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Abstract

If entrepreneurs have private information about factors influencing the outcome of an investment, individual lending is inefficient. The literature emphasizes improvements through non-market organizations that harness local information through peer monitoring. I investigate the complementary question of designing a credit mechanism when local information is limited, disabling peer monitoring. I show that a pooling mechanism that does not rely on peer monitoring can implement a market for rights-to-borrow, restoring efficiency. The mechanism achieves a strict Pareto improvement - providing incentive for each type of agent to join. Further, even though the mechanism involves pooling - and consequent implicit transfers from better types to worse types - it has a "collective" feature that makes it immune to the Rothschild-Stiglitz cream-skimming problem under competing contracts. Finally, the presence of even weak 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 monitoring. I apply the results to contracts offered by rural moneylenders in developing countries.

KEYWORDS: *Informal Credit, Market for Rights-To-Borrow, Participation Incentives, Competition in Contracts and Cream Skimming, Local Information, Rural Moneylending*

JEL CLASSIFICATION: O12, D78, D82

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1 Introduction

The problem of excessive default in agrarian economies that distort formal credit markets, and the emergence of remedial non-market institutions for credit are widely discussed issues in the literature on development economics. If borrowers have private information about factors influencing the outcome of an investment, individual lending can be inefficient. Many borrowers might use the loan to undertake projects with little chance of success, raising the rate of default and causing the formal lending market to fail. This has lead to the growth of informal moneylenders as well as a variety of non-market institutions such as credit cooperatives, group lending arrangements with joint liability, and rotating savings and credit associations[(1)].

The literature typically assumes that even though the formal lenders cannot observe project quality or effort, the borrowers themselves have full information, and can potentially monitor each other. In their insightful analysis of cooperative design, Banerjee, Besley, and Guinnane (1994) show how local information can be harnessed through peer monitoring. The focus therefore is on making use of the abundant local information by creating incentives for peer monitoring[(2)].

This paper explores a different route and presents a theory of a non-market credit mechanism that does not rely on peer monitoring. This shows that it is possible to construct a theory of non-market credit as an optimal institutional response to the informational environment even if borrowers do not have privileged knowledge about the characteristics of their peers. The paper relates the results to evidence on rural moneylending collected by Aleem (1993).

The paper analyzes a model in which the return from a project depends both on its intrinsic quality and on the effort of the agent who operates the project - and both quality and effort are the agent's private information. As Ghatak and Guinnane (1999) point out, there are

(1)See Besley (1995b) for a succinct outline of the literature. See also Ghatak and Guinnane (1999) for a detailed survey of the literature on group lending.

(2)Following the classification in Banerjee, Besley and Guinnane, a second view in the literature is the *long term interaction* view, which stresses investment incentives generated through repeated local interaction, using, presumably, local knowledge about the actions of agents. Thus while the approach described above uses explicit monitoring, the long-term interaction view is based on implicit monitoring through repeated-game strategies.

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 - ensuring only high quality borrowers invest and take the right effort. I assume that the outcome of investment is observable (so state verification is not a problem), and repayment is enforceable.

The problem is as follows. The “internal” design must ensure that only agents with high enough productivity invest, and all investing agents adopt high effort. Given the internal design, the “sustainability” problem is to ensure that (a) all agents choose to participate in the mechanism, and (b) the equilibrium contract is proof against competing contracts, so that no other lending contract can skim the cream (successfully attract away the best quality borrowers and earn a positive profit).

The main result of this paper is that even without monitoring, it is possible to sustain a particular pooling mechanism that does not rely on either peer monitoring or local information in general, but solves informational problems by implementing an appropriate market. Further, the mechanism is budget balanced and sustainable in the sense described above, so that all types have the incentive to join and even though the mechanism involves pooling and consequent transfers from better types to worse types, it has a “collective” feature that makes it proof against poaching of the better types by competing contracts, avoiding the Rothschild-Stiglitz cream-skimming problem.

So far the contract has no special institutional features that make it a non-market credit institution. A distinguishing feature of non-market credit organizations is that they incorporate some local information. The paper shows that if even weak local information (say, some advantage in initially weeding out completely frivolous applicants) 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 peer monitoring.

