(1 - l^N)} - \gamma I^m \qquad (25) \end{aligned}$$

Note that $\underline{A}^m(c)$ is *independent* of the number of borrowers per delegate because the delegate is here assumed to be able to post sufficient intermediary capital to eliminate delegation rents. Monitoring has two opposed effects on the minimum collateral requirement. On the one hand, a marginal increase in monitoring lowers $B(c)$, which reduces the size of the borrower's limited liability rent and hence the collateral requirement by $B_c(c)/(1-l)$. But each extra dollar's worth of monitoring cost reduces the net project project returns out of which lender repayments and borrower incentives can be fashioned. If we assume that the first dollar spent on monitoring lowers the collateral hurdle, or that $B_c(0)/(1-l) > -1$, then a positive level of monitoring will be chosen. The assumption of diminishing returns to monitoring ($B_{cc} > 0$) guarantees that there must eventually be some monitoring intensity $\overline{c}$ beyond which further monitoring becomes counterproductive. Threshold $\overline{c}$ is defined by $B_c(\overline{c})/(1-l) = -1$.

Figure 1 illustrates how the minimum collateral requirement might fall over the range $(0, \overline{c})$ and rise thereafter.

Figure 1 about here

Since delegation costs use up real resources, monitored lending will always be more expensive than uninformed lending. It stands to reason that only borrowers with assets below $\underline{A}_1 = \underline{A}_1^m(0)$, who cannot gain access to direct collateral-based loans, would turn to monitored finance, and that they would then choose loans with the minimal required level of monitoring to just lower the collateral requirement to their available collateral asset level A. The optimal monitoring intensity is therefore zero for borrowers with assets $A \geq \underline{A}_1$. Those who have less then this amount choose a loan with minimum monitoring intensity $c_m = c_m(A)$ to just bring down the minimum collateral requirement to the level of their assets, or $\underline{A}^m(c_m) = A$. Monitored lending can reduce collateral requirements, but only up to monitoring intensity $\overline{c}$, beyond which it becomes counterproductive.[16]

Since a borrower makes expected repayment of $\gamma I + c^m(A)$ on I dollars borrowed, the implicit interest rate on any type of monitored loan is $\rho(A) = \gamma + c^*(A)/I$. Collateral-poor borrowers must pay higher implicit interest rates to cover the delegation costs.

To this point we have assumed that the number of borrowers to be monitored by each delegate was exogenously fixed at N per monitor. From expression (22) it is clear however that, all else equal, the minimum investment stake per borrower I_N^m declines monotonically with N and in the limit vanishes. This, of course, is closely related to the observation first made by Diamond (1984) This suggests that, if every borrower's project is stochastically independent, the infinite size bank.

2.5 Joint Liability loans with costly monitoring

Next we consider lending arrangements that assign the task of *costly* monitoring to a group of peers rather than to an outside delegate. Monitoring and production both involve costly and non-verifiable action choices and borrowers' interact non-cooperatively, although we will want to also check they cannot gain from colluding against the outside lender.

One obvious potential advantage of using group peers rather than a non-group delegated monitor is that peers might have a *better* monitoring technology for reasons including the fact that they may belong to the same social networks and may already interact with each other in other economic exchange relationships. This may be important and relevant, although it seems just as possible that over time a professional delegated monitor might come to be as or more effective at monitoring and repayment collection than would a peer, who may not feel comfortable placing pressure on a friend or a relative. It also seems possible that peers may be more likely to collude amongst themselves against an outside lender, precisely because they interact in other spheres.

The surprising result we shall find is that, under certain circumstances, a peer monitoring arrangement may dominate a delegated monitoring arrangement even if the delegate has a slightly better monitoring technology $B(c)$ than a peer-monitor and

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[16] I've implicitly assumed that the borrower's own participation constraint does not bind before monitoring level $\overline{c}$ has been reached. If the farmer's has a reservation utility given by K, then his binding participation constraint $E(s_i|\overline{\pi}) = E(x_i|\overline{\pi}) - \gamma I - c = K$ defines a cutoff level $c^k = E(x_i|\overline{\pi}) - \gamma I - K$. The assumption therefore is that $\overline{c} \leq c^k$.

even if the delegate has more intermediary capital and a large diversified portfolio of borrowers.

Consider the joint liability contract between a single uninformed lender and a symmetric two-member group. Let s^n_{ij} denote the return to borrower n under contract s following outcome X^1_i on borrower 1's project and outcome X^2_j for borrower two. Without loss of generality we focus on the terms of borrower one's contract denoted simply below by s_{ij} .

To isolate the *contractual* mechanisms that give joint liability loans an advantage, as distinct from explanations based on an assumed initial monitoring advantage, assume that the monitoring technology employed by each borrower *cum* peer-monitor is *the same* one available to an outside delegated monitor. Specifically, each group member is assumed to be able to lower the private benefit $B(c)$ that another borrower stands to capture from non-diligencevia costly monitoring actions, in just the same way that an outside delegate monitor would.[17]

The contract design problem can be viewed as a mechanism design problem. The terms of the offered contract s_{ij} determine the payoff structure of a game in monitoring intensities and production action choices played by two borrowers. Figures 3 and 4 depict the payoffs and the timing of the game. If a joint liability contract is accepted, borrowers play a first-stage non-cooperative game in monitoring intensities. The chosen monitoring intensities (c^1, c^2) then determine the payoff structure $\zeta(c^1, c^2)$ of a second-stage subgame in diligence choices. The desired outcome to be implemented is for each borrower to choose an equilibrium monitoring intensity c at the first game stage which helps implement diligence as the equilibrium outcome in production actions in the second stage. We search for a subgame-perfect Nash equilibrium (SPNE) implementation in pure strategies. Since monitoring is an expensive activity, an optimal contract will aim to keep the value of c to the minimum consistent with maintaining incentives.

Figures 2 and 3 about here

The following functions summarize the payoffs to borrower 1 in each of the four cells of a subgame $\zeta(c^1, c^2)$

$$\begin{aligned} DD(c^1, c^2) &= E(s_{ij}|\overline{\pi}, \overline{\pi}) - c^1 \\ ND(c^1, c^2) &= E(s_{ij}|\underline{\pi}, \overline{\pi}) - c^1 + B(c^2) \\ DN(c^1, c^2) &= E(s_{ij}|\overline{\pi}, \underline{\pi}) - c^1 \\ NN(c^1, c^2) &= E(s_{ij}|\underline{\pi}, \underline{\pi}) - c^1 + B(c^2) \end{aligned} \tag{26}$$

For example $ND(c^1, c^2)$ is the payoff to borrower 1 when he is not diligent (chooses $\underline{\pi}$)

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[17] Monitoring expense c can be thought of as including the opportunity cost of time and resources as well as the direct disutility from attending regular group meetings, applying social pressure and individual monitoring, etc.

and monitors the other borrower at intensity c^1 while borrower 2 chooses diligence $\overline{\pi}$ and monitors borrower 1 at intensity c^2.

