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Optimal Collective Contract Without Peer Information or Peer Monitoring

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Abstract

If entrepreneurs have private information about factors influencing the outcome of an investment, individual lending is inefficient. The literature typically offers solutions based on the assumption of full peer information to solve adverse selection problems and peer monitoring to solve moral hazard problems. In contrast, I show that it is possible to construct a simple budget-balanced mechanism that implements the efficient outcome even if each borrower knows only *own* type and effort, and has neither privileged knowledge about others nor monitoring ability. The mechanism satisfies participation incentives for all types, and is immune to the Rothschild-Stiglitz cream skimming problem despite using transfers from better types to worse types. The presence of some local information implies that the mechanism cannot be successfully used by formal lenders. Thus a local credit institution can emerge as an optimal response to the informational environment even without peer information or monitoring. Finally, I investigate the role of monitoring in this setting and show how costly monitoring can increase the scope of the mechanism.

KEYWORDS: *Informal Credit, Adverse Selection, Moral Hazard, Pricing Participation in Investment, Cream Skimming, Local Information, Costly Partial Monitoring*

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1 INTRODUCTION

Failure of formal credit markets and the emergence of remedial institutions are widely discussed issues in development economics. If borrowers have private information about factors influencing the outcome of an investment, individual lending can be inefficient. Some borrowers might use the loan to undertake projects with little chance of success, raising the rate of default. Coupled with the problem that collateral, if offered at all, is usually of little market value, this causes loan markets to fail.

Such problems have lead to the growth of informal moneylenders as well as a variety of "non-market institutions:" a variety of credit arrangements that rely on self-enforcement rather than on formal contracts enforced by external agents such as courts of law. Such institutions can have detailed rules, and adherence is often ensured through incentives born of social interactions. Examples include credit cooperatives, group loans, and rotating savings and credit associations.

There is a large literature on the design of incentives under a variety of asymmetric information problems. The usual assumption this literature makes at the outset is that agents themselves have full information on relevant variables (types, outcomes etc) for all agents and can monitor the actions of peers. The lender, who does not have this information or monitoring ability, must then design schemes to make use of such "peer information" and "peer monitoring."[(1),(2)]

[(1)] In the context of group lending, Ghatak (1999) and Van Tassel (1999) develop the idea of assortative matching in models with adverse selection, assuming peers can observe types. In models dealing with moral hazard, the central idea - introduced by Stiglitz (1990) and Varian (1990) - is to use peer monitoring to induce the right effort or choice of project. In their insightful analysis of cooperative design, Banerjee, Besley, and Guinnane (1994) show how local information can be harnessed through peer monitoring. Finally, if the outcome of investment is not verifiable, the issue of strategic default arises. Besley and Coate (1995) provide an analysis of the problem. Other papers studying this include Armendáriz de Aghion (1999), who studies the question of optimal design of peer monitoring in ameliorating strategic default, and Rai and Sjöström (2004), who present a scheme that makes use of cross-reporting, which increases the bargaining power of unsuccessful borrowers and induces successful types to help the others repay. Ghatak and Guinnane (1999) provide an excellent survey of the extensive literature on lending with joint liability. See also Townsend (2003) for a discussion of individual and group loans in the context of microcredit.

[(2)] Madajewicz (2005) takes a different stance and shows that a group loan may yield a lower welfare compared to an individual loan for the wealthier among credit-constrained borrowers.

This paper explores a different route and shows that it is possible to construct a mechanism that implements the efficient outcome even if each borrower knows only his *own* type and effort, and peer monitoring is not possible. In other words, the efficient outcome can be implemented even if borrowers have neither superior knowledge about each other compared to the lender, nor the ability to monitor each other's effort choice.

The paper analyzes a model in which the return from a project depends on its intrinsic quality as well as the effort of the operating agent. Both quality and effort are the agent's private information. As Ghatak and Guinnane (1999) point out, there are four major problems facing lenders - gaining knowledge about the quality of borrowers (adverse selection), ensuring correct choice of effort once the loan is made (moral hazard), learning about of the outcome of investment (costly state verification), and enforcement of repayment. The analysis here focuses on the first two problems, and the task is to ensure only high quality borrowers invest and take the right effort. It is assumed that the outcome of investment is observable so that state verification is not a problem, and repayment is enforceable.

The efficient solution requires that only agents with high enough productivity invest, and all investing agents adopt high effort. However, in the only possible equilibrium under individual lending, all types are pooled: either all invest or none. In the former case, there is overinvestment: even low types generating a negative surplus participate. Further, lower types adopt low effort, adding to the distortion.

As noted above, a solution emerges if it is assumed that types are observable, and effort can be monitored by peers. The primary contribution of this paper is to show that full peer information and ability of peers to monitor are not necessary assumptions. There is a simple budget balanced mechanism that can partially separate the types: it implements a cutoff such that higher types invest and take high effort, and lower types do not invest. The investing types themselves are pooled, with no further separation possible, and the same is true of the non-investors. In what follows I abuse terminology slightly and refer to this solution as "separating." The paper shows that the mechanism can restore efficiency, and all types are strictly better off compared to individual lending.

The intuition behind the welfare improvement through the mechanism is as follows. The market failure under individual lending is caused by the fact that access to credit is free and thus even borrowers who have low quality projects and intend to take low effort find it worthwhile to participate. This raises the repayment rate required by the lender, which reduces the incentive to take high effort for all types, which in turn leads to a distorted or even non-existent credit market under individual lending. A potential solution is trading in a market for rights-to-borrow. However, since everyone has free access to credit, no one would buy a right to borrow at a positive price. This paper shows that a mechanism can *implement* such a market using a simple budget-balanced transfer mechanism. The transfer "prices" participation in investment and separates investors and non-investors.

The transfer implies that higher types subsidize lower types in the separating equilibrium. Therefore it is also important to explain why agents–especially the higher types–participate in the mechanism instead of choosing individual loans. The paper shows that the mechanism attains a strict Pareto improvement over individual lending, ensuring participation incentives. Further, cross-subsidization implies potential scope for a competing lender to attract away only the investing types (by offering a slightly lower repayment), leaving the original lender with only the non-investors - a problem known as cream skimming. The mechanism solves this by including a simple "collective" clause which ties the transfers received by non-investors to the presence of investors. This ensures that a competing contract that attracts the investors also attracts the non-investors, making the offer unprofitable. As discussed in section 10, the idea is related to the solution concepts proposed by Wilson (1977) and Riley (1979) to preclude cream skimming. The same collective feature also makes the mechanism coalition proof, and in this regard is also related to the concept of incentive compatible core proposed by (Boyd et al., 1988).

So far the contract uses no special information advantage. Even if full peer information is not available, non-market organizations typically benefit from some local information. Suppose there is some small local advantage in the initial screening of frivolous applicants. The paper shows that if even such weak local information is added to the model, the mechanism cannot be successfully used by formal lenders. Thus a local credit organization can be an optimal response to the informational environment even without full peer information or peer monitoring.

Next, the paper extends the model to consider whether monitoring can have a role in this setup. Suppose investment takes place over a unit length of time, and the credit organization can monitor an agent over any fraction of time. Such monitoring ensures that agents who otherwise take low effort must take high effort while being monitored - incurring part of the cost of high effort. This raises the effort cost for the types who would otherwise adopt low effort, which reduces the underlying "free-access-to-credit" problem. The paper shows that such "partial monitoring" successfully extends the scope of the mechanism so long as the cost of monitoring is not very high. The original transfer mechanism attains efficiency when moral hazard is relatively severe, while a combination of transfers and monitoring is required for cases of less severe moral hazard. The paper characterizes the nature of the mix and clarifies how the optimal arrangements vary as the cost of monitoring changes.

Finally, let us consider the relevance of the theory in the context of development economics. The model here features both adverse selection and moral hazard. In small rural communities adverse selection is often not a problem for lenders, especially for agricultural projects(3). For example, it is likely that members of a Grameen bank lending group in rural Bangladesh have extensive information about each other(4). However, it is unlikely that larger credit cooperatives, especially those in urban and semi-rural areas(5) possess all relevant information about members. In such cases, even after initial screening, residual adverse selection problems are likely to be relevant for the design of lending contracts in addition to the usual moral hazard issues. The model analyzed here addresses such problems.

To consider the relevance of the theory to credit cooperatives in particular, let us compare its predictions to the observations presented in Banerjee et al. (1994) on early 20th century German cooperatives. The fact that lends support to the theory they develop is that almost all rural cooperatives had unlimited liability while urban cooperatives principally featured limited liability, and the latter, but not the former, paid dividends to internal lenders. The authors show that both unlimited liability and dividend payments can provide an incentive to the non-borrowing members to monitor the investors, but only one of the two incentives need to be used, and therefore the data is consistent with the theory. Here, within a setting with limited liability, the theory also predicts a high internal rate of return(6), and is obser-

(3)However, as Aleem (1993) shows, screening costs can be substantial for even long-standing informal lenders.

(4)It is worth noting that the close social ties that engender full peer information could also lead to problems with extractability of such information for certain lenders. A cooperative that includes, say, two neighbors who are the source of information about each other might not be able to extract unfavorable information about either member. Guinnane (1994) reports a similar failure with respect to social enforcement in Ireland.

(5)Banerjee et al. (1994) report (from original sources cited in their paper) that in 1908 the average urban (rural) German credit cooperative had 469 (94) members. Several urban cooperatives were large. Munich, for example, had one with 2600 members.

