A little skin in the game: reducing moral hazard in joint liability lending through a mandatory collateral requirement*

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Abstract

Both collateralized individual loans and joint liability group loans have received much attention in the microfinance literature. Yet, each has important limitations. Collateralized individual loans exclude those who lack the requisite collateral assets, or are unwilling to put them at risk. On the other hand, joint liability loans are subject to moral hazard and free-riding, especially by those with little social reputation at risk. In this paper, we ask whether a hybrid contract, which combines joint liability with an individual collateral requirement, could resolve these tradeoffs. We show theoretically that adding an individual collateral requirement to joint liability unambiguously reduces moral hazard through both carrot and stick effects. Some positive level of collateral is optimal for many, but not all borrower types. Some may exit the credit market in the face of a collateral requirement, although we find that this selection is advantageous or lenders. To gain empirical purchase on these issues, we employ a framed field experiment with credit group members in Tanzania. We find that a modest (20%) collateral requirement reduces moral hazard, and defaults falls by 15-20% depending on the level of social connectedness. Moreover, while the fraction of the population willing to borrow decreases by 7% overall, we find that it increases for group members who are highly socially connected.

Keywords: Credit Rationing, Moral Hazard, Collateral, Field Experiments, Joint Liability

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1 Introduction

Over the past three decades, microfinance has eased liquidity constraints for millions of low-wealth people around the developing world.[1] In making loans to low-wealth borrowers, microfinance lenders face not inconsequential problems of moral hazard and adverse selection given that small loan sizes and fixed information costs make it expensive to select and monitor borrowers. To combat these challenges, lenders typically rely on either conventional, collateralized individual loans, or on joint liability loan structures. Both devices have their limitations. The former can induce various forms of credit rationing, while the latter may discourage credit uptake because it exposes borrowers to the morally hazardous behavior of others in their borrowing group for whom they are financially liable. Given these tradeoffs, we use economic theory and a framed field experiment to see if a hybrid loan contract, that mixes joint liability with individual collateral, can dominate these conventional, mono-liability alternatives.

While much of the theoretical economics literature has considered individual collateral and joint liability in isolation from each other, there is a continuum of contracts that mixes individual collateral and joint liability. For example, the liability for an individual's \$100 share of a larger group loan can be split between the individual and the borrowing group by requiring the individual to pledge, say, a \$20 collateral that is forfeited if the individual cannot pay her share of the group loan. The group remains jointly liable for the \$80 residual share of the individual's portion of the group loan. Seen from this perspective, the standard contracts are the opposite corner solutions to a more general mixed liability problem: The standard individual liability contract is the corner solution in which the individual liability is 100%, while the standard joint liability contract is one in which the collateralized individual liability share is 0%. Motivated by the intuition that corner solutions are unlikely to be optimal in the face of the tradeoffs presented by individual versus joint liability, we explore the interactions between joint liability and individual collateral, focusing on how different contracts along that continuum perform with respect to moral hazard, loan demand and repayment.

Intuitively, while collateral has an obvious incentive effect under individual liability by increasing the cost of failure, it also has an additional effect under joint liability in that it makes the successful state more lucrative, since the collateral serves as partial insurance against having to cover other group members' losses. As such, collateral may act both as a stick and as a carrot under joint liability. Moreover, while collateral is unambiguously a burden for borrowers under individual liability, adding collateral to a joint liability contact may actually increase the utility of safe borrowers by reducing the expected amount that the group will have to cover for defaulting members.[2] In particular, our model shows that collateral has an ambiguous impact on credit mar-

[1] While there is no doubt that microfinance has spread wide and far, its impacts are subject to debate. For example, see the discussion in Banerjee et al. (2015).

[2] This assumes that interest rates do not adjust in response to the addition of collateral. If interest rates are

ket participation under joint liability, increasing it for socially connected people, and decreasing it for risk-averse people with low social collateral.

To test the predictions of the theoretical model, we conducted a framed field experiment, in which a sample of Tanzanian smallholder sunflower farmers already enrolled in joint liability groups played a series of microfinance games, similar to those conducted in Giné et al. (2009). The results of our experiments show that adding a collateral requirement to a joint liability loan reduces moral hazard (effort diversion), and that this behavioral change by itself reduces defaults by almost 20% when social collateral is modest. Also consistent with the theory, the experimental findings show an ambiguous impact of the collateral requirement on credit market participation, increasing it for highly socially connected people, but on average, reducing the fraction of the population willing to borrow by 7%. To the best of our knowledge, this is the first paper to explicitly model the effect of combining joint liability with a collateral requirement. It is also the first paper to experimentally test the effect of adding collateral to an existing joint liability contract.

Rooted in the Grameen Bank model developed by Nobel Peace Prize laureate Muhammad Yunus, joint liability group lending has received much attention in the economics literature. Under a typical group liability contract, borrowers form groups consisting of five to twenty members, who receive individual loans but are all mutually responsible for the total repayment to the lender. Proponents of group liability contracts argue that this feature can help overcome problems of moral hazard and adverse selection in small-scale lending where lenders lack credit information about potential borrowers and do not have the resources to monitor individuals. In particular, positive assortative matching in group formation can reduce informational asymmetries (Ghatak, 1999; van Tassel, 1999), and strong social collateral within existing groups might help reduce voluntary default and other morally hazardous behavior (Besley and Coate, 1995; Anderson and Nina, 1998).