If a contract is to implement the diligence strategy profile $(\overline{\pi}, \overline{\pi})$ as a Nash equilibrium within subgame $\zeta(c, c)$ then the following incentive compatibility constraint must hold for borrower 1 (and symmetrically for borrower 2):

$$DD(c, c) \geq ND(c, c) \tag{27}$$

In addition, borrower 1 (and symmetrically borrower 2) must have incentive to not deviate from the minimum required monitoring intensity c:

$$DD(c, c) \geq DD(0, c) \tag{28}$$

These incentive contraints provide each borrower with incentives to choose monitoring and to remain diligent in their non-cooperative strategic choices. Note that separate incentive constraints are required for monitoring and production diligence because group members simultaneously commit to monitoring choices before they later make production choices.

In addition to these individual constraints a rational lender will want to impose the following 'no-collusion constraint' of the form

$$DD(c, c) \geq NN(0, 0) \tag{29}$$

to make sure that borrowers as a group earn more by choosing the SPNE to be implemented than from 'colluding' to accept a contract but then choose to both not monitor and choose non-diligence in production. Since under the optimal contract proposed below $NN(0, 0)$ is also an SPNE the purpose of this constraint is to dissuade borrowers from 'colluding' to agree, via pre-play cheap-talk or other coordination device, to a different SPNE that might be more harmful to the lender's interests.

Proposition 9 *Consider two borrowers each with assets in the range* $A \in (\underline{A}_2^g(0),\ \underline{\underline{A}}^g(c^g))$ *where*

$$\underline{A}_2^g(c) = \frac{B(c)}{(1-l)} - (Ex - \gamma I) \tag{30}$$

and

$$\underline{\underline{A}}_2^g(c) = \frac{B(0) + c}{(1-l^2)} - (Ex - \gamma I) \tag{31}$$

and c^g *is defined by* $\underline{A}_2^g(c^g) = \underline{\underline{A}}_2^g(c^g)$. *Then, if* $\overline{\pi} B_c(0) < -1$ *and* $B(c) > c$ *for all* $c \leq c^g$, *then a symmetric joint liability loan contract will be offered to, and preferred by the borrowers over separate individual liability monitored loans. The contract implements diligence on both borrowers' projects at minimum monitoring intensity* $c(A)$, *defined by* $A = \underline{A}_2^g(c)$ *and is of the form* $s_{ss} = \frac{B(c)}{\overline{\pi}^2(1-l)} - A$ *and* $s_{ij} = -A$ *for all* $ij \neq ss$.

The proposed group loan contract uses a joint-liability structure to generate incentives to peer monitor, but in a different way from the costless peer-monitoring case. In that earlier case joint liability worked to lower the total cost of providing incentives because, by assumption, each borrower internalized the consequence of their lack of diligence on expected returns to the entire group. The problem could then be analyzed essentially as a multi-task problem. The trick in effect was to replace a collection of individual incentive constraints by a more relaxed global coalition incentive constraint.

In the present setting borrowers interact non-cooperatively. We must now satisfy two types of individual incentive compatibility constraints for each borrower: one (28) to induce first-stage costly monitoring and another (27) to provide incentives to diligence in production. In addition, the contract must satisfy a group-level 'no collusion' global incentive constraint. A joint-liability structure of the LDC form again proves optimal, not just because it is the best way to satisfy the global coalition constraint as before, but also because it is the most efficient way to satisfy both types of individual incentive constraints simultaneously. To see this, let's substitute a contract of the LDC form $s_{ss} = Z(c) - A$ and $s_{ij} = -A$ for all $ij \neq ss$ into incentive constraint (27). Rearranging, it is clear that if each borrower is to have incentives to produce diligently then $Z(c)$ must satisfy:

$$\begin{aligned} \overline{\pi}\overline{\pi}Z(c) - \underline{A}_2^g(c) - c &\geq \overline{\pi}\underline{\pi}Z(c) - \underline{A}_2^g(c) + B(c) - c && (32) \\ Z(c) &\geq \frac{B(c)}{\overline{\pi}^2(1-l)} && (33) \end{aligned}$$

Likewise, if incentive constraints (28) are to be met so that each borrower has incentives to monitor at intensity c then $Z(c)$ must satisfy

$$Z(c) \geq \frac{c}{\overline{\pi}^2(1-l)} \tag{34}$$

Since $B(c) > c$ at $c = 0$, constraint (33) will bind before constraint (34) at initial levels of monitoring. Assume for the moment that 'no-collusion' constraint (29) is also satisfied with slack. Then, by now familiar reasoning, binding incentive contraint (33) and limited liability constraints $s_{ij} \geq -A$ will together imply that each borrower must receive a limited liability rent of at least $E[s_{ij}|\overline{\pi}, \overline{\pi}] = B(c)/(1-l) - A$ if they are to remain diligent at production *and* at monitoring. Substituting this delegation cost into the lender's binding participation constraint (5) allows us to solve for the minimum collateral requirement for a peer-monitored group loan given by $\underline{A}_2^g(c)$ in (30).

Note that the expression for $\underline{A}_2^g(c)$ can be rewritten in either of the follwoing two ways:

$$\begin{aligned} \underline{A}_2^g(c) &= \underline{A}^m(c) - c \\ &= \underline{A}_N^d(c) - \frac{c}{(1-l^N)} \end{aligned}$$

which reveals that, for any chosen level of monitoring c, joint liability loans have a lower collateral requirement compared to the most efficient monitored individual liability loan using an identical monitoring technology, and certainly compared to any loan with delegated monitors who lack intermediary capital. Intuitively, in a group the same contractual incentive s_{ss} that provides motive for a borrower to be diligent at production also provides incentives for the borrower to be diligent at monitoring. Whereas the total cost of providing incentives in a delegated monitoring arrangement will be *the sum* of delegation costs paid to the outside monitor (either c or $c/(1-l^N)$ depending on whether the delegate has intermediary capital or not) and the limited liability rent paid to the borrower $(B(c)/(1-l))$, the total cost of providing incentives to a peer monitor is *the larger of* delegation cost or the limited liability rent.

Hence, so long as the no-collusion constraint does not bind first (discussed below), group loans can thus be offered at a lower total cost of funds to collateral poor borrowers. To see this consider the borrower with collateral assets A in figure 3. To lower the collateral requirement to her available level of assets a group loan requires monitoring intensity c^g given by $\underline{A}_2^g(c^g) = A$. An individual liability monitored by a delegate with the same monitoring technology and no lack of intermediary capital would require a monitoring intensity $c^m > c^g$ given by $\underline{A}^m(c^m) = A$.