(6)The model assumes agents have zero own wealth, and therefore the transfer to non-investors imply an infinite rate of return. However, if agents are assumed to have some wealth (but not enough to fund investment vationally equivalent to the theory based on monitoring. However, the high internal rate of return plays a different role here. As noted before, it prices participation in investment and therefore discourages inefficient investment by agents who have projects of low quality and intend to adopt low effort. Similar to the "peer monitoring" effect, this "pricing participation" effect raises the repayment rate of the organization. Further, the theory shows that the two effects are not incompatible - indeed, monitoring also discourages investment with low effort, and the two ways to provide incentives can be fruitfully combined in certain cases. Of course, the relative importance of these effects is impossible to untangle without much further empirical work. The principal contribution here is simply to point out that a theory can be constructed to explain the success of an informal organization such as a credit cooperative without necessarily relying on peers to provide information and monitoring.

The paper is organized as follows. The next section describes the model, and section 3 shows the market failure under individual lending. Section 4 describes a credit mechanism, and section 5 shows that this solves the market failure. Section 6 discusses the incentive to participate as well as the problem of cream skimming. Section 7 explains how even a weak local information advantage implies that only a local institution can use the mechanism. Section 8 extends the model to explore the role of costly monitoring. Section 9 shows how the optimal mechanism varies across the extent of moral hazard and cost of monitoring. Section 10 relates the paper to the literature and discusses modelling features. Finally, section 11 concludes. Proofs not in the body of the paper are collected in appendix A.

2 The Model

There is a continuum of agents. Each agent owns a project requiring an indivisible investment of 1 unit of the numéraire good. Each agent has a zero endowment of this good. An agent can either earn a safe return or engage in production. Throughout the paper, "return" implies gross return. I normalize the safe return to 1.

The return from production is a random variable that can take two values 0, and $R > 0$. The state where the realized value is R is called "success," and the other state is called "failure." The probability of success of a project depends on the project's type as well as the effort of

fully) which non-investors lend to the organization, the results would be qualitatively unchanged but the rate of return for non-investors would be finite.

the agent. Project type is a random variable p with a uniform distribution on $[0, 1]$.

The effort of an agent could be high or low. If an agent takes high effort (uses better quality private inputs), the success probability of his project is given by p, the project's type. If, on the other hand, the agent takes low effort, the success probability is reduced to αp, $0 < \alpha < 1$. Low effort is costless, while high effort has a utility cost of $g > 0$.

The type of a project as well as the level of effort exerted are the agent's private information. However, the distribution of project types and the moral hazard parameter α are public information. Further, investment is observable (which rules out direct consumption of a loan).

The benchmark

If the return from investment exceeds the safe return, it is socially optimal to invest. The return from investment with high effort is $pR - g$. I assume that whenever it is socially optimal to invest, it is optimal to provide high effort, i.e. whenever $pR - g \geqslant 1$, it is also true that $pR - g \geqslant \alpha pR$.

Let the "first-best cutoff for investment" be defined as the type p for which $pR - g = 1$. This type is such that it is efficient for all higher types to invest, and for all lower types not to invest. I denote the first-best cutoff by p_{fb}, which is given by

$$p_{\text{fb}} = \frac{1+g}{R}. \tag{2.1}$$

If $R \leqslant 1 + g$, the efficient solution is no investment (or, in the case of equality, investment by a measure zero set of types). I preclude this trivial case by assuming

$$R > 1 + g. \tag{2.2}$$

Further, for high effort to be efficient for all $p \geqslant p_{\text{fb}}$ (as assumed above), it must be that $pR - g \geqslant \alpha pR$ for all $p \geqslant p_{\text{fb}}$. If this holds for $p = p_{\text{fb}}$, it also holds for all higher value of p. Using the value of p_{fb} from equation (2.1), the required condition is

$$\frac{\alpha g}{1-\alpha} \leqslant 1. \tag{2.3}$$

I assume this holds. Therefore, the **efficient outcome** requires that all types $p \geqslant p_{\text{fb}}$ invest with high effort, and all types $p < p_{\text{fb}}$ do not invest.

3 Individual Lending and Market Failure

As in Stiglitz and Weiss (1981) and deMeza and Webb (1987), the model here features a continuum of risk neutral agents, and separation of types is not possible under individual lending contracts. The only solution is to offer the same contract to all types (i.e. a pooling solution).(7)

A general form of an individual lending contract specifies a payment T_S by the agent if the project succeeds, and T_F if it fails. Agents are subject to limited liability, implying that $T_F \leqslant 0$.

Efficiency requires that types $p \geqslant p_{\text{fb}}$ invest with high effort, and types $p < p_{\text{fb}}$ do not invest. For any type p to invest and take high effort, the following incentive constraint must be satisfied:

$$pR - [pT_S + (1-p)T_F] - g \geqslant \alpha pR - [\alpha p T_S + (1-\alpha p)T_F] \,.$$

Let p_* be the marginal project for which the incentive constraint binds. Simplifying the above, the incentive cutoff p_* is defined implicitly by:

$$p_*(R - T_S) + p_* T_F = \frac{g}{(1-\alpha)}. \tag{3.1}$$

Efficiency requires (a) $p_* = p_{\text{fb}}$ and (b) any type $p < p_*$ does not invest. For the latter condition to be true, it must be that the participation constraint for $p < p_*$ does not hold. Since types $p < p_*$ take low effort if they participate, the required condition is $\alpha pR - [\alpha p T_S + (1-\alpha p)T_F] \leqslant 0$, which implies that $\alpha p(R - T_S) - (1-\alpha p)T_F \leqslant 0$.

However, since $T_F \leqslant 0$, from equation 3.1, $R - T_S > 0$. Thus $\alpha p(R - T_S) - (1-\alpha p)T_F > 0$. Thus the condition above does not hold and the outcome is necessarily inefficient.

In fact, whenever there is any positive measure of types who have an incentive to participate with high effort (i.e. whenever $p_* < 1$), the participation constraint for all types $p < p_*$ holds as well. Therefore all such types invest and adopt low effort. This in turn implies that in equilibrium, if investment takes place at all, it is characterized by extreme overinvestment (all types invest) coupled with low effort taken by some types.

(7)For the sake of completeness, this point is clarified in appendix B. Here agents have zero own wealth. The pooling result is unchanged if all agents have the same initial wealth $0 < W < 1$ (this is the assumption made by Stiglitz-Weiss and deMeza-Webb).

4 THE CREDIT MECHANISM

Under individual lending all types invest, and the lower types who exert low effort cause a market failure. The problem could be solved if there were a market allowing agents to buy and sell their rights to borrow. Such a market would price participation in investment correctly: low types would prefer to sell their rights to borrow rather than invest. However, since access to a credit is free, such a market cannot easily arise. The mechanism below shows how such a market can be implemented.

4.1 THE MECHANISM

The lending organization running the mechanism borrows from the formal sector and lends to its members. By design, the mechanism is budget-balanced. Thus it always repays its loan. It is assumed that the formal lending sector is competitive. The organization can therefore borrow at the competitive rate (here normalized to one).

The mechanism is parameterized by three variables L, π and ρ, and denoted by $\mathbf{M}(L, \pi, \rho)$. This is described by 1-3 below.

1. Initially, offer a loan of $L < 1$ to all borrowers. An agent can either choose to accept or exit. Agents who accept simultaneously decide whether to borrow a further $(1 - L)$ and invest, or not to invest. Let θ_I denote the proportion of agents who choose to become investors. Let $\theta_L = 1 - \theta_I$.

2. A borrower who wants access to further credit (further than the L above) must invest (recall that investment process is observable) and pay $1/\overline{p}$ (where $\overline{p}$ is the average probability of success) plus a credit-access fee of π, both payable in the success state. The specified payment in the failure state is 0.

3. Any borrower who does not want to invest must become an internal lender, and lend L to the organization. This earns a return $\left(\theta_I/\theta_L \rho\right) L$ where $\theta_I/\theta_L \rho \in [0, 1]$. Note that for any $\theta_I/\theta_L \rho > 0$, a non-investor receives a transfer[8].

[8] It is being implicitly assumed, as under individual lending, that once an agent accepts a loan he cannot simply "take the money and run." If this were possible, enforcement issues would be central. As mentioned

The transfer received by non-investors depends on the ratio ${}^{\theta_I}/_{\theta_L}$, determined by the aggregate decision of agents. This feature of the payoff to non-investors, which I refer to as the **"collective clause"**, is important in avoiding some standard problems with competing individual contracts. The issue is explored further in section 6.2.

4.2 Solving the game

The two-stage game analyzed here is as follows. At time 0, all agents simultaneously decide whether to join the mechanism or stay out. At time 1, all agents who join participate in the mechanism.

In what follows, I assume that all agents join initially[9] and analyze the outcome of the mechanism in this subgame. The next section then takes up the question of whether joining is part of an equilibrium in the whole game.