The intuition behind the pooling 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. However, they impose a negative externality on other borrowers leading to a distorted (or even non-existent) credit market. A potential solution is trading in a market for rights-to-borrow. But this is not feasible - since everyone has free access to credit, no one would buy a right to borrow at a positive price. This paper shows that a credit mechanism can *implement* such a market using a simple budget-balanced mechanism. The mechanism requires the organization to disburse a certain amount of funds initially (a fraction of the amount needed by each agent), charge a fee for access to further credit and allow partial default. The basic intuition for welfare improvement through the mechanism lies in the fact that the initial loan plus the possibility of default creates the right level of *endogenous* collateral[3], while the credit-access fee balances the budget.

The structure of the mechanism that delivers efficiency is broadly consistent with evidence collected by Aleem (1993) on rural moneylending. An initial loan coupled with the possibility of default are part of the reported lending mechanism. These are precisely the features exploited here. The evidence is discussed further in section 8.

Finally, 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 "partial monitoring" ensures that agents who otherwise take low effort must take high effort while being monitored - incurring part of the cost of high effort. Suppose such partial high effort has no impact on output. The paper shows that even such apparently useless monitoring complements the mechanism and extends its scope. The intuition is that such monitoring raises partially the effort cost for the types who would otherwise adopt low effort. This reduces the underlying "free-access-to-credit" problem.

The paper is organized as follows. Section 2 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 solve the market failure. Section 6 discusses sustainability. Section 7 explains how a weak local information advantage implies that a local institution is uniquely sustainable. Section 8 discusses application of the results to rural moneylending. Section 9 extends the model to explore the role of monitoring in this setup. Section 10 relates the mechanism analyzed here to the literature, and section 11 concludes. Proofs not in the body of the paper are collected in appendix A.

[3] This is discussed further in section 10.

2 The Model

There is a continuum of economic agents. Each agent owns a project, operating which requires 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 the agent. Project type is a random variable p with a uniform distribution on $[0, 1]$.

The effort of the agent could be high or low. If the agent takes high effort (use better quality private inputs), the success probability of the 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 cost-less, 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

I assume that the first-best level of investment is always strictly positive (i.e. the first-best cutoff is strictly less than 1). The first-best investment cutoff is given by p_{fb} where $Rp_{\text{fb}} - g = 1$, i.e.

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

If $R < 1+g$, the efficient solution is no investment. We preclude this trivial case by assuming

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

3 Individual Lending and Market Failure

The model here features a continuum of risk neutral agents as in Stiglitz and Weiss (1981), and deMeza and Webb (1987). As in those models, separation of types is not possible under individual lending contracts, and the only solution is to offer the same contract to all types (i.e. a pooling contract). For the sake of completeness, this point is clarified formally in appendix B.

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

Efficiency requires that all types $p \geqslant p_{\text{fb}}$ invest with high effort, and all 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:

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

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

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

Thus efficiency requires (a) $p_* = p_{\text{fb}}$ and (b) any $p < p_*$ 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 $\alpha pR - [\alpha pT_S + (1-\alpha p)T_F] \leqslant 0$, 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 measure of types who have an incentive to participate with high effort (i.e. the incentive cutoff is $p_* < 1$), the participation constraint for all types $p < p_*$ holds as well. Thus all such types invest and adopt low effort. Thus 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.

The basic problem is that the lower types who exert low effort participate in investment, and impose a negative externality on the higher types.

4 The Credit Mechanism

What is a solution to the inefficiency? As noted in the last section, the root of the problem is the negative externality imposed by agents who cannot be excluded from participating with a low effort. If there were a market where agents could buy and sell their right to borrow, agents with low types would prefer to sell their right to borrow rather than invest - which would reduce the externality. However, given free access to a credit market, such a market cannot easily arise - no one would buy a right to borrow from another person. The mechanism below shows how such a market can be implemented.

4.1 The Mechanism

The organization running the mechanism borrows from the formal lending 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 a competitive rate (here normalized to zero).