Figures 4 about here

A contract must also insure against the possibility that the borrowers could accept a contract but then collude to choose an action profile other than the proposed equilibrium. To guard against this possibility contracts must be chosen so that borrowers prefer the payoffs they obtain from choosing diligence and optimal monitoring intensity c to what they could obtain by choosing not to monitor each other and choosing non-diligence:

$$\begin{aligned} DD(c,c) &\geq NN(0,0) \\ E(s_{ij}|\overline{\pi},\overline{\pi}) - c &\geq E(s_{ij}|\underline{\pi},\underline{\pi}) + B(0) \end{aligned} \tag{35}$$

which once again can be met at minimum collateral expense by using a LDC structure that places as much of the borrower's reward as possible on s_{ss} while setting all the other s_{ij} as low as possible (which means full payment out of collateral). Substituting the proposed LDC structure into expression (35) above yields:

$$Z(c) \geq \frac{B(0)+c}{(\overline{\pi}^2 - \underline{\pi}^2)}$$

Substituting this into the investor's participation constraint restricts the minimum collateral requirement to always lie above:

$$\underline{\underline{A}}^g(c) = \frac{B(0) + c}{(1 - l^2)} - (Ex - \gamma I) \geq \underline{A}^g(c)$$

Figure 4 shows that group loan contracts will not be offered to any borrower with assets below $\underline{\underline{A}}(c^g)$, because these borrowers cannot commit to not colluding against the lender. As depicted, some poorer borrowers with assets below this cutoff may still obtain funding from loans monitored by more expensive moneylenders or intermediaries. As in the scenario described in the previous section, the poorest of the poor – those below $A(\overline{c})$ remain excluded from the credit market entirely. Both of these results are consistent with analyses that suggest that even Grameen Bank is not really lending to the poorest of the poor (Morduch, 1999) and that microfinance has not completely displaced existing moneylenders .

It is worth dwelling on the reason why an intermediary structure with an outside delegate cannot reproduce these results. Couldn't an outside monitor also also take advantage of diversification effects? From Diamond (1984) we know that the delegation costs of using an intermediary monitor fall as the monitor's portfolio of monitored borrowers becomes larger and more diverse. It is easy to see, however, that this does nothing to help reduce the total costs of lending under the individual liability modality because by construction the delegated monitor-lender earned no enforcement rent and so delegation costs were already zero. Diversification effects would help lower the delegation costs of employing hired staff who cannot post bonds, or lower the amount of capital I^m the delegate needs to have at stake in each borrower's project. In either case, however, it is the need to repay an outside monitor for his monitoring expense c which is adding to the cost of operating under individual liability loans.

Summarizing the discussion, peer-monitored loans therefore offer an advantage over outside monitored loans, and this advantage does not rest upon a presumed information advantage held by insiders. Any information or enforcement advantage that group members may have relative to an outside intermediary will of course only strengthen the advantage. The scope for employing group loans will be limited, however, by lenders fear that borrowers could collude against a lender and will guard against this possibility by only agreeing to collusion-proof loans.

Note that the explicit money interest charges on group loans is always γI for all qualifying borrowers, although of course the total cost of funds to the borrower must also include the cost of monitoring others. The model predicts that implicit interest charges will be lower on group loans compared to outside monitored loans for borrowers in the same asset class. We again find that the implicit interest rate of borrowing is higher for borrowers with less collateral.

2.6 Discussion and Extensions

2.6.1 Joint versus Relative Performance Evaluation

Following Che and Yoo (2001) let the probability distribution of joint outcomes now depend not only on the agents' individual diligence choices but also on a common environmental shock. If the common shock is favorable, which occurs with exogenous probability σ, then both borrowers' projects will succeed no matter what diligence level each chose. If instead the common shock is unfavorable, which occurs with probability $(1-\sigma)$, then the probability of success on one's own project depends on one's own chosen level of diligence, as before. Hence, when a borrower chooses diligence level $i \in \{0,1\}$ his project succeeds with probability $\sigma+(1-\sigma)\pi_i$ and fails with probability $(1-\sigma)(1-\pi_i)$. The expected monetary return under contract s when borrowers 1 and 2 choose diligence levels $i \in \{0,1\}$ and $j \in \{0,1\}$ is then given by:

$$\begin{aligned} E[s|i,j] &= (\sigma+(1-\sigma)\pi_i\pi_j)s_{11} && (36)\\ &\quad +(1-\sigma)[\pi_i(1-\pi_j)s_{10}+(1-\pi_i)\pi_j s_{01} && (37)\\ &\quad +(1-\pi_i)(1-\pi_j)s_{00}] && (38) \end{aligned}$$

Suppose each borrower has collateral A. Then, adapting Proposition 1 in Che and Yoo (2001), it is easy to demonstrate the following result

Recall that in the case where $\sigma=0$ IPE and JPE were equivalent.

Proposition 10 *When $\sigma>0$ the optimal Nash contract is the RPE contract $s^R=(-A, s^J_{10}, -A, -A)$ where*

$$s^J_{10} = \frac{B}{(1-\sigma)(\pi_1-\pi_0)(1-\pi_1)} - A \qquad (39)$$

This is a special case of Holmstrom (1982) and Mookherjee's (1984) well understood result on relative performance evaluation and tournaments. The optimal contract rewards a borrower

Notice that the scope for making joint liability loans work depends on the assumed timing of the game in a rather crucial way. As is standard in most of the literature on monitored lending and hierarchical agency structures, I have assumed that monitoring actions by the intermediary or group members are chosen and committed prior to the borrower's choice of diligence. Any threatened or implied sanctions that might form part of this monitoring strategy are hence assumed to be in place and credibly believed by the borrower to whom they are directed. The possibilities for peer-monitoring unravel under the alternative assumption that both monitoring and productive action strategies are chosen simultaneously:

Remark 11 *If the the game is modified so that borrower-cum-monitors choose their monitoring and productive activity actions simultaneously rather than sequentially, then the scope for creating social collateral through peer-monitoring collapses.*

This result is helpful for understanding the strong negative result obtained by Itoh (1991) that teamwork will only be optimal under the assumption that "the marginal disutility of monitoring effort is zero at zero monitoring." That group lending collapses when the game is simultaneous can be demonstrated by contradiction. For assume otherwise. Then a group contract does exist which implements the symmetric action pair. Since this is the assumed Nash equilibrium outcome, $(\overline{\pi}, c)$ must be a symmetric best response. But this cannot in fact be the case because borrower 1 will reason that his best response to $(\overline{\pi}, c)$ is in fact $(\overline{\pi}, 0)$: given that borrower two will choose diligence, borrower one can only gain by economizing on the costly monitoring activity c. Borrower two will then reason that his best response to borrower 1's $(\overline{\pi}, 0)$ is $(\underline{\pi}, 0)$, which in turn leads borrower one to change to $(\underline{\pi}, 0)$. Thus the only symmetric equilibrium action-monitoring strategy of the game is $(\underline{\pi}, 0)$.