An agent invests and subsequently takes high effort if the following conditions hold:

- High-effort payoff exceeds payoff from not investing:

$$\text{(Participation-in-Investment Constraint)} \quad p\left(R - \pi - \frac{1}{\overline{p}}\right) - g \geqslant \frac{\theta_I}{\theta_L}\rho L. \tag{4.1}$$

- High-effort payoff exceeds low-effort payoff: $p\left(R - \pi - {}^{1}/_{\overline{p}}\right) - g \geqslant \alpha p\left(R - \pi - {}^{1}/_{\overline{p}}\right)$, which simplifies to

$$\text{(Incentive Constraint)} \quad p\left(R - \pi - \frac{1}{\overline{p}}\right) \geqslant \frac{g}{1-\alpha}. \tag{4.2}$$

The participation-in-investment and incentive constraints summarize the incentive properties of the mechanism. To analyze the outcome of the mechanism, I first define the concept of implementation of a cutoff p_*.

Definition 1. ***(Implementation)*** *The mechanism* $\mathbf{M}(L, \pi, \rho)$ *is said to implement a cutoff* $p_* < 1$ *if, in equilibrium, agents with type* $p \geqslant p_*$ *invest and take high effort and those with type* $p < p_*$ *do not invest.*

in the introduction, here the focus is on information asymmetries (adverse selection and moral hazard) rather than enforcement or state verification.

[9] Footnote (10) explains why all agents joining is important.

The analysis proceeds as follows. First, there is no reason to pay the non-investors any more than L. Therefore to implement any cutoff p_*, ρ should be set so that ${}^{\theta_I}/_{\theta_L}\rho = 1$. Since $\theta_L = p_*$,

$$\rho = {}^{p_*}/_{(1 - p_*)}. \tag{4.3}$$

Next, suppose the participation-in-investment constraint binds at p_{pc}. Then all types $p \geqslant p_{\text{pc}}$ participate, and the types below do not. Further, suppose the incentive constraint binds at p_{ic}. Suppose $p_{\text{ic}} > p_{\text{pc}}$. Then types in the interval $[p_{\text{pc}}, p_{\text{ic}}]$ have the incentive to participate in investment, but do not have the incentive to take high effort. These types would invest and take low effort, making the outcome inefficient. Therefore the mechanism must ensure $p_{\text{ic}} \leqslant p_{\text{pc}}$, i.e. the participation-in-investment cutoff must be at least as high as the incentive cutoff. Comparing equations (4.1) and (4.2), and substituting the value of ρ from equation (4.3), it is easy to see that ensuring $p_{\text{ic}} \leqslant p_{\text{pc}}$ requires setting $L + g \geqslant {}^{g}/_{(1-\alpha)}$, which implies $L \geqslant {}^{g\,\alpha}/_{(1-\alpha)}$. For small enough values of α, it is clearly it is possible to find $L < 1$ which satisfies this inequality.

The next step is to choose the right L so that the participation-in-investment constraint binds at p_*. Given that this constraint binds at a higher cutoff compared to the incentive constraint, this ensures all types $p \geqslant p_*$ invest and take high effort.

Finally, the payments to types lower than p_* must be paid for - and so π is set to balance the budget. The next result characterizes the investment cutoffs that can be implemented in this way.

Lemma 1. *Suppose L satisfies $\dfrac{g\alpha}{(1-\alpha)} \leqslant L < 1$, $\pi = \dfrac{2p_*L}{1-p_*^2}$, $\rho = \dfrac{p_*}{1-p_*}$, and $p_* \in [0,1]$ solves*

$$p_*\left(R - \frac{2}{1+p_*} - \pi\right) - g = L. \tag{4.4}$$

Then the mechanism $\mathbf{M}(L, \pi, \rho)$ implements p_*, and is budget balanced.

4.3 Interpreting the mechanism

Under individual lending, all types invest, and separation is impossible. The credit mechanism, on the other hand, separates agents into investors and non-investors. An investor must pay ${}^{1}/_{\overline{p}} + \pi$ in the success state. A payment of ${}^{1}/_{\overline{p}}$ ensures zero profit for the mechanism if $L = 0$. The additional amount, π, can be thought as a fee for access to further credit, which raises funds to pay a transfer to non-investors. Thus a non-investor virtually "sells" his right to borrow to the investors at a positive "market-clearing" price (given by ${}^{\theta_I}/_{\theta_L}\rho L$). In this sense the mechanism implements a market for rights-to-borrow.

5 Attaining first-best

Let

$$L^* = \frac{(R-(1+g))^2}{R^2+(1+g)^2}. \tag{5.1}$$

Clearly, $0 < L^* < 1$. Let $\overline{\alpha}(R,g)$ be the solution for α to $L^* = \dfrac{g\alpha}{1-\alpha}$. Thus

$$\overline{\alpha}(R,g) = \frac{1}{(1+g/L^*)} \tag{5.2}$$

It can be easily checked that this is increasing in R and decreasing in g. The result below shows that whenever $\alpha \leqslant \overline{\alpha}(R,g)$, the mechanism can restore first-best . Moreover, the first-best cutoff for investment is implemented uniquely.

Theorem 1. ***(Attaining first-best)*** *Let L^* be given by* (5.1), *$\pi^* = {}^{2p_{\text{fb}}L^*}/_{(1-p_{\text{fb}}^2)}$, and $\rho^* = {}^{p_{\text{fb}}}/_{(1-p_{\text{fb}})}$. For any $0 < \alpha \leqslant \overline{\alpha}(R,g)$, the mechanism $\mathbf{M}(L^*,\pi^*,\rho^*)$ satisfies budget balance and uniquely implements the first-best cutoff p_{fb}.*

6 Participation incentives and cream skimming

For the mechanism to implement a cutoff in equilibrium, agents must have the incentive to participate in the mechanism. I show below that each agent choosing to participate in the mechanism is an equilibrium. I also show no other lending contract can attract away some fraction of borrowers and earn a positive profit - i.e. the mechanism is proof against cream skimming.

6.1 Participation incentives

The last section assumed all agents join, and analyzed the outcome of the mechanism. Here I show that all agents participating is part of the equilibrium.[(10)] The first step is to show that the equilibrium outcome under the mechanism is a strict Pareto improvement over individual lending.

Lemma 2. ***(Welfare Comparison with Individual Lending)*** *Given any $0 < \alpha < \overline{\alpha}(R, g)$, the payoff of any type $p \in [0, 1]$ under the mechanism strictly exceeds that under individual lending.*

Obviously, the transfer makes the lower types better off than if they were to invest. More interestingly, the investors gain also in spite of paying an extra fee. The intuition is as follows. Under individual lending, the lower types participate and take low effort. This lowers the average probability of success and raises the required repayment. Thus low types impose a negative externality on the higher types. As noted before, this implies that there are gains from trade - if the lower types could sell their rights to borrow to the higher types, everyone would be better off. This missing market is exactly what the mechanism implements. The extra fee the investors have to pay is simply the "market clearing price" in this market which prices the externality. And the fact that the mechanism achieves a strict Pareto improvement reflects the gains from trade in the market for the externality.

The second step is to show that if all others participate, no single agent can deviate profitably. By not participating in the mechanism, an agent can obtain an individual loan and at best face the same terms as described in section 3. But as the lemma above shows, the payoff under the mechanism is strictly higher for *every type* compared to individual lending. Therefore, so long as others participate in the mechanism, no single agent can deviate and get a higher payoff. It follows that the mechanism satisfies participation incentives: if all others join, joining is the strict best response for any agent.

[(10)] There are two reasons why everyone joining is important. If agents decide on participation before learning own types, ex ante incentives are relevant. Since agents are ex ante symmetric, in this case all must join since the alternative is no one joins. Looking at ex post incentives, it is clear that low types would join (they receive a transfer). Thus if only a subset joined - that could only leave out higher types - and it is necessary to ensure all these types join for the mechanism to perform well. In other words, the highest types have non-trivial participation constraints, and section 6.1 shows that in fact such constraints hold.

6.2 Competition in contracts: cream skimming

The mechanism implements a separating equilibrium with cross subsidization - the higher types pay a transfer to the lower types. This raises the possibility of cream skimming: a competing contract might profitably attract away some of the higher types by offering them a slightly lower repayment.

The mechanism is in fact immune to this cream skimming problem. Once a new contract is offered, types simultaneously decide whether to switch or not to switch. Iteratively eliminating strictly dominated strategies, I show that all types (both investors and non-investors) switch to the new contract, leaving the new contract with a negative payoff. Thus cream skimming is not possible.

The intuition is as follows. Note first that if a competing contract attracts away any investing type p, it must also attract away *all* investing types. This is because the payoff of any investing type p under the mechanism is given by $p(R - T_S^*) - g$ where T_S^* is the repayment in the success state. Now, suppose a competing lender offers a contract with repayment $T_S^* - \varepsilon$. Whenever $\varepsilon > 0$, this is clearly attractive to all types p who invest, since $p(R - T_S^* - \varepsilon) - g > p(R - T_S^*) - g$ irrespective of p. Thus any cream skimming contract must attract away all investors. In other words, when a competing offer is made with a lower repayment, we can eliminate the dominated strategy "not switch" by all investing types.

But now the "collective clause" comes into play. This clause ties the payment made to non-investors to the presence of investors. Specifically, the payoff of non-investors is $\left({}^{\theta_I}\!/_{\theta_L}\right) \rho L$, where θ_I is the proportion of agents who invest and $\theta_L = 1 - \theta_I$. The argument above shows that all investors switch to the new contract, and therefore the payoff of non-investors from not switching is zero (since now $\theta_I = 0$). But payoff from taking up the new contract and investing is positive. Therefore, the second round of elimination of dominated strategies suggest that all non-investors switch as well.