Parametrized by three variables L, π and ρ, and denoted by $\mathbf{M}(L, \pi, \rho)$, the mechanism 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. The agents who accept simultaneously decide whether to borrow a further $(1 - L)$ and invest, or decide to not 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 repay $\left(1 - {\theta_I}/{\theta_L}\rho\right) L$ where ${\theta_I}/{\theta_L}\rho \in [0, 1]$. Note that for any ${\theta_I}/{\theta_L}\rho > 0$, the mechanism allows (at least partial) default[4].

[4]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

4.2 Solving the Game

The extensive 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. I then 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 would decide to invest and take high effort subsequently if the following two conditions are satisfied:

- High-effort payoff exceeds payoff from defaulting on initial loan:

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

- 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 and incentive constraints summarize the incentive properties of the mechanism.

Implementation is defined as follows.

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

The following result characterizes the cutoffs the mechanism can implement.

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

$$p_*\left(R - \frac{2}{1+p_*} - \pi\right) - g = L. \tag{4.3}$$

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

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

While the formal proof is in appendix **A**.1, the idea is simple. Allowing default on the initial loan makes it more attractive for low types to default and not invest rather than invest, and setting the credit access fee π at the right level, the loss through default can be recovered from the high types who invest. Equation 4.3 characterizes the investment cutoffs that can be implemented through this mechanism.

4.3 Interpreting the Mechanism

The mechanism as a market for rights-to-borrow

To interpret the mechanism, note that it separates the low-type-and-potentially-low-effort agents from the high-type-and-potentially-high-effort agents. With individual lending, separation is impossible. Everyone can borrow freely at the going market rate, and since only the success state matters, even for very low types it is better to borrow, invest and take low effort than not participating at all. The credit mechanism, on the other hand, separates agents into two groups - the first group decides to be defaulters and thus cannot invest, while the second group decides to access further credit and invest. An investor must pay ${}^{1}\!/_{p} + \pi$ in the success state. A payment of ${}^{1}\!/_{p}$ 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 for the default by non-investors. Thus a defaulter 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.

"Collective" nature of mechanism

The repayment by non-investors depend on the ratio ${}^{\theta_I}\!/_{\theta_L}$, determined by the aggregate decision of agents. This "collective" nature of payoff to non-investors is important in avoiding some standard problems with competing individual contracts. This issue is explored further in section 6.2.

Defaulters as internal lenders

The current mechanism allows default by non-investors. While this is a standard feature of rural moneylending (see the discussion in section 8), internal lending (lending by current non-investors to current investors) is a standard feature of credit cooperatives. Default by non-investors in the current mechanism can be reinterpreted as internal lending. An alternative description of the mechanism is as follows. Initially, all agents get a loan of $L < 1$. Agents either decide to invest (and borrow a further $(1 - L)$ with the specified repayments) or become internal lenders, and lend L to the organization. An internal lender receives a payment of ${}^{\theta_I}\!/_{\theta_L}\rho L$.

5 Attaining First-Best

Let

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

Since $R > (1 + g)$ by assumption, $0 < L^* < 1$.

Let $\overline{\alpha}(R, g)$ be the solution for α to $L^* = \dfrac{g\alpha}{1-\alpha}$. Thus $\overline{\alpha}(R, g) = \dfrac{1}{(1 + g/L^*)}$. It can be easily checked that that this is increasing in R and decreasing in g. The result below shows that whenever $\alpha < \overline{\alpha}(R, g)$, the mechanism can restore first-best.

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 $0 < \alpha < \overline{\alpha}(R, g)$, the mechanism $\mathbf{M}(L^*, \pi^*, \rho^*)$ satisfies budget balance and implements the first-best cutoff p_{fb}.*

6 Sustaining the Credit Mechanism

A mechanism is defined as "sustainable" if the following conditions are satisfied.

1. (Participation) Each agent optimally choosing to join the mechanism is an equilibrium.
2. (Proof against competing contracts) No other lending contract can attract away some fraction of borrowers and earn a positive profit - i.e. no other contract can skim the cream.