This paper therefore shows a way out of Itoh's dilemma. This points to an important aspect of the design of group contracts. It is not enough simply to create a joint liability contract to induce peer monitoring; the contract must also rely on a particular timing sequence and requires commitment. Actual lending practices may be reflecting these facts. The scheduling of regular group meetings, the use of periodic interim evaluations and monitoring reports, contingent loan renewals over time and the practice of rotating loans amongst borrowers so that not all have a loan at the same time, etc., are all mechanisms that may help to make monitoring strategies credible and may also be aimed at reducing the possibility of collusion. This is an area that merits further investigation.

There are many directions that this analysis can be extended. Allowing the borrowers to operate variable investment scale projects, to choose continuous action choice sets or to operate production technologies with multiple project outcomes should not alter the main findings in a fundamental way; nor should making borrowers risk averse[18].

The problem would be complicated in more interesting ways by introducing a more general correlation structure in the production project returns across borrowers. Several complementary and offsetting forces would then likely come into play to determine the shape of the final optimal contract. On the one hand, one might want the contract to encourage monitoring interaction among the members through joint liability contracts for the reasons analyzed here. The contract would make each borrower's reward an *increasing* function of the measured performance of other borrowers in the group.

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[18] In work that was carried out independently of my earlier 1996 paper on group loans, Madajewicz (1997) studied a model similar to the one of this paper and extends some results to the case of risk averse agents, under somewhat restrictive assumptions about risk preferences.

If, however, there is sufficient correlation in the production project outcomes across borrowers, then one might want the contract to work in the opposite direction. For the reasons identified in the relative performance evaluation (RPE) literature, one might want to make each borrower's reward a *decreasing* function of the other borrower's measured performance.

While these two effects will therefore typically be in conflict, in a somewhat more general setting a lender might be able to design a structure that involves elements of both types of contract. For example, the lender might group borrowers into small borrowing circles within which joint liability incentives are used to encourage peer-monitoring, while at the same time using relative performance evaluation across groups.

3 Policy debates

Those who have been skeptical of joint liability lending appeared to score points when in 2003 joint–liability lending pioneer Grameen Bank announced a revealing policy shift away from explicit joint liability penalties on borrowers toward a model that gives much more explicit monitoring control to trained loan staff officers. As Grameen founder Muhammed Yunus explains the adoption of the new "Grameen Generalised System (GGS)," it was partly a response to dissatisfaction amongst borrowers:

> "Now both the bank and the borrowers can be free from all tension - no more chasing of the problem-borrowers or defaulters. Nobody needs to look at anyone with suspicion.
>
> Group solidarity is used for forward-looking joint-actions for building things for the future, rather than for the unpleasant task of putting unfriendly pressure on a friend ...

The implied sugggestion is not so much that joint liability did not work to create peer-monitoring incentives but rather that the pressures it generated were deemed onerous by the borrowers. Yunus goes on to suggest that joint liability may have been optimal while the bank was still expanding into new areas, but that monitored individual-liability loans became better suited over time:

> GCS [the earlier group loan system] is a "single-size-fits-all" kind of methodology. This feature gives GCS the simplicity which was most needed for the implementation of an idea which was totally unknown to the world. Now microcredit has matured ... GGS is different. It allows a staff to be creative. He can design his loan product to make it a best fit for his client in terms of duration, timing of the loan, scheduling of the installment, etc. The more a staff becomes a creative artist, the better music he can produce ... (Yunus, 2003)"

What is evident from these passages is that close monitoring of borrowers is an essential element of Grameen's microfinance practice under either liability system.[19] The difference between intermediary structures lies in how much monitoring responsibility falls to the borrower's peers as opposed to the bank's hired delegates. The move from joint to individual liability lending would have been natural as Grameen bank staff became more familiarized with a given set of borrowers. There are good reasons to believe that after some time a specialized delegated monitor would be able to develop a better monitoring technology than that available to the borrowers in the group.

4 Conclusion

Much of the legal institutional infrastructure that is taken for granted in more affluent and developed areas of the world that helps to frame and enforce economic transactions is often either imperfectly established or entirely missing in poorer areas, developing countries, and economies in transition. In such circumstances, lenders will find it simply unprofitable to lend to small and poor borrowers without additional collateral guarantees, even when they are free to charge whatever interest rate they want to recover expenses. If the poor are to have a chance to build upon their energies and abilities rather than remain marginalized because of the misfortune of having too few liquid resources, then effective intermediary institutions and contract arrangements to build bridges between the poor and new credit and trade opportunities will be needed.

Joint liability lending appears to be one such innovative mechanism, not only because it builds upon existing information and enforcement methods in local communities but more fundamentally because it may potentially stimulate new monitoring and enforcement activities. While other analyses of group loans under moral hazard have relied upon an assumed information advantage or full side-contracting assumptions and costless monitoring, this paper has shown that an advantage to joint liability loans exists even under the more realistic assumption that borrowers cannot side-contract and monitoring is costly and subject to moral hazard. While group loans were shown to be sometimes optimal, the limits to group lending were also made apparent, and different types of financial contracts will be optimal for different types of borrowers.

A strong case can be made that joint liability contracts are far more ubiquitous in our society than economists commonly teach: a large part of all economic activity

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[19] Descriptions of Grameen's earlier operating practices by Jain (1996), Fuglesgang (1993), Pitt and Khandker's (1999) and others suggest that the Bank has always in fact relied on a mix of monitoring by highly motivated loan officers and peer-monitoring within groups. This suggests that the changes reflect more a rebalancing of assigned responsibilities and liabilities, rather than a fundamental paradigm shift. Diagne (2000) and Wydick (2000) report survey evidence from Malawi and Guatemala that also suggest that peer pressure generated by joint liability keeps repayment up, but that at the same time group borrowers find it highly onerous to have to pressure other group members.

takes place within households, firms, partnerships, work teams, and other sorts of group which are organized at least in part by property relations that imply some form of profit sharing or joint liability (Holmstrom, 1999). Rather than just being narrowly compensated for their individually measured performance or contribution to a project, members share in the fortunes and misfortunes of the overall enterprise. There is still room for much further research on these topics.

Appendix

Proof. of Proposition 1. The following claim will be used for proving Proposition 1. ■

Claim 12 *For any given* N, *the likelihood ratio*

$$1-\frac{\underline{\pi}^j(1-\underline{\pi})^{N-j}}{\overline{\pi}^j(1-\overline{\pi})^{N-j}} \tag{40}$$

is non-decreasing in j.