Therefore the new contract attracts away all types and this makes it unprofitable. The steps above are formally verified in the proof of the result below in appendix **A**.4.

Theorem 2. *The mechanism specified in section* 4.1 *satisfies the incentive for all agents to participate. Further, the mechanism is proof against cream skimming.*

7 The Mechanism as a Non-Market Institution

So far the collective mechanism uses no special informational advantage. However, a typical feature of non-market credit institutions is that they incorporate some local information.[(11)] A local organization could have some advantage in project evaluation, verifying the return from production, or enforcing the mechanism (ensuring agents do not "take-the-money-and-run").

Since the effect of local information here is simply to increase the cost of credit provision by the formal sector relative to the informal sector, different ways of modeling local information lead to the same result. Here I consider local information in project evaluation. So far, the type p of a project is drawn independently from a uniform distribution on $[0, 1]$. Projects are symmetric ex ante and therefore each project is "potentially worthwhile" since it might draw a high probability of success. Let us now suppose that there is also a mass of "frivolous" projects with a zero chance of success, and suppose local information enables an organization to distinguish potentially worthwhile projects from frivolous ones. Without local information, a cost $c > 0$ must be incurred to evaluate a project initially. Since all projects must be screened to isolate the frivolous ones, the total cost of evaluation can be quite high. Thus even a relatively small local information advantage can translate into a large cost advantage.

Next, if a formal sector bank uses the mechanism, it would either include the frivolous projects, or screen them out at a cost. Therefore a competing local contract can offer the same L and ρ, but a lower π. This attracts away all investing types and also all non-investing types (for the same reason as in section 6.2). Since the original contract must have made a non-negative profit, the new contract makes a strictly positive profit. Thus a formal sector bank using the mechanism cannot survive competition in contracts. This proves the following result.

Theorem 3. *In the presence of even weak local information, the mechanism is not sustainable under the formal sector. Thus a local credit organization is the optimal institutional response to the informational environment.*

[(11)] Aleem (1993) reports that informal lenders generally give unsecured loans but face a lower risk of default than formal lenders, who normally lend against collateral but rarely foreclose. Thus the formal sector is clearly at a disadvantage compared to a local lender. Also see Bell (1993).

8 Costly Partial Monitoring: An Augmented Mechanism

The mechanism above attains efficiency for severe moral hazard ($\alpha < \overline{\alpha}(R, g)$). The reason for the restriction can be seen from the constraint $L \geqslant \alpha g/(1-\alpha)$. For high values of α, L needs to be high - making investment unattractive. Resolving the problem requires a way to keep L low even if α is high. In this section I show that this is possible if a little bit of monitoring is added to the model, so long as this is not too costly.

Suppose the lender can also monitor the effort choice of each borrower, and suppose production takes place over a unit interval of time. Over any measurable interval of time, the operator of a project can take either low or high effort. The usual concept of monitoring translates to monitoring over the entire unit interval enforcing high effort throughout. **Partial monitoring,** on the other hand, refers to monitoring over any interval of length $m < 1$, ensuring high effort on that interval. To make the conclusions sharp, I assume that partial monitoring has no direct benefit.

Assumption: For any project of type $p \in [0, 1]$, if in the production process low effort is taken for any strictly positive interval of time, the expected gross return is $\alpha p R$.

An agent who takes low effort, when monitored partially, would adopt high effort over the monitoring interval, but low effort otherwise. By assumption, output would not improve at all, ensuring partial monitoring has no direct benefit. However, crucially, effort cost of such an agent would increase over the monitoring interval, reducing the underlying externality problem.

Denote the augmented mechanism by $\widehat{\mathbf{M}}(L, \pi, \rho, m)$. This is similar to $\mathbf{M}(L, \pi, \rho)$ except for the following addition. Each investor is monitored for a time interval of length $m < 1$. I assume monitoring has a constant marginal cost $C > 0$. For each investor, the lender now spends an additional $m\,C$. Thus each investor must pay back $1/\overline{p} + \pi$ as before plus an additional $m\,C/\overline{p}$.

The participation-in-investment constraint is now given by $p\left(R - \pi - \frac{1+mC}{\overline{p}}\right) - g = \rho\frac{\theta_I}{\theta_N}L$, and the incentive constraint now simplifies to $p\left(R - \pi - \frac{1+m\,C}{\overline{p}}\right) \geqslant \frac{g(1-m)}{1-\alpha}$. Note that monitoring adds a degree of freedom - given any participation cutoff p_*, m can be set so that the incentive cutoff is also p_*.

8.1 Attaining first-best

I now show that the augmented mechanism can implement the efficient outcome for *any* $\alpha \in (0,1)$ so long as the cost of monitoring is not very high. Specifically, I need $C \leqslant \overline{C}$ where

$$\overline{C} = \min\left(\frac{1-p_{\text{fb}}}{2p_{\text{fb}}}, \frac{{p_{\text{fb}}}^2}{1-p_{\text{fb}}}\right) \tag{8.1}$$

The reason is as follows. First, investing types must pay for the cost of monitoring as well as that of transfers to lower types. As C increases, to preserve the incentive to invest, L_M^* must fall. $L_M^* \not< 0$ then implies $C \leqslant (1-p_{\text{fb}})/2p_{\text{fb}}$. Note that for p_{fb} close to 1, a small measure of investors must pay for transfers to lower types as well as monitoring, making $\overline{C}$ low. Second, for any extent of monitoring $m > 0$, welfare of all types is decreasing in C. Ensuring that investors participate (rather than choose an individual loan) requires $C \leqslant {p_{\text{fb}}}^2/(1-p_{\text{fb}})$. Note that for p_{fb} close to 0 there is little distortion under individual lending, thus $\overline{C}$ is low.

Let L_M denote the initial loan, and let its optimal value be given by

$$L_M^* = \frac{g(1-p_{\text{fb}})(1-p_{\text{fb}}\,(1+2\,\alpha\,C))}{p_{\text{fb}}\,(g\,p_{\text{fb}} - 2\,C\,(1-\alpha)\,(1-p_{\text{fb}})) + g} \tag{8.2}$$

Note that for $C = 0$, L_M^* coincides with the optimal transfer without monitoring (given by (5.1)). The following properties of L_M^* are useful for later proofs.

Lemma 3. *For any $\alpha \in [\overline{\alpha}(R,g),1)$, L_M^* is decreasing in C, $L_M^* < 1$, and finally $L_M^* \geqslant 0$ whenever $C \leqslant \overline{C}$.*

Finally, let the optimal monitoring extent m^* be given by the following:

$$m^* = \begin{cases} 0 & \text{for } 0 < \alpha \leqslant \overline{\alpha}(R,g)\text{, and} \\ \alpha - (1-\alpha)L_M^*/g & \text{otherwise.} \end{cases} \tag{8.3}$$

The main result under the augmented mechanism follows.

Theorem 4. (Attaining first-best Under Augmented Mechanism) *Let L_M^* be given by* (8.2), *$\pi_M^* = 2p_{fb}L_M^*/(1-p_{fb}^2)$, $\rho^* = p_{fb}/(1-p_{fb})$, and m^* be given by equation* (8.3)*. For any $\alpha \in (0,1)$, the augmented mechanism $\widehat{\mathbf{M}}(L_M^*, \pi_M^*, \rho^*, m^*)$ satisfies budget balance and implements the first-best cutoff for investment p_{fb} whenever $C \leqslant \overline{C}$, where $\overline{C}$ is given by* (8.1).

8.2 Participation incentives and cream skimming

I first consider the payoff of types who invest in equilibrium.

Lemma 4. *For any $\alpha \in (0,1)$, and for any type $p \geqslant p_{fb}$, the payoff under the augmented mechanism is greater than the payoff under individual lending whenever $C \leqslant \overline{C}$.*

This shows that if all others participate, any type $p \geqslant p_{\text{fb}}$ cannot profitably deviate from participation. Since non-participation is dominated in equilibrium for types $p \geqslant p_{\text{fb}}$, any outside lender must believe that a deviating agent is of type lower than p_{fb}. Since it is unprofitable to lend to such types, an agent of type $p < p_{\text{fb}}$ gets a zero payoff by deviating, while the payoff under the mechanism is $L_M^* \geqslant 0$. Thus all agents participating in the augmented mechanism is a Nash equilibrium. Finally, the augmented mechanism is proof against cream skimming for the same reason as before.

9 Transfers versus Monitoring

For severe moral hazard ($\alpha < \overline{\alpha}(R,g)$), efficiency can be achieved through the original mechanism which makes use of implicit transfers. In this case monitoring would be wasteful. For $\alpha \geqslant \overline{\alpha}(R,g)$, efficiency is achieved by adding partial monitoring to transfers. The following result shows how the mix between monitoring and transfers changes with the cost of monitoring.

Corollary 1. *As the cost of monitoring C increases, the optimal monitoring level m^* increases and the level of transfer L_M^* falls.*

Proof: The extent of the transfer and monitoring are given by L_M^* (equation (8.2)), and m^* (equation 8.3), respectively. From lemma 3, L_M^* is decreasing in C. Therefore, from equation (8.3), m^* is increasing in C. $\square$

The intuition is as follows. Both transfers and cost of monitoring must be paid for by the investors. As the cost rises, to preserve the incentive to participate in investment the transfer must fall. But this raises the incentive of types lower than p_{fb} to participate in investment. To eliminate this, the extent of monitoring must rise. Thus, interestingly, the extent of monitoring rises in the cost of monitoring. As C rises to $\overline{C}$, L_M^* falls to zero, and the mechanism becomes purely monitoring-based. Figure 1 shows the different regimes.