I show below that both conditions are satisfied. These properties, coupled with the fact that efficiency can be attained show that a credit organization with a collective feature is an optimal institutional response to the informational environment.

6.1 Participation Incentives

The last section assumed all agents join, and analyzed the outcome of the mechanism. Here I analyze whether agents joining is part of the equilibrium. I show that indeed each type of agent has an incentive to join.

The following result shows that the mechanism makes each type strictly better off compared to individual lending. Thus if all others join, joining is the strict best response for any agent. Therefore all agents participating in the mechanism is a Nash equilibrium.

Lemma 2. ***(Welfare Comparison)*** *For any $\alpha < \overline{\alpha}(R, g)$, for any type $p \in [0, 1]$, the payoff 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 that elimination of low effort improves greatly the average probability of success, and lowers the payment required from successful projects to recover the original loan.

6.2 Competition in contracts: Cream Skimming

The mechanism here uses a pooling contract. In Rothschild and Stiglitz (1976), a pooling equilibrium cannot survive competition in contracts - another contract can skim the cream - i.e. attract only the better types away and make a positive profit. Is there scope for a similar cream skimming by a competing contract here? I show that the answer is no. The intuition lies in the fact that payment made to non-investors is tied to the proportion of investors. Thus a contract that tries to compete away the high types (i.e. investing types) would also attract the non-investors. This "collective" feature differentiates the mechanism here from pooling equilibria in Rothschild and Stiglitz.

To hope to make a positive profit by attracting away higher types, any competing contract must lower the payment that these investing types pay in the success state. Types simultaneously decide whether to switch or not to switch. Iteratively eliminating strictly dominated strategies, I show below 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.

Let T_S^* denote the payment in the success state under the original mechanism. 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 $\epsilon > 0$. Then all types $p \geqslant p_c$, where p_c is such that $p_c\left(R - T_S^* + \epsilon\right) = L + g$, will take up the new contract and invest with high effort.Thus we can eliminate the dominated strategy "not switch" by types $p \geqslant p_c$.

Recall that payoff of non-investors (given by the allowed default amount) 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 we can eliminate "not switch" by types $p < p_c$.

Therefore all types would take up the new contract and invest. This lowers the average probability of success so that in fact the new contract earns a negative payoff. This is formally verified in the proof of the result below in appendix **A**.4.

Theorem 2. *The mechanism specified in section* 4.1 *is sustainable so that all agents participating in the mechanism is an equilibrium, and the mechanism is proof against competing contracts.*

The result shows that the "collective" nature of payments to defaulters avoids the Rothschild-Stiglitz type cream-skimming problem caused by competing contracts.

7 The Mechanism as a Non-Market Institution

The results above show that the mechanism addresses the problem of sustainability and implements the efficient solution. So far the contract has no special institutional features that make it a non-market credit institution. A distinguishing feature of such institutions is that they incorporate some local information.

Let us extend the model to incorporate some local information. So far, the projects in the model are of type p, where p is drawn independently from a uniform distribution on $[0, 1]$. These can be thought of as "potentially worthwhile" projects (i.e. projects that can potentially have a high probability of success). Let us now augment the model and suppose that there is also a mass of "frivolous" projects with a zero chance of success.

Assume that local information allows a local organization distinguish between potentially worthwhile projects and frivolous projects. However, an organization without local information faces a cost $c > 0$ to evaluate each project initially to screen out the frivolous projects. Given that all projects (potentially worthwhile and frivolous) must be screened before the frivolous projects can be isolated, the total cost of screening can be high. Thus even a small local information advantage can translate into a large cost advantage for a local organization.

The next step is to show that in the presence of even such weak local information, a local organization is the unique optimal institution.

Suppose a formal sector bank uses the mechanism. Since the bank does not have access to local information, any such collective would either include the frivolous projects with success probability 0, or screen them out at a cost. In either case, the investing types have to pay a higher fee compared to a local organization that can screen out the low quality projects using local information. This creates scope for a profitable offer by a competing local contract - it can offer a credit contract with the same L and ρ, but a slightly lower π. This will attract away all investing types - and thus also all non-investing types (for the same reason as in section 6.2), but since the original contract must have made a non-negative profit (otherwise it would not be offered), the new local contract can clearly make a strictly positive profit. Thus a formal sector bank using the mechanism cannot survive competition in contracts, and therefore such an organization is not sustainable.