Intuitively, better joint outcomes are more likely when the agent is diligent on more tasks. This is monotone likelihood ratio property. To prove this we must show that

$$1-\frac{\underline{\pi}^{k-1}(1-\underline{\pi})^{N-k+1}}{\overline{\pi}^{k-1}(1-\overline{\pi})^{N-k+1}} \leq 1-\frac{\underline{\pi}^k(1-\underline{\pi})^{N-k}}{\overline{\pi}^k(1-\overline{\pi})^{N-k}} \tag{41}$$

Using $l=\underline{\pi}/\overline{\pi}$ and noting that when $k=N$, the likelihood becomes $1-l^N$ we can rearrange to get

$$l^{k+1}\frac{(1-\underline{\pi})^{N-k}}{(1-\overline{\pi})^{N-k}} \leq l^k\frac{(1-\underline{\pi})^{N-k+1}}{(1-\overline{\pi})^{N-k+1}} \tag{42}$$

$$l \leq \frac{(1-\underline{\pi})}{(1-\overline{\pi})} \tag{43}$$

which is always satisfied as long as $l=\underline{\pi}/\overline{\pi}<1$. Q.E.D.

Given that borrowers are risk-neutral, and limited liability restricts the ability to impose large negative punishments on low outcome states, the most efficient way to reduce limited liability rents by economizing on incentive bonuses is to concentrate all reward on the outcome with the lowest likelihood ratio, which by the above Claim is the one associated with the joint outcome where all projects succeed, and the likelihood ratio $1-l^N$.

Stated slightly differently, we must show that the proposed contract satisfies all the constraints and at least weakly dominates any other contract. By construction, the proposed contract satisfies $E[s|N,N]=\overline{\pi}^N Z_N-\underline{A}_N=Ex-\gamma I$ and hence the lender's participation constraint is met exactly. By construction also, the contract exactly satisfies the 'global' incentive constraint $E[s|N,N]=E[s|N,0]+B$ that the borrower prefer diligence on all contracts to diligence on none. Under the proposed contract all the remaining incentive constraints in (11) now take the form

$$\overline{\pi}^N Z_N - \underline{A}_N \geq \overline{\pi}^k \underline{\pi}^{N-k} Z_N - \underline{A}_N + (N-k)B/N \quad \text{for } k \in \{1, N\} \tag{44}$$

which can be shown to be always satisfied so long as $\overline{\pi} > \underline{\pi}$.[20] To see why a LDC structure weakly dominates all other contract forms, suppose otherwise. Then there is a non-LDC contract $\widehat{s}$ that offers a lower minimum collateral requirement $\underline{A}$ and sets $\widehat{s}_{i_1 \ldots i_N} > -\underline{A}$ for at least one contingency other than the 'all success' outcome, where now we are subscripting $\widehat{s}$ by $I = (i_1, ..i_N)$ to allow for more specific contingencies. Suppose that that outcome involved k successes and $N-k$ failures. Now construct a new contract, call it $\widehat{\widehat{s}}$, that is identical to $\widehat{s}$ in all dimensions except that it replaces $\widehat{s}_I$ by $-\underline{A}$ and adds $\frac{\overline{\pi}^k(1-\overline{\pi})^{N-k}}{\overline{\pi}^N}(\widehat{s}_I + \underline{A})$ to the 'all success' outcome. The new contract yields the same expected return to the borrower under all diligence yet it is easy to verify that due to the fact that we've re-arranged reward to fall on an outcome with a higher likelihood ratio, the new contract will now satisfy the global incentive constraint with slack. This however means that the alternative contract $\widehat{s}$ could not have in fact have been optimal since any slack means the collateral requirement could not have been a minimum.

To show that the proposed contract s_{ij} is optimal requires that we show that it induces a symmetric subgame perfect Nash equilibrium (SPNE) where each borrower chooses the strategy profile $(c, \overline{\pi})$ and monitoring expense c is kept at a minimum.To do this we first characterize equilibria to the subgames $\zeta(\cdot, \cdot)$ and then argue why the contract induces each player to choose minimum monitoring intensity c in the first stage.

Figure 5 helps visualize the payoffs to different cells in the subgames $\zeta(\cdot, \cdot)$ discussed below. The figure is drawn for borrower 1 monitoring at intensity c. Borrower 1's payoff is then drawn on the vertical and borrower two's monitoring intensity is on the horizontal. Note that the structure of the optimal contract discussed in Proposition **??** requires $DD(c,c) \geq NN(0,0) \geq NN(c,0)$ where the first inequality follows from the no-collusion constraint (35) and the second inequality is obvious. Since $DD(c,c) = DD(c,0)$, it follows that $DD(c,0) \geq NN(c,0)$. The figure is drawn for the case where this holds as a strict equality (point C).

Lemma 13 *Under the proposed optimal contract* $DD(c,c) - ND(c,c) > DN(c,c) - NN(c,c)$.

Proof: Assume not. Then $DD(c,c) - ND(c,c) \leq DN(c,c) - NN(c,c)$. Substituting the optimal contract of the form $s_{ss} = Z(c)$ and $s_{ij} = -\underline{A}(c)$ for all other

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[20] Using $Z_N = B/(\overline{\pi}^N - \underline{\pi}^N)$ and $(1-l^N) = (\overline{\pi}^N - \underline{\pi}^N)/\overline{\pi}^N$ the incentive constraints can be rewritten $\left(\frac{N}{N-k}\right)\left(\frac{1-l^{N-k}}{1-l^N}\right) \geq 1$, which can be shown to always hold for all N, $0 < l < 1$ and $k < N$.

i, j and rearranging leads to the conclusion that $\overline{\pi}Z(c) \leq \underline{\pi}Z(c)$, a contradiction since by assumption $\overline{\pi} > \underline{\pi}$. ■

The fact that $DD(c,c) - ND(c,c) > DN(c,c) - NN(c,c)$ suggests that the player's actions in the subgame $\zeta(c,c)$ are *strategic complements*: player 1's marginal payoff to choosing diligence over non-diligence is increasing in player two's level of diligence, and vice-versa. The presence of strategic complementarities alerts us to the possibility of multiple, pareto ranked equilibria in this subgame (Cooper and John, 1988). As the following claim establishes, this is indeed the case.

Lemma 14 *: $(\overline{\pi}, \overline{\pi})$ and $(\underline{\pi}, \underline{\pi})$ are Pareto ranked Nash equilibria of subgame $\zeta(c,c)$, with $DD(c,c) > NN(c,c)$.*

Proof: $(\overline{\pi}, \overline{\pi})$ is a Nash equilibrium by construction since $DD(c,c) \geq ND(c,c)$ (recall 27). To see that $(\underline{\pi}, \underline{\pi})$ is also a Nash equilibrium requires that $NN(c,c) \geq DN(c,c)$. From the previous lemma the vertical distance $DD(c,c) - DN(c,c)$ is larger than the vertical distance $ND(c,c) - NN(c,c)$ (segment EG is larger than segment ED in the figure). Thus $NN(c,c')$ will intersect $DN(c,c')$ at some point $c^{**} > c$. This is indicated by point F in the figure. Thus $NN(c,c) > DN(c,c)$, and $\underline{\pi}$ is a best response to $\underline{\pi}$ and vice-versa.