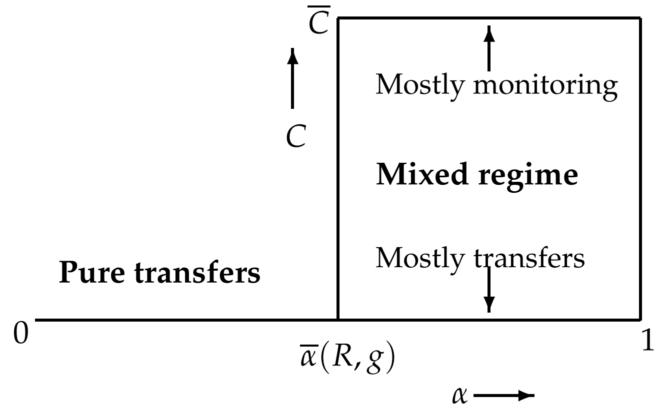

Figure 1: The mix between transfers and monitoring for $0 < C \leqslant \overline{C}$.

10 DISCUSSION

10.1 RELATED MODELS

The fact that information asymmetries can cause the formal individual lending to be distorted is very well known. There are famous credit rationing results by Jaffee and Russell (1976) and Stiglitz and Weiss (1981). Jaffee and Russell focus on the constraint on loan size arising from strategic default incentives. In the Stiglitz-Weiss model, as in this paper, the focus is on investment incentives. However, as deMeza and Webb (1987) show, an inefficiency arises in the Stiglitz-Weiss model only because the form of contracts is restricted arbitrarily to debt contracts. In fact an equity contract is optimal in their setting, under which the outcome is efficient. deMeza and Webb show that if projects are ranked by probability of success, a debt-contract is optimal, and under optimal contracts there is overinvestment. Here the quality of projects are ranked in this manner, and the model also adds an effort choice decision by agents. Unsurprisingly, the market outcome for individual lending is distorted under the optimal contract.

The mechanism here implements a separating equilibrium with cross subsidization, which creates the possibility of cream skimming. The problem is similar to that arising in the insurance model of Rothschild and Stiglitz (1976). However, let us first note the differences between the two settings.

In the insurance model, the utility functions of the good and bad types satisfy the single crossing (i.e. Spence-Mirrlees sorting) property[(12)], and there is a separating equilibrium without cross subsidization, and a pooling equilibrium with cross subsidies which is subject to cream skimming. In contrast, in the current model, there is a continuum of risk neutral agents subject to limited liability, and individual lending contracts can only specify the repayment amount. Therefore no separation is possible under individual lending contracts[(13)], and the issue of cream skimming does not arise. This becomes an issue only under the mechanism, which achieves separation between investors and non-investors through transfers.

The mechanism solves this by including a simple collective clause which ties the transfers received by non-investors to the presence of the investors. This implies that a competing contract that attracts the investors also attracts the non-investors, making the offer unprofitable. Let us now compare this to other solutions proposed in the literature.

10.2 Alternative solutions to cream skimming

Solutions to cream skimming proposed by Wilson (1977) and Riley (1979) modify the solution concept by incorporating further reactions to the original deviation. The solution here is related to these, in particular to Wilson's "anticipatory equilibrium." In this concept, a firm contemplating offering a cream skimming contract also anticipates that the original contract will be dropped, nullifying the advantage from the deviation. Riley's "reactive equilibrium" disallows any deviation that is itself vulnerable to credible deviations. This ensures survival of separating equilibria without cross subsidies, and, as Kahn and Mookherjee (1995) show[(14)], also ensures survival of pooling equilibria with cross subsidies. Basically, if the original contract involves cross subsidies, cream skimming damages the original lender, and dropping the contract is then a credible deviation. Thus in either concept, the augmenting factor that immunizes equilibria with cross subsidization from cream skimming is foresight about the post-deviation dropping of the original contract.

Here the mechanism implements a separating equilibrium with cross subsidies, and the collective clause plays a similar role: it implies that the contract would be dropped if the investors take up a different contract, ensuring that any deviating contract that attracts the

(12) The marginal rate of substitution between incomes in the two states (in one of which a loss occurs) is uniformly higher for the type with a relatively lower probability of loss (the "good" type).

(13) A formal discussion of this point is included in appendix B.

(14) See footnote 18, page 130.

investors also attracts the non-investors, preventing cream skimming.

The next question is whether in the absence of such a clause the solution can be sustained as a market outcome. Hellwig (1987) shows that the Rothschild-Stiglitz non-existence problem disappears if we consider a three stage game: the lenders make contract offers, then the agents choose among offers, and finally the lenders can withdraw any contract. However, such a game cannot support a separating contract with cross subsidies - if such a contract is offered and accepted, the lender will drop the contract for the types who are being subsidized. Therefore in the current model the three stage game would result in all types investing to start with (since any type who chooses not to invest in stage 2 knows its contract will be dropped in stage 3) - bringing us back to the inefficient pooling equilibrium under individual lending.

The discussion above shows that the mechanism considered here requires commitment by the lender as well as the ability of non-investors to observe any deviation by investors. Therefore the mechanism is best interpreted as a non-market organization rather than as a market outcome. This point is clarified further in the discussion below on coalition proof equilibria.

10.3 Coalitional deviations

A related issue in the context of informal organizations concerns the idea of coalition proof equilibria. Suppose a coalition of some of the investors deviate to another contract. As noted before, the equilibrium separates investors and non-investors, but the investors themselves are pooled, and cannot be separated any further. Therefore if some investing types find the deviation attractive, all investing types must find it attractive. But, given the collective clause, the non-investors would also find it profitable to join the deviating coalition, rendering the deviation unprofitable.

The solution above can be thought of as implementing (in a purely non-cooperative framework) the same idea that arises in the literature on the incentive compatible core (IC core) in adverse selection economies. In the formulation of Boyd et al. (1988), the IC core outcomes are unblocked by coalitional deviations. It is assumed that any such deviation is observed by all agents, and the residual coalition reoptimizes. The IC core supports cross-subsidized allocations since the subsidized types would optimally join a deviating coalition of subsidizing types, rendering the deviation unprofitable - which is exactly the logic behind the solution arising here through the collective clause.

Boyd et al. (1988) interpret the grand coalition as forming a non-market organization, an interpretation that is natural in the current setting as well. A more decentralized trading oriented approach is considered by Kahn and Mookherjee (1995). In their model firms offer contracts and individuals select a firm and make a trade request. In this game they consider coalition proof equilibria, with the modification that non-members of any given coalition cannot condition their strategy on deviations by that coalition. They show that an equilibrium exists and that any allocation with cross subsidies cannot be supported as an equilibrium. If such a market model is applied to the current setting, it would clearly rule out the separating allocation with cross subsidies considered here - any lender offering such contracts can profitably deviate by dropping the contract for non-investors.(15)

The discussion above shows that the contract here can be successfully interpreted only as a non-market institution. There is no natural way to implement the cross-subsidized separating contract considered here as a market allocation.

10.4 Welfare

The mechanism considered here implements the first-best outcome. The analysis implicitly assumes equal welfare weights on all types and maximizes the total utility. However, the model can also accommodate different welfare weights, and the optimal outcome varies continuously in such weights. For example, a higher weight on types who choose to invest in equilibrium (or some subset of these types) would result in the new optimum involving a some more types investing (i.e. the cutoff type for investment would be lower) and a lower transfer. This raises the payoff of the investing types at the cost of admitting investment by some types who generate a negative surplus.

The intuition is that the transfer keeps the marginal investor indifferent between investing and not investing (and receiving the transfer). Since the payoff of investors is increasing in

(15)Indeed, such a trading process would result in the same inefficient outcome as under individual lending: all types pool (all invest). This outcome also involves cross subsidies - but this cannot be eliminated by coalitional deviations since, as noted before, the types cannot be separated under individual lending contracts. See appendix B for a formal discussion.

type, a lower investment cutoff implies a lower required transfer. This reduces the payoff of non-investors, and increases the payoff of investors by lowering the repayment.[(16)]

10.5 Modelling issues

The model features both adverse selection and moral hazard. While a model with only adverse selection[(17)] can capture the basic intuition, the problem can then also be solved through trivial schemes. For example, consider setting the payment in the success equal to the entire return (i.e. set $T_S = R$), then redistributing the total amount equally among agents. Since payoff is independent of investment decision, it is an equilibrium for types $p \geqslant p_{\text{fb}}$ to invest and $p < p_{\text{fb}}$ to not invest[(18)]. An obvious criticism is that such an arrangement is not robust to introducing a costly private effort. Introducing moral hazard along with adverse selection precludes such schemes, and makes for a more interesting solution. Moreover, introducing moral hazard allows an investigation of the role of monitoring.

Next, it is important to see how different ways of modelling the structure of project returns affect the results. In this model, the outcome R in the success state is fixed, while the type p varies. In an alternative model, the success state outcome could depend on p. The expected outcome of type p is then $\mathbb{E}(p) = pR(p)$. If $\mathbb{E}(p)$ increases in p, the model is simply a generalized version of the current one[(19)].