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 informational environment.*

8 Comparison with evidence on rural moneylending

Aleem (1993) presents a detailed picture of rural moneylending in the Chamber area in Pakistan. He finds that there are a large number of informal lenders operating in the same area (60 in the Chamber area). The key aspects of the evidence he presents and comparability with the features of the theory presented here are summarized below.

Aleem finds evidence to show that "interest rates are close to the average costs of lending and above marginal cost in the Chamber market." The data is consistent with average cost pricing and free entry. This is precisely the setting here.

Second, while there is considerable variation in the methods used by individual lenders, there are some important common features. If a farmer passes screening, he gets a small initial loan for one season before the lender satisfies all his legitimate credit needs. The mechanism here relies on exactly such a feature - there is an initial loan, and those who do not default get further credit. The possibility of default helps separate the high types from lower types.

Third, average cost pricing implies that the cost of default is borne by the investors. The quantity and extent of initial loans to borrowers must depend on the moneylender's anticipation of the proportion of non-defaulters. This gives rise to a "collective" feature that allows the mechanism here to survive competition from any competing contract.

Finally, the paper extends the model to include some local information. Aleem reports that a formal credit market with uniform and relatively low rates of interest coexists with an informal market that charges a widely dispersed set of relatively high rates. 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. Each lender faces a considerable cost of evaluating projects - with no reduction in this cost even after several years. This suggests that each moneylender has some local information advantage about his clientele compared to other lenders operating in the area. This is consistent with the local information aspect of the extended model in this paper, which helps to show that a local non-market institution arises as the unique optimal response to the informational environment.

The moneylenders also monitor the projects to some extent. So far the paper has not considered whether there is a role for monitoring in the current setting. The question is taken up in the following extension.

9 Partial Monitoring: An Augmented Mechanism

Is there a role for monitoring in this model? To answer this question, note the cases in which the mechanism above cannot attain efficiency. For severe enough moral hazard (i.e. $\alpha < \overline{\alpha}(R, g)$), the mechanism above restores first-best. However, for high values of α (low moral hazard), the mechanism cannot ensure first best. Of course, in such cases the distortion is not great to start with. Still, the distortion is positive and there is scope for improvement.

The problem is the constraint $L \geq \alpha g/(1-\alpha)$. For high values of α, L needs to be very high - making default very attractive, and investment very unattractive. To resolve the problem, we need a way to keep L low yet allow α to be high. I show that this is possible if a little bit of monitoring is added to the model.

To introduce the idea of partial monitoring, suppose, first, that the organization running the mechanism can also monitor each borrower. To keep the analysis simple, suppose such monitoring is costless. Now 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. Usual (full) monitoring then refers to monitoring effort over the entire unit interval and results in high effort throughout, and an output corresponding to high effort. This is the kind of monitoring the literature assumes at the outset. **Partial monitoring** refers to monitoring over any interval of length $m < 1$. This results in high effort on that interval, and depending on incentives, low or high effort on the rest. To make the conclusions about the usefulness of partial monitoring sharp, and to distinguish it from the usual ideas of monitoring, 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 αpR.

The expected gross return from any project of type p is pR under high effort, and αpR under low effort. An agent who takes low effort, when monitored partially, would take high effort over the monitoring interval, but low effort over the rest of time. By assumption, the output would not improve at all, ensuring partial monitoring has no direct benefit.

Even though it has no direct benefit, monitoring here increases the cost of participating with low effort (an agent who otherwise takes low effort must take high effort while being monitored, incurring a cost over that interval). This reduces the underlying externality by reducing the "free-access-to-credit" problem. This is the intuition behind the usefulness of partial monitoring.