That the equilibria are pareto ranked follows from the fact that $DD(c,c) \geq NN(0,0) > NN(c,0) \geq NN(c,c)$ where the first inequality follows from the no-collusion constraint, the second one is obvious because monitoring is a cost, and the last inequality follows because $B(0) \geq B(c')$ for all $c' \geq 0$. I assume that the borrowers coordinate on the higher equilibrium. ■

Lemma 15 *: $(\underline{\pi}, \underline{\pi})$ is the unique Nash equilibrium to subgames $\zeta(0,c)$, $\zeta(c,0)$ and $\zeta(0,0)$.*

Proof: Consider subgame $\zeta(0,c)$. From the figure it is evident that $(\overline{\pi}, \overline{\pi})$ cannot be a Nash equilibrium because $ND(c,0) \geq DD(c,0)$ so borrower one's best reaction to $\overline{\pi}$ is $\underline{\pi}$. However, borrower one chooses $\underline{\pi}$ as a best response to two's $\underline{\pi}$ because $NN(0,c) > DN(0,c)$. Since borrower two would do likewise $(\underline{\pi}, \underline{\pi})$ is the unique Nash equilibrium of the subgame. A symmetric line of reasoning establishes the result for $\zeta(0,c)$ and $\zeta(0,0)$. ■

Moving back in the game tree, since the equilibrium payoff $DD(c,c)$ to borrower one from subgame $\zeta(c,c)$ is higher than the equilibrium payoff $NN(0,c)$ from subgame $\zeta(0,c)$ it is evident that c is a best response to c at the first stage. It is just as easy to see that $(0,0)$ is also a Nash equilibrium of the game in monitoring intensities. The no-collusion constraint (35) requires, however, that payoffs to each borrower under (c,c) exceed those from $(0,0)$ to assume the two borrowers will not collude to choose the former equilibrium. Thus $\{(c, \overline{\pi}), (c, \overline{\pi})\}$ emerges as the chosen subgame perfect Nash equilibrium of the overall game.[21]

To see that the proposed solution minimizes on monitoring costs, note that the borrower's overall return $E(s_i|\overline{\pi}, \overline{\pi}) = E(x|\overline{\pi}) + \gamma I - c$ will be maximized when monitoring intensity is at a minimum. The minimum monitoring intensity is obtained when the borrower uses all of his available collateral resources, at $A = A^g(c)$, which is the value used in the proposed optimal contract.

A last step is to check whether there are in fact any gains to monitoring within a group, in other words, whether the first dollar spent on monitoring reduces the collateral requirement or whether $\frac{dA^g(c)}{dc}|_{c=0} < 0$. This condition simplifies to $B_c(0) < -\frac{1}{\overline{\pi}}$, the condition stated at the outset of Proposition. ■

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[21] It is straightforward to show that the first-stage game in monitoring intensities also displays strategic complementarities, or that $DD(c, c) - NN(0, c) > NN(c, 0) - NN(0, 0)$.

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Figure 1

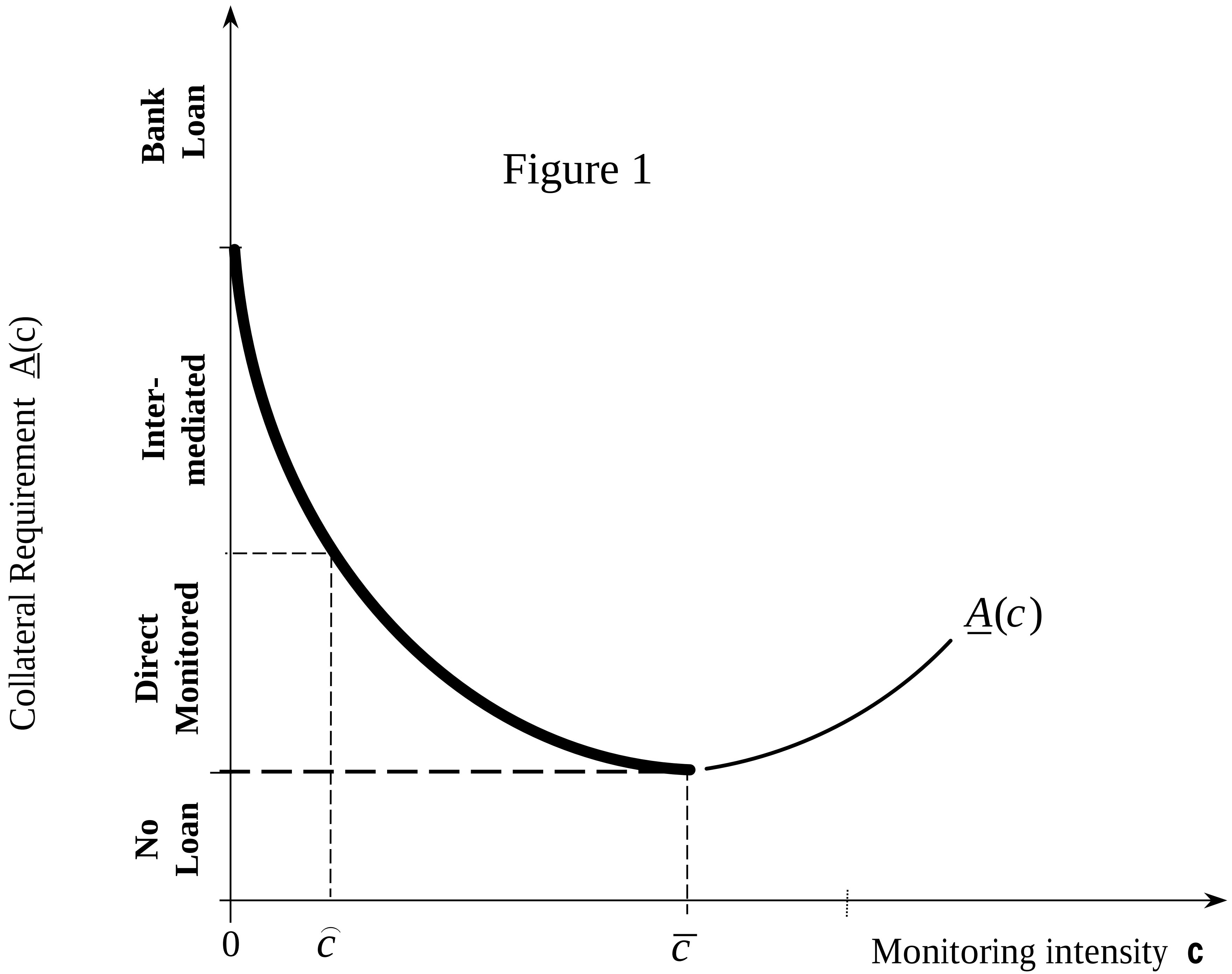
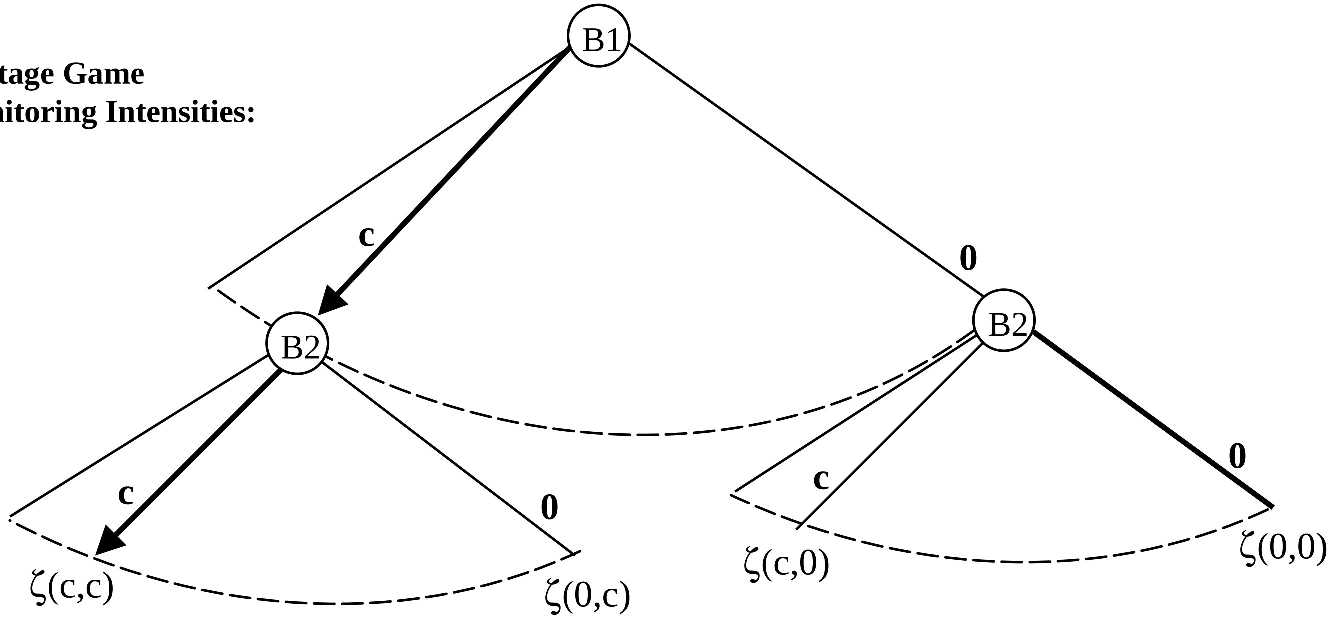