A second variation, which features in a large number of models, assumes that $R(p)$ varies with p so that $\mathbb{E}(p) = K$, where K is a positive constant. There are two problems with such a setting. First, this does not capture the problem analyzed here. To see this, assume $\alpha K < K - g$ so that high effort is efficient. Also, assume $K > 1 + g$, since otherwise zero investment is efficient. But now the efficient solution is for all projects to invest, precluding the concerns here about preventing low types from investing. Second, in this case individual lending could itself be efficient - so that there is no market failure to address. Ignoring moral hazard, this setting is similar to that of Stiglitz and Weiss (1981). As noted in section 10.1 above,

(16) This is easy to show formally. I omit the proof.

(17) Here this can be obtained by setting $\alpha = 1$ and $g = 0$.

(18) Of course, any $p_* \in [0, 1]$ is a Nash equilibrium.

(19) With bounded $R(\cdot)$, $\mathbb{E}(p)$ must be increasing in p for low p. If $\mathbb{E}'(p) < 0$ for higher values of p, efficiency requires investment with high effort by some interval of types in the middle. A mechanism similar to the one used here is likely to work, the difference being that types are now ranked by $\mathbb{E}(p)$ rather than p.

in the Stiglitz-Weiss model individual lending is efficient under an equity contract. The credit rationing result obtains purely because the paper arbitrarily restricts attention to debt contracts. Even with moral hazard added, an equity contract attains efficiency whenever α is low enough[20].

Another feature of the model is that the size of investment is fixed. If the model is generalized to include investments of different sizes, does that help in separating types under individual lending? For this to happen, it must be less costly (in terms of effort or some other personal cost) for higher types to invest a higher amount. While this would complicate matters substantially, there might be a separating equilibrium in which higher types take loans of a higher size. However, even if such an equilibrium exists, separation incentives must require that types lower than the first-best also invest (albeit with a lower loan size) - which is inefficient. This does not address the main question here: how to stop the low types from investing when such investment is inefficient.

Finally, there are two different enforcement issues in the model. First, agents must adhere to the mechanism (i.e. cannot take the money and run). This assumption can be thought of as reflecting the fact that the borrowers have local ties making it difficult for them to leave the area, and the lender operates over many periods and can deter deviations through social sanctions or a penalizing denial of future credit. A second issue is whether the lender can commit to the mechanism if a multi-period model is considered. If types are drawn every period, using the mechanism in any period does not reveal any useful information for future, and the assumption of commitment is innocuous. But if types persist over time, lack of commitment ability could give rise to a "ratchet effect" (see Freixas et al. (1985)) - inducing inefficient outcomes (compared to static optimum) in early periods to induce revelation. In this case the implicit assumption of commitment by the lender might be restrictive.

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[20] An equity contract requires a repayment of a fraction $\gamma \in [0,1]$ of the outcome. Set γ such that $\gamma K = 1$. This ensures that the lender breaks even. The payoff of a project from high effort is $(1-\gamma)K - g = K - (1+g) > 0$, and the payoff from low effort is $\alpha(1-\gamma)K = \alpha(K-1)$. For α such that $K - (1+g) \geqslant \alpha(K-1)$, the outcome is efficient.

11 Conclusion

Informational problems combined with lack of sufficient collateral often distort formal credit markets. This paper considers a model with adverse selection and moral hazard in which all types are necessarily pooled under individual lending, and the outcome is inefficient. The literature on informal organizations offers improvements based on the assumptions that agents themselves have complete information on their peers, and can monitor the effort of peers.

This paper, in contrast, constructs a simple budget-balanced mechanism which does not rely on peer information or monitoring, but eliminates the inefficiency by pricing the participation of the lower types in investment through a transfer from higher types to lower types. The mechanism implements an equilibrium that separates investors from non-investors, ensures that investors adopt high effort, and restores efficiency. It also raises the payoff of every type, which explains why all agents participate. In addition, it includes a simple collective clause tying the payoff of non-investors with the presence of investors, which ensures that the mechanism is proof against cream skimming despite using transfers across types. The result establishes that a collective organization can achieve efficiency even without any privileged peer information or peer monitoring. Further, if some small local information advantage is added to the model, the mechanism cannot be successfully used by formal lenders. Thus a local collective organization emerges as an optimal solution to the market failure.

The paper also extends the model to consider the role of monitoring. It shows that partial monitoring of effort can extend the scope of the mechanism so long as the cost of monitoring is not very high. The intuition is that monitoring raises the effort cost for the types who would otherwise adopt low effort, reducing the underlying externality problem. The paper characterizes the optimal mix between transfers and monitoring and clarifies how the mix changes as the extent of moral hazard and the cost of monitoring change.

In the context of an informal organization such as a credit cooperative, a higher-than-market internal rate of return is typically taken as an incentive for peer monitoring. This theory shows that there is an another explanation for this fact. A high internal rate of return can serve as a price of participation in investment, improving efficiency by discouraging investment by certain types.

APPENDIX A: PROOFS

A.1 PROOF OF LEMMA 1

If p_* is the investment cutoff, $\theta_I = 1 - p_*$, and $\theta_L = p_*$. Thus ${}^{\theta_I}/_{\theta_L}\rho = 1$. Thus the participation-in-investment constraint (given by equation 4.1) reduces to

$$\text{(Participation-in-Investment Constraint)} \quad p\left(R - \pi - \frac{1}{\overline{p}}\right) \geqslant L + g. \tag{A.1}$$

The fact that $L \geqslant \alpha g/(1-\alpha)$ implies $L + g \geqslant g/(1-\alpha)$, and thus the participation-in-investment constraint (given by equation (A.1)) binds at a higher p compared to the incentive constraint (given by equation (4.2)).

This implies that the high-effort cutoff is the type p_* for which the participation-in-investment constraint binds exactly:

$$p_*(R - \pi - \frac{1}{\overline{p}}) = L + g. \tag{A.2}$$

To ensure that no one participates with low-effort, note that any such agent must have a type p for which the incentive constraint does not hold - i.e. $p(R - \pi - 1/\overline{p}) < g/(1-\alpha)$. For any such p, the payoff from investing (with low effort) is $\alpha p(R - \pi - 1/\overline{p}) < \alpha g/(1-\alpha)$. Since $L \geqslant \alpha g/(1-\alpha)$ by construction, any such agent would prefer not to invest.

Thus if p_* is the investment cutoff, all $p \geqslant p_*$ take high effort. This implies that the average probability of success is given by $\overline{p} = E(p|p \geqslant p_*) = (1 + p_*)/2$. Substituting the value of the average probability of success in equation A.2 above, the resulting equation is the same as equation (4.4).

Thus the high-effort cutoff satisfies equation (4.4), and there are no agents who participate with low effort. This proves that under the conditions mentioned in the statement of the lemma, the mechanism implements the required cutoff.

Finally, budget balance needs to be checked. Given the investment cutoff p_*, a fraction $(1 - p_*)$ of types participate and each gets a loan of 1. Thus the total loan made by the mechanism is $(1 - p_*)$. Since ${}^{\theta_I}/_{\theta_L}\rho = 1$, the total transfer to non-investors is $p_* L$. The expected receipts are

$$\begin{aligned} Prob(p \geqslant p_*)E(p|p \geqslant p_*)(\pi + \frac{1}{p}) &= \left(\pi + \frac{1}{p}\right)\int_{p_*}^{1} pdp \\ &= \left(\frac{2p_*L}{1-p_*^2} + \frac{2}{1+p_*}\right)\frac{(1-p_*^2)}{2} \\ &= p_*L + (1-p_*), \end{aligned}$$

which is exactly equal to the total of transfers and loans advanced. Thus the budget deficit is zero. □

A.2 Proof of Theorem 1

Clearly, $L^* < 1$. Further, for $\alpha < \overline{\alpha}(\cdot,\cdot)$, $L^* > g\alpha/(1-\alpha)$. Also, π^* and ρ^* are equal to π and ρ specified in lemma 1 for $p_* = p_{\text{fb}}$. Finally, substituting the value of L^* and π^* in equation (4.4), solving for p_*, and discarding the negative solution: $p_* = (1+g)/R = p_{\text{fb}}$. Thus, from lemma 1 it follows directly that for $\alpha \leqslant \overline{\alpha}(r,g)$, $\mathbf{M}(L^*, \pi^*, \rho^*)$ implements p_{fb}, and satisfies budget balance. Further, since $p_* = p_{\text{fb}}$ is the only positive solution of equation (4.4) under the given values of L^* and π^*, the implementation is unique. □

A.3 Proof of Lemma 2

Step 1. First, note that under any optimal individual lending contract, $T_F = 0$. From limited liability, $T_F \leqslant 0$. If $T_F < 0$, this only dilutes incentives as follows. As T_F becomes more negative, from equation (3.1), p_* increases. Now, the measure of the projects undertaking high effort is $(1-p_*)$, and that of projects undertaking low effort is p_*. Thus an increase in p_* distorts aggregate effort further. So the optimal choice is to set $T_F = 0$.