9.1 The Augmented Mechanism

Denote the augmented mechanism by $\widehat{\mathbf{M}}(L, \pi, \rho, m)$. This is identical to $\mathbf{M}(L, \pi, \rho)$ except for the following addition. Any agent who obtains further credit in order to invest, is monitored for an interval of time of length $m < 1$.

The incentive properties of the augmented mechanism are as follows. The participation constraint is the same as in the original mechanism (given by (4.1)). The new incentive constraint is given by $p\left(R - \pi - 1/\overline{p}\right) - g \geqslant \alpha p\left(R - \pi - 1/\overline{p}\right) - mg$, which simplifies to

$$\text{(Modified Incentive Constraint)} \quad p\left(R - \pi - 1/\overline{p}\right) \geq \frac{(1-m)g}{1-\alpha}.$$

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

Lemma 3. *Suppose $0 \leq m < \alpha$ is such that L satisfies $\dfrac{g(\alpha - m)}{1-\alpha} \leqslant L < 1$, π and ρ are as in lemma 1, and $p_* \in [0, 1]$ solves equation (4.3). Then the augmented mechanism $\widehat{\mathbf{M}}(L, \pi, \rho, m)$ implements p_*, and is budget balanced.*

Attaining First-Best The result below shows that the augmented mechanism can implement first-best for *any* $\alpha \in (0, 1)$. Let m^* be given by the following:

$$m^* = \begin{cases} 0 & \text{for } 0 < \alpha \leq \overline{\alpha}(R, g), \text{ and} \\ \alpha - (1-\alpha)L^*/g & \text{otherwise.} \end{cases} \tag{9.1}$$

where L^* is given by equation (5.1). Clearly, $m^* < 1$ for any $\alpha < 1$, implying partial monitoring. Also, $m^* > 0$ only for $\alpha > \overline{\alpha}(R, g)$. Thus for $\alpha \leq \overline{\alpha}(R, g)$ the augmented mechanism coincides with the mechanism without monitoring.

Theorem 4. (Attaining First-Best Under Augmented Mechanism) *Let (L^*, π^*, ρ^*) be as in theorem 1, and let m^* be given by equation (9.1). For any $\alpha \in (0, 1)$, the augmented mechanism $\widehat{\mathbf{M}}(L^*, \pi^*, \rho^*, m^*)$ satisfies budget balance and implements the first-best cutoff p_{fb}.*

Sustainability The augmented mechanism generates the same incentives to participate as the original mechanism. The result below follows directly from lemma 2. Note that, as expected, the only change is in the scope of the mechanism - the improvement now holds for all $\alpha \in (0,1)$ rather than only for low values of α.

Corollary 1. *For any $\alpha \in (0,1)$, for any type $p \in [0,1]$, the payoff under the mechanism strictly exceeds that under individual lending.*

Finally, the augmented mechanism is proof against competing contracts for exactly the same reason as before.

10 Related literature

Before discussing related literature, it is worth clarifying the intuition for the welfare improvement achieved through the mechanism. All agents are given an initial loan. An agent who abstains from investing and defaults on the initial loan, obtains a transfer. Thus the initial loan acts as own wealth/collateral[(5)], which induces the agents to be more "responsible" in choosing whether to invest. Thus endogenous collateral at the right level adjusts the incentive to invest, and separates investors and abstainers.

In their insightful analysis of cooperative design, Banerjee, Besley, and Guinnane (1994) show how local information can be harnessed through peer monitoring. In their model, there is a productive agent who borrows funds and invests, and a non-investing agent who can lend own funds to the cooperative, and potentially monitor project choice by the investing agent. By setting the extent of internal borrowing (borrowing from non-investing agent), the extent of the monitor's liability, and the interest rate paid on the internal funds, the cooperative induces the non-investing agent to monitor investment optimally. The central objective in their paper is to generate incentives for peer monitoring. Here, on the other hand, there is no monitoring. The objective is to generate endogenous collateral which creates incentives for non-participation. As noted in section 4.3, the default can be interpreted

[(5)]Collateral and own wealth are formally the same. Stiglitz and Weiss (1981) assume the existence of collateral, but no own wealth, while deMeza and Webb (1987), as well as this paper assume the reverse. However, as noted by both Stiglitz and Weiss (footnote 8), and deMeza and Webb (footnote 1), ability to offer collateral is formally the same as increase in own wealth.

as an internal loan - making this a theory of credit cooperatives that do not rely on monitoring. However, the paper also shows how even apparently useless monitoring can be useful.