Bank Loan
Inter-mediated
Direct Monitored
No Loan
Collateral Requirement $\underline{A}(c)$
$\underline{A}(c)$
0
$\hat{c}$
$\bar{c}$
Monitoring intensity **c**

Figure 2

First Stage Game
in Monitoring Intensities:



Subgames ζ(c^1,c^2) :

ζ(c,c)

	$\overline{\pi}$	$\underline{\pi}$
$\overline{\pi}$	*DD*(c, c)	*DN*(c, c)
$\underline{\pi}$	*ND*(c, c)	*NN*(c, c)

ζ(0,c)

DD(0, c)	*DN*(0, c)
ND(0, c)	*NN*(0, c)

ζ(c,0)

DD(c, 0)	*DN*(c, 0)
ND(c, 0)	*NN*(c, 0)

ζ(0,0)

DD(0, 0)	*DN*(0, 0)
ND(0, 0)	*NN*(0, 0)

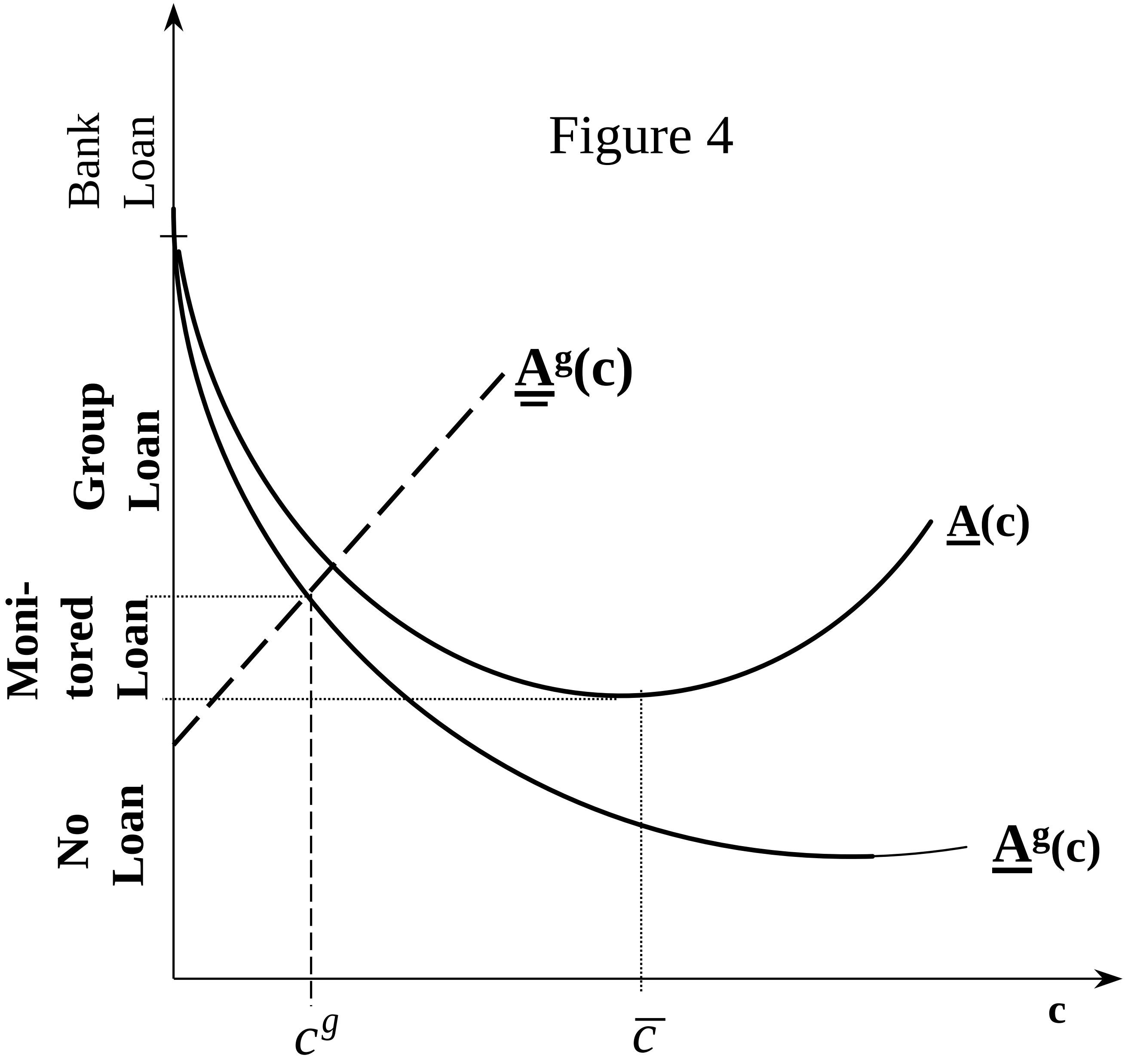
Figure 3

		Borrower Two	
		$\overline{\pi}$	$\underline{\pi}$
Borrower One	$\overline{\pi}$	$E(s_{ij} \mid \overline{\pi},\overline{\pi})$ $-c^1$	$E(s_{ij} \mid \overline{\pi},\underline{\pi})$ $-c^1$
	$\underline{\pi}$	$E(s_{ij} \mid \underline{\pi},\overline{\pi})$ $+B(c^2)-c^1$	$E(s_{ij} \mid \underline{\pi},\underline{\pi})$ $B(c^2)-c^1$