Step 2. Second, any type taking low effort under an individual lending contract benefits strictly under the mechanism. To see this, note that types $p < p_*$, where p_* is the high effort cutoff given by equation (3.1), take low effort under an individual lending contract. From equation (3.1), putting $T_F = 0$, $p_*(R - T_S) = g/(1-\alpha)$. Using this, the payoff of type p_* is $p_*\,(R - T_S) - g = \alpha g/(1-\alpha)$. Thus any type $p < p_*$ (recall that any such type takes low effort) earns a payoff of $\alpha p\,(R - T_S) = \alpha \dfrac{p}{p_*}\dfrac{g}{(1-\alpha)} < \dfrac{\alpha g}{1-\alpha}$. Under the mechanism, such a type can earn at least ${}^{\theta_I}/_{\theta_L}\rho^* L^* = L^*$ (this follows from the fact that $\theta_I = 1 - p_{\text{fb}}$, $\theta_L = p_{\text{fb}}$, $\rho^* = p_{\text{fb}}/(1-p_{\text{fb}})$), and $L^* > {}^{\alpha g}/_{(1-\alpha)}$ for $\alpha < \overline{\alpha}(r,g)$.

Step 3. It remains to show that each type taking high effort (i.e. $p \geqslant p_*$) benefits strictly under the mechanism. The payoff from individual lending for any such type is given by

$$Y(p) = p(R - \frac{1}{p}) - g. \tag{A.3}$$

Now, the average probability of success $\overline{p}$ under individual lending is given by

$$\begin{aligned} \overline{p} &= Prob(p \geqslant p_*)E(p|p \geqslant p_*) + Prob(p < p_*)E(\alpha p|p < p_*) \\ &= \int_{p_*}^{1} p dp + \int_0^{p_*} \alpha p dp \\ &= \frac{1}{2} - (1-\alpha)\frac{p_*^2}{2} \end{aligned} \tag{A.4}$$

Since $\overline{p} < \frac{1}{2}$, it follows that

$$Y(p) < p(R-2) - g. \tag{A.5}$$

Let $D(p)$ denote the difference between the payoff of type p under the credit mechanism and individual credit. There are two possibilities to consider.

First, suppose $p_* < p_{\text{fb}}$. Consider any type p such that $p_* \leqslant p < p_{\text{fb}}$.

$$\begin{aligned} D(p) &= L^* - Y(p) \\ &> L^* - Y(p_{\text{fb}}) \\ &> L^* - p_{\text{fb}}(R-2) + g \\ &= \frac{2(1+g)^3}{R((1+g)^2 + R^2)} \quad > \quad 0, \end{aligned}$$

where the third step uses (A.5). Second, suppose p_* is either lower than or greater than p_{fb}, and consider any type p such that $p \geqslant p_{\text{fb}}$.

$$\begin{aligned} D(p) &= p\left(R - \pi^* - \frac{2}{1+p_{\text{fb}}}\right) - g - Y(p) \\ &> p\left(R - \pi^* - \frac{2}{1+p_{\text{fb}}} - (R-2)\right) \\ &= p\left(\frac{2(1+g)^2}{(1+g)^2 + R^2}\right) \quad > \quad 0, \end{aligned}$$

where the second step uses (A.5). This completes the proof. $\square$

A.4 PROOF OF THEOREM 2

The discussion in section 6.1 and lemma 2 prove the first part. The proof of the second part is as follows.

Let T_S^* denote the payment in the success state under the original mechanism. The investment cutoff is given by p_* such that

$$p_* \left(R - T_S^*\right) = L + g$$

Suppose a competing contract is offered with a specified payment of $T_S^* - \epsilon$ in the success state, and 0 in the failure state, where $\epsilon > 0$. Let p_c be given by

$$p_c \left(R - T_S^* + \epsilon\right) = L + g$$

Then p_c is the investment cutoff under this new contract - all types $p \geqslant p_c$ take up the new contract and invest with high effort.[(21)]

Clearly, the coefficient of p_c is higher, and therefore $p_c < p_*$. Therefore, when the new contract is offered, all types above p_* (i.e. all investing types in the original contract) switch to the new contract and moreover, some types (between p_* and p_c) who were non-investors in the original contract also switch to the new contract in the first round of elimination of dominated strategies.

Thus the strategy "not switch" by types $p \geqslant p_c$ is dominated, and can be eliminated.

Recall that the payoff of non-investors is $\left(\theta_I/\theta_L\right) \rho L$. Knowing that types $p \geqslant p_c$ have a dominant strategy to switch, each type below p_c faces a payoff of 0 (as now $\theta_I = 0$) by choosing to stay. By switching and investing, any type $p \in (0, p_c)$ earns a strictly positive payoff. Thus the strategy "not switch" by types $p < p_c$ is dominated, and can be eliminated.

Therefore all types would take up the new contract and invest. I now show that this lowers the average probability of success so that in fact the new contract earns a negative payoff.

Since all types invest, there is some cutoff p_* (the type for which the incentive constraint holds with equality) such that types below p_* adopt low effort. The average probability of

(21) The incentive constraint is similar to equation 3.1 on page 7, and is given by $p_* \left(R - T_S^* + \epsilon\right) \geqslant g/(1-\alpha)$, which holds whenever the participation constraint is satisfied because $L + g \geqslant g/(1-\alpha)$ whenever $L \geqslant \alpha g/(1-\alpha)$.

success $\overline{p}$ is therefore given by

$$\begin{aligned}\overline{p} &= Prob(p \geqslant p_*)E(p|p \geqslant p_*) + Prob(p < p_*)E(\alpha p|p < p_*) \\ &= \int_{p_*}^{1} p dp + \int_{0}^{p_*} \alpha p dp \;=\; \frac{1}{2} - (1-\alpha)\frac{p_*^2}{2} \;<\; \frac{1}{2}.\end{aligned}$$

From theorem 1, the payment by an investor in the success state under the original mechanism is $(2/(1+p_{\text{fb}}) + \pi^*)$. Thus the profit of the competing contract, denoted by π_{cc} is given by:

$$\begin{aligned}\pi_{\text{cc}} &= \overline{p}\left(\frac{2}{1+p_{\text{fb}}} + \pi^* - \epsilon\right) - 1 \\ &< \frac{1}{2}\left(\frac{2}{1+p_{\text{fb}}} + \pi^*\right) - 1 \\ &= \frac{p_{\text{fb}} L^*}{1-{p_{\text{fb}}}^2} + \frac{1}{1+p_{\text{fb}}} - 1 \\ &= \frac{p_{\text{fb}}}{1+p_{\text{fb}}}\left(\frac{L^*}{1-p_{\text{fb}}} - 1\right) \\ &= \frac{p_{\text{fb}}}{1+p_{\text{fb}}}\left(\frac{R^2 - R(1+g)}{R^2 + (1+g)^2} - 1\right) \;<\; 0.\end{aligned}$$

where the third and final steps use the values of π^* and L^*, respectively, from theorem 1. The final step also uses the fact that $p_{\text{fb}} = (1+g)/R$. Since $\pi_{\text{cc}} < 0$, the competing contract is unprofitable. This completes the proof. $\square$

A.5 Proof of Lemma 3

$$L_M^* = \frac{g(1-p_{\text{fb}})\big(1-p_{\text{fb}}\,(1+2\,\alpha\,C)\big)}{p_{\text{fb}}\,(g\,p_{\text{fb}} - 2\,C\,(1-\alpha)\,(1-p_{\text{fb}})) + g}$$

Note that at $C = 0$, $L_M^* = L^*$, where L^* is the optimal transfer without monitoring (given by equation (5.1)). From equation (5.1), $L^* < 1$. Below I show that L_M^* is decreasing in C for $\alpha > \overline{\alpha}(R,g)$. This then also proves that $L_M^* \leqslant L^*$ and therefore $L_M^* < 1$.

Let Z_1 denote the denominator of the expression for L_M^* above. Differentiating L_M^* with respect to the marginal monitoring cost C,

$$\frac{\partial L_M^*}{\partial C} = -\,\frac{2g\,(1-\alpha)\,p_{\text{fb}}\,(1-p_{\text{fb}})\,(1+{p_{\text{fb}}}^2)\,Z_2}{Z_1^2}, \tag{A.6}$$

where

$$
\begin{aligned}
Z_2 &= \frac{g\alpha}{1-\alpha} - \frac{(1-p_{\text{fb}})^2}{1+{p_{\text{fb}}}^2} \\
&= \frac{g\alpha}{1-\alpha} - \frac{(R-(1+g))^2}{R^2+(1+g)^2} \\
&= \frac{g\alpha}{1-\alpha} - L^*
\end{aligned}
$$

where L^* is the optimal transfer without monitoring (given by equation (5.1)). Now, as derived in section 5, $\overline{\alpha}(R,g)$ is the solution for α to $L^* = \dfrac{g\alpha}{1-\alpha}$.

Therefore $Z_2 = 0$ for $\alpha = \overline{\alpha}(R,g)$, and $Z_2 > 0$ for $\alpha > \overline{\alpha}(R,g)$. It follows from equation (A.6) that for $\alpha > \overline{\alpha}(R,g)$, $\dfrac{\partial L_M^*}{\partial C} < 0$.

Finally, the highest C for which L_M^* is non-negative can be obtained by solving $L_M^* = 0$ for C. For any $\alpha \in [\overline{\alpha}(R,g), 1)$, this is given by $(1-p_{\text{fb}})/(2\alpha p_{\text{fb}})$. From equation (8.1), $C \leqslant \overline{C}$ implies C does not exceed this amount for any such α. □

A.6 Proof of Theorem 4

The proof proceeds through the following result, which is very similar to lemma 1, and characterizes the cutoffs that the augmented mechanism can implement. The proof is very similar to that of lemma 1, and is omitted.