Further, while Banerjee, Besley, and Guinnane (1994) focus only on the incentive to monitor and invest, this paper also addresses the question of sustainability - it explains why agents participate and why the contract is not vulnerable to competing contracts.

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 incentives for strategic default by some borrowers, and the resulting constraint on loan size. The analysis here, however, focuses entirely on investment incentives and assumes that enforcement is not a problem. This is perhaps not inappropriate in analyzing non-market local credit institutions. In the Stiglitz-Weiss model, on the other hand, the focus is indeed on investment incentives. However, deMeza and Webb (1987) show, an inefficiency arises only if the form of contracts is restricted a-priori to debt contracts. Without this restriction, the optimal contract in the Stiglitz-Weiss model is an equity contract, which restores first best investment. deMeza and Webb show that if projects are ranked by probability of success, a debt-contract is optimal, and under optimal (individual lending) contracts there is overinvestment. Here the quality of projects are ranked just as in the deMeza-Webb model and adds also an effort choice decision by agents, unsurprisingly, the market outcome for individual lending is distorted.

In the mechanism here, investors subsidize non-investors in equilibrium. Subsidization across types also occurs in the insurance model of Rothschild and Stiglitz (1976). However, the nature of the cross-subsidizations is very different, and it is worth noting the differences.

First, the setting of credit market here is very different from the insurance problem. In the setting of Rothschild and Stiglitz (1976), the utility functions of the good and bad types satisfy the single crossing (i.e. Spence-Mirrlees sorting) property[(6)]. This creates the possibility of a separating contract - and indeed, if an equilibrium exists, it is of this type. In contrast, in this model, as in Stiglitz and Weiss (1981) and deMeza and Webb (1987), there is a continuum of risk neutral agents - and as in those models, separation is not possible under individual

[(6)]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).

lending contracts. The only solution is pooling[7].

While a separating individual lending contract does not exist, the credit mechanism achieves separation between investors and non-investors by creating endogenous collateral and inducing low types to not invest. Such a mechanism would not work in the insurance context, where the risk faced is not consequence of any action (e.g. choosing to invest), but exogenous, and thus the incentive to take the best possible insurance contract by the "bad" types is unaffected by transfers.

However, while the nature of the problem is different, cross-subsidization gives rise to the same problem of sustainability under competing contracts as that in Rothschild-Stiglitz. What prevents a competing contract from attracting away the better types? The solution here lies in a "collective" feature of the mechanism that differs from the contracts considered by Rothschild and Stiglitz. The proposed mechanism specifies a payoff for the non-investing types that depend upon the aggregate decisions, so that it is impossible to attract away only investing types. Thus a competing contract must accommodate all types, and still do better. In this model, since a local organization has extra screening ability, it can attract away all types from the formal sector and still do better, but the reverse is not true.

11 Conclusion

Informational problems combined with lack of sufficient collateral often distort formal credit markets. The literature typically assumes local information is complete, and focuses on making use of this information through peer monitoring.

This paper constructs a theory of a non-market credit institution that does not rely on monitoring. The paper shows that even without monitoring, a simple credit mechanism can implement the efficient solution. The mechanism provides incentive for each type of agent to participate, and despite using a pooling solution, is proof against poaching of the better types by a competing contract.

The market failure is caused by the fact that the lower types who exert low effort in equilibrium participate in investment, and impose a negative externality on the higher types who exert high effort in equilibrium. Through the device of an initial loan and the possibility of

[7] To clarify this point further, I have included a formal discussion in appendix B.

default, the mechanism prices the externality, and balances its budget by charging an appropriate fee for access to credit from the investors. The mechanism raises the payoff of every type, which explains participation incentives. Further, the payoff of the defaulters rely on the proportion of investors. This "collective" aspect implies that any attempt to skim the cream ends up attracting all types, making such an attempt unprofitable.