<u>or</u>

		Borrower Two	
		$\overline{\pi}$	$\underline{\pi}$
Borrower One	$\overline{\pi}$	$DD(c^1,c^2)$	$DN(c^1,c^2)$
	$\underline{\pi}$	$ND(c^1,c^2)$	$NN(c^1,c^2)$

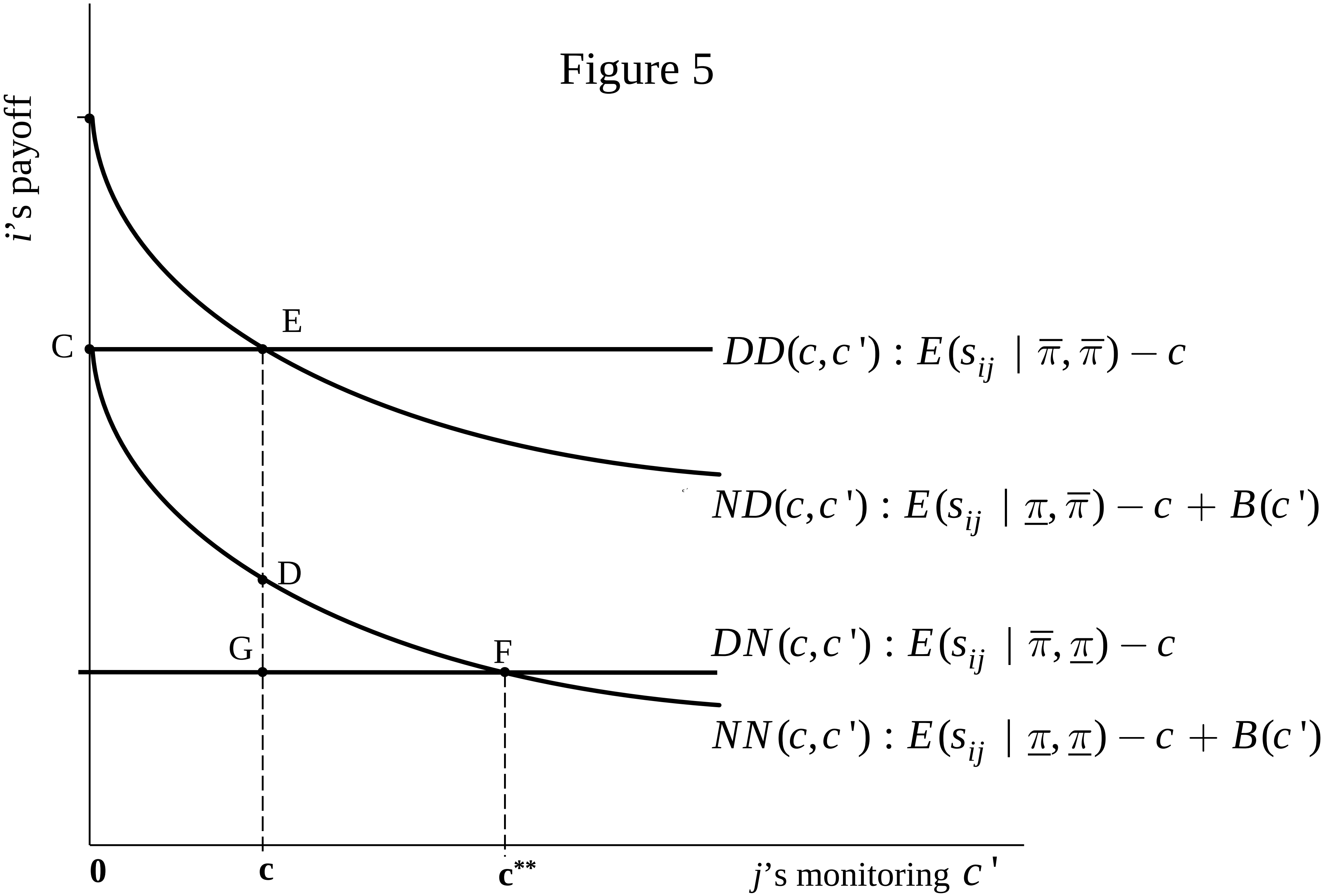
(only payoffs to
borrower one are shown)



Bank Loan
Group Loan
Moni-tored Loan
No Loan
$\underline{\underline{\mathbf{A}}}^{g}$(c)
$\underline{\mathbf{A}}$(c)
$\underline{\mathbf{A}}^{g}$(c)
c^{g}
$\overline{c}$
c

Figure 4

Figure 5



i's payoff
C
E
$DD(c,c') : E(s_{ij} \mid \overline{\pi}, \overline{\pi}) - c$
$ND(c,c') : E(s_{ij} \mid \underline{\pi}, \overline{\pi}) - c + B(c')$
D
G
F
$DN(c,c') : E(s_{ij} \mid \overline{\pi}, \underline{\pi}) - c$
$NN(c,c') : E(s_{ij} \mid \underline{\pi}, \underline{\pi}) - c + B(c')$
0
c
c**
j's monitoring c'