Lemma 5. *For any $\alpha \in (0,1)$ and $L < 1$, let $m \leqslant \alpha$ satisfy $\dfrac{g(\alpha - m)}{1-\alpha} \leqslant L$. Let π and ρ be as in lemma 1. For any $L \geqslant 0$ and $C \geqslant 0$ suppose $p_* \in [0,1]$ solves*

$$p\left(R - \pi - \frac{2}{1+p_*}(1+m\,C)\right) = L + g. \tag{A.7}$$

Then the augmented mechanism $\widehat{\mathbf{M}}(L,\pi,\rho,m)$ implements p_*, and is budget balanced.

Now, from lemma 3, $L_M^* < 1$. The addition of m^* ensures that for any $\alpha \in (0,1)$, $L_M^* \geqslant g(\alpha - m)/(1-\alpha)$. Further, for any $C \leqslant \overline{C}$, $L_M^* \geqslant 0$.

Also, π_M^* and ρ^* are equal to π and ρ specified in lemma 5 for $p_* = p_{\text{fb}}$. Finally, substituting the value of L_M^*, π_M^*, and m^* in equation (A.7), solving for p_*, and discarding the negative solution: $p_* = (1+g)/R = p_{\text{fb}}$. Thus, from lemma 5 it follows that for any $\alpha \in (0,1)$, $\widehat{\mathbf{M}}(L_M^*, \pi_M^*, \rho^*, m^*)$ implements p_{fb}, and satisfies budget balance. □

A.7 Proof of Lemma 4

Consider any type $p \geqslant p_{\text{fb}}$. Under individual lending, the payoff $Y(p)$ is given by (A.3). From (A.5), $Y(p) < p(R-2) - g$.

Case 1: $R \leqslant 2$**:** Clearly, if $R \leqslant 2$, individual lending breaks down. In this case, an agent has an incentive to participate in the mechanism so long as his payoff is at least zero. Now, under the mechanism, non-investors receive a payoff $L_M^* \geqslant 0$. The marginal investor type p_{fb} receives the same payoff, and $p > p_{\text{fb}}$ receive higher payoffs. Thus all types receive a positive payoff, and therefore the participation constraint holds for all types $p \in [0,1]$.

Case 2: $R > 2$**:** For any type $p \geqslant p_{\text{fb}}$, let us subtract the payoff under individual lending from that under the mechanism. Let $D(p)$ denote the difference.

$$\begin{aligned}
\widehat{D}(p) &= p\left(R - \pi_M^* - \frac{1+m^*C}{(1+p_{\text{fb}})/2}\right) - g - Y(p) \\
&> p\left(2 - \pi_M^* - \frac{1+m^*C}{(1+p_{\text{fb}})/2}\right)
\end{aligned}$$

where the second step follows from the fact that $Y(p) < p(R-2) - g$.

Now, if $D(p) \geqslant 0$ for $C = \overline{C}$, it follows that $D(p) \geqslant 0$ for any $C < \overline{C}$ as well.

Therefore I need to show that $D(p) \geqslant 0$ for $C = \overline{C}$.

Step 1. From equation 8.1, for $p_{\text{fb}} \geqslant 1/2$, $\overline{C} = (1-p_{\text{fb}})/2p_{\text{fb}}$. Using this value for C, and substituting the values of π^* and m^* (from theorem 4), $D(p) = \frac{2p_{\text{fb}}-1}{p_{\text{fb}}}$. Since for this case $p_{\text{fb}} \geqslant 1/2$, $D(p) \geqslant 0$.

Step 2 For $p_{\text{fb}} < 1/2$, $\overline{C} = {p_{\text{fb}}}^2/(1-p_{\text{fb}})$. Using this value for C, and substituting the values of π^* and m^* (from theorem 4),

$$\begin{aligned}
D(p) &= \frac{2p\,(1-\alpha)\,{p_{\text{fb}}}^2(1+g-2p_{\text{fb}})}{(1-(1-\alpha){p_{\text{fb}}}^2)\,Z(\alpha)} \\
&= \frac{2p\,(1-\alpha)\,{p_{\text{fb}}}^3(R-2)}{(1-(1-\alpha){p_{\text{fb}}}^2)\,Z(\alpha)}
\end{aligned}$$

where the second step follows from the fact that $(1+g) = p_{\text{fb}}R$, and where

$$Z(\alpha) = g(1+{p_{\text{fb}}}^2) - 2{p_{\text{fb}}}^3(1-\alpha).$$

Since the coefficient of $Z(\alpha)$ is strictly positive, the sign of $D(p)$ is the same as that of $Z(\alpha)$. I now show that $Z(\alpha) > 0$ for $\alpha \in [\overline{\alpha}(R,g), 1)$. Since $Z(\alpha)$ is increasing in α, it is sufficient to show that $Z(\overline{\alpha}(R,g)) > 0$ for $i \in \{1,2\}$.

Using the value of $\overline{\alpha}(R,g)$ from equation (5.2), and the fact that $p_{\text{fb}} = (1+g)/R$,

$$Z(\overline{\alpha}(R,g)) = \frac{g p_{\text{fb}}(1+{p_{\text{fb}}}^2)^2}{(1-p_{\text{fb}})^2 + g(1+{p_{\text{fb}}}^2)} (R-2) \; > \; 0.$$

Therefore for any $p \geqslant p_{\text{fb}}$, $D(p) > 0$. This completes the proof. □

Appendix B

As mentioned in section 3 (as well as footnote (13) in section 10.1), this section clarifies the point that in the model considered here (featuring a continuum of risk neutral types), separation of types is not possible under individual lending contracts, and the only solution is a pooling contract. This property is exactly the same as in the models of Stiglitz and Weiss (1981), and deMeza and Webb (1987).

Let us ignore the moral hazard problem for the time being. Suppose two different contracts $T \equiv (T_S, T_F)$ and $t \equiv (t_S, t_F)$ are offered. Recall that limited liability implies $T_F \leqslant 0$, and $t_F \leqslant 0$. Suppose there is some cutoff $p^* \in [0,1]$, such that types $p \geqslant p^*$ choose the contract T, and types $p < p^*$ choose the contract t. For this to happen, it must be that $T_S \leqslant t_S$, and $-T_F \leqslant -t_F$. This is because higher types care more about the payment in the success state and lower types care more about the receipt (negative payment) in the failure state.

In what follows I show that if the two contracts are different (so that at least one of $T_S \neq t_S$ and $T_F \neq t_F$ is satisfied), and if T earns zero profit, then t must earn a strictly negative profit.

First, note that the incentive constraints are as follows.

$$p(R - T_S) + (1-p)T_F \;\; \geqslant \;\; p(R - t_S) + (1-p)t_F \qquad \text{for } p \geqslant p^*, \tag{B.8}$$

$$p(R - t_S) + (1-p)t_F \;\; \geqslant \;\; p(R - T_S) + (1-p)T_F \qquad \text{for } p < p^*. \tag{B.9}$$

Can both contracts earn a zero profit? Suppose the expected profit from the contract T is zero. Then $Prob(p \geqslant p^*)E\left(pT_S + (1-p)T_F | p \geqslant p^*\right) = 0$, i.e.

$$\int_{p^*}^{1} \left(pT_S + (1-p)T_F\right) dp = 0.$$

Simplifying, $T_S - T_F = -\dfrac{2T_F}{1+p^*}$. Now, the inequality (B.8) holds with equality for type $p = p^*$. Using the above in (B.8) for $p = p^*$, and simplifying,

$$p^*(t_S - t_F) = T_F \frac{(1-p^*)}{(1+p^*)} - t_F. \tag{B.10}$$

Finally, the profit from the contract t (denoted by $V(t)$) is given by

$$\begin{aligned} V(t) &= Prob(p < p^*)E\left(pt_S + (1-p)t_F | p < p^*\right) \\ &= \int_0^{p^*} \left(pt_S + (1-p)t_F\right) dp \\ &= \frac{p^*}{2}\left[p^*(t_S - t_F) + 2t_F\right]. \end{aligned} \tag{B.11}$$

Using equation (B.10), the above becomes

$$V(t) = \frac{p^*}{2}\left[\left(\frac{1-p^*}{1+p^*}\right) T_F + t_F\right].$$

If $1 - p^* = 0$, this implies that all types adopt contract t. Similarly, $p^* = 0$ implies all types adopt T. Thus for non-trivial separation, $0 < p^* < 1$. Since $T_F \leqslant 0$ and $t_F \leqslant 0$, and $0 < p^* < 1$, the right hand side of equation (B.11) above is non-positive. Thus $V(t) \leqslant 0$, and further, $V(t) < 0$ if any one of T_F and t_F is strictly negative.

Thus, for contract t to earn a zero profit, it must be that $T_F = t_f = 0$. But then the incentive compatibility condition (B.8) reduces to $T_S \leqslant t_S$, and (B.9) reduces to $T_S \geqslant t_S$. The only way the two inequalities can be satisfied simultaneously is if $T_S = t_S$. But then the two contracts are not different.

Finally, adding a moral hazard problem on top of the adverse selection problem only changes the probability of success for some projects from p to αp, and changes the value of the cutoff p^*. These changes only make it harder for the low-types contract t to earn a zero profit - and thus leaves the conclusion unchanged.

This shows that under individual lending separation is impossible, and pooling is the only solution.

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