The paper also extends the model to consider the role of monitoring in this setup. It shows that adding partial monitoring of borrowers by the credit organization can extend the scope of the mechanism. This is true even if such monitoring has no direct benefit in raising output. The intuition is that such monitoring raises partially the effort cost for the types who would otherwise adopt low effort. This reduces the underlying "free-access-to-credit" problem.

Finally, if some local information advantage (e.g. a lower cost of initially screening out frivolous projects) is added to the model, the mechanism cannot be successfully used by formal lenders. Thus a local credit organization that does not rely on peer monitoring emerges as an optimal solution to the market failure.

The paper compares the optimal design to evidence on credit design in rural moneylending. As Aleem (1993) reports, the behavior of moneylenders is consistent with average cost pricing. Further, an initial loan coupled with the possibility of default are part of such arrangements. These are precisely the features exploited here.

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 constraint (given by equation 4.1) reduces to

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

From the fact that $L \geqslant \alpha g/(1-\alpha)$, we get $L + g > g/(1-\alpha)$, and thus the participation 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 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 to default rather than 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 (4.3).

Thus the high-effort cutoff satisfies equation (4.3), 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

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

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 (4.3), solving for p_*, and discarding the negative solution: $p_* = (1+g)/R = p_{\text{fb}}$. Thus, from lemma 1 it follows directly that for $\alpha < \overline{\alpha}(r,g)$, $\mathbf{M}(L^*, \pi^*, \rho^*)$ implements p_{fb}, and satisfies budget balance. □

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

$$Y_m(p) = p(R - \frac{1}{\overline{p}}) - g.$$

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

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

Using the last inequality,

$$Y_m(p) < p(R-2) - g. \tag{A.3}$$

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 $p_* \leqslant p < p_{\text{fb}}$.

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

where the third step uses (A.3). Second, suppose p_* is either lower than or greater than p_{fb}, and consider any type p such that $p \geqslant p_{\text{fb}}$.

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

where the second step uses (A.3). This completes the proof. □

A.4 Proof of Theorem 2

The discussion in section 6.1 and lemma 2 prove the first part. As for being proof against competing contracts, the discussion in section 6.2 shows that a competing contract must attract all types. 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 success $\overline{p}$ is therefore given by

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

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 Theorem 4

The addition of m^* ensures that for any $\alpha \in (0,1)$, $L^* \geq g(\alpha - m)/(1-\alpha)$. The rest follows directly from the proof of theorem 1. Thus for any $\alpha \in (0,1)$, the augmented mechanism $\widehat{\mathbf{M}}(L^*, \pi^*, \rho^*, m^*)$ satisfies budget balance, and implements p_{fb}. $\square$

Appendix B

As mentioned in section 3 (as well as footnote (7) in section 10), 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.

$$p(R - T_S) + (1 - p)T_F \;\geqslant\; p(R - t_S) + (1 - p)t_F \qquad \text{for } p \geqslant p^*, \tag{B.4}$$

$$p(R - t_S) + (1 - p)t_F \;\geqslant\; p(R - T_S) + (1 - p)T_F \qquad \text{for } p < p^*. \tag{B.5}$$

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.4) holds with equality for type $p = p^*$. Using the above in (B.4) for $p = p^*$, and simplifying,

$$p^*(t_S - t_F) = T_F \frac{(1 - p^*)}{(1 + p^*)} - t_F. \tag{B.6}$$

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

$$\begin{aligned} V(t) &= Prob(p < p^*)E\left(pt_S + (1-p)t_F | p < p^*\right) \\ &= \int_0^{p^*} \left(pt_S + (1-p)t_F\right) dp \\ &= \frac{p^*}{2}\left[p^*(t_S - t_F) + 2t_F\right]. \end{aligned} \tag{B.7}$$

Using equation (B.6), 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.7) 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.4) reduces to $T_S \leqslant t_S$, and (B.5) 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 separation is impossible, and pooling is the only solution.

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