Despite these potential benefits of group liability, there is mixed evidence, both theoretical and empirical, on the relative merits of group versus individual liability (Morduch, 1999; Huppi and Feder, 1990; Giné and Karlan, 2014). Critics of group liability argue that such contracts are prone to free-riding and collusion (Giné et al., 2009; Laffont and Rey, 2003), that they deter relatively safe borrowers who would not default under an individual contract but would do so under a group lending contract (Besley and Coate, 1995), and that they may induce excessively prudent behavior (Banerjee et al., 1992). Moreover, positive assortative matching may only work partially, especially if group sizes are large. Finally, social hierarchies within groups or strong social ties among group members may distort or weaken the value of the social collateral, as successful borrowers might be reluctant to pressuring less fortunate, less abled, or more powerful group members to repay (Wydick, 1999; Giné and Karlan, 2014).

Limitations to conventional individual loan contracts are also well-studied. Stiglitz and Weiss

endogenous, it is possible that certain borrowers under individual liability prefer a collateralized contract over a non-collateralized one. In our model, we explore both the case of exogenous and endogenous interest rates.

(1981) demonstrate in their seminal paper, that a lender's inability to distinguish between different borrower types and to enforce and monitor borrower behavior results in adverse selection and moral hazard, respectively. To combat these issues, a profit-maximizing lender will set an interest rate lower than the market-clearing rate, thus leading to credit rationing. In response to these findings, Bester (1985a) extends the Stiglitz and Weiss model and shows that when banks can set the interest rate and the collateral requirement simultaneously, perfect sorting of borrowers is possible, thus eliminating adverse selection and thereby credit rationing. Later, Bester (1987) finds that also moral hazard can be eliminated if banks can vary both the interest rate and the collateral requirement.

However, while collateralization can be an effective screening and incentive device that helps reduce adverse selection and moral hazard in lending, its effectiveness is limited both by borrowers' collateralizable wealth and by their risk preferences. Bester (1987) shows that if borrowers have insufficient wealth to cover the collateral requirement, perfect sorting is no longer possible, and some credit rationing will persist. This is especially a problem in a developing country context, where borrowers are typically poor and often limited in their ability to pledge collateral. Moreover, collateral requirements unavoidably shift risk from lender to borrower. Building on this observation, Boucher et al. (2008) identify another type of credit rationing, which they call risk rationing. Risk rationing occurs when an individual with adequate collateral assets would borrow under a lower collateral, higher interest rate contract, but does not borrow and retreats to a safe lower-yielding activity when asymmetric information truncates the menu of available contracts to those with high collateral requirements.

Given the drawbacks of both individual and joint liability contracts, this paper explores an intermediate or hybrid contract that mixes the two forms of liability. It is important to distinguish the hybrid model studied here from joint liability loans that sometimes require a joint or group collateral. Some MFIs, for example, require the group to establish a savings account that serves as a collateral that can be seized by the lender in the case of default (Dowla and Alamgir, 2003; Hermes and Lensink, 2007). VisionFund Tanzania, with whom we worked to implement the field experiment described below, requires members in a majority of their joint liability groups to deposit 20% of the loan amount into a savings account as a group collateral. While such group collateral reduces default risk for lenders (other things equal), they do not fundamentally alter the free-rider problem generated by fully joint liability.

The paper that most closely relates to ours is Allen (2016), who studies the effect of partial group liability on strategic default behavior, and finds that partial liability may be optimal in maximizing repayments. The current paper considers the effect of an individual collateral requirement, which is similar to partial joint liability in that it reduces the burden imposed on other borrowers when some members default. However, in contrast to partial liability, the individual collateral requirement under our hybrid model also transfers some of the loan responsibility back to the individual borrower, thus strengthening the incentive effect.[3]

The remainder of the paper is structured as follows. Section 2 presents a theoretical model analyzing the interactions between joint liability and collateral. Section 3 discusses the design of the framed field experiment and the data collected, while section 4 lays out the empirical approach and presents the results. The final section concludes and discusses potential policy implications.

2 Theoretical model

This section develops a theoretical framework for understanding the effect of adding a collateral requirement to a joint liability group lending contract. We start by defining the economic environment and then characterize the optimal effort level under an individual loan contract. The analysis then proceeds to study optimal effort under a joint liability group lending contract and demonstrates that a collateral requirement may in fact increase credit market participation for certain borrower types. Central to our model is the idea that under a group lending contract, a collateral requirement serves to reduce moral hazard not only by making the cost of failure higher, but also by making the successful state more lucrative, since the collateral serves as partial insurance against having to cover other group members' losses.

2.1 Model assumptions

We consider the case of a small-farm household, i, who has access to a risky, but on average, profitable entrepreneurial project that has unit cost and yields a payoff of $\bar{X}$ if successful ($s_i = g$) and 0 if unsuccessful ($s_i = b$). Borrower i can influence the probability of success, $p(e_i)$ by applying effort, $0 \leq e_i \leq \bar{e}_i$, where $0 \leq p(e_i) < 1$, $p(0) = 0$, $p'(e_i) > 0$, and $p''(e_i) < 0$. In this model, effort can be thought of as the time dedicated to farm production, and thus $\bar{e}_i$ can be interpreted as a time constraint. Moreover, we assume that working on the farm has an opportunity cost equal to $\gamma_i e_i$, where γ_i can be interpreted as the value of time (effort).[4] The agent has the option not to borrow and can instead exercise a fallback option of working full-time and earning a non-stochastic income of $\omega_i = \gamma_i \bar{e}_i$.

We assume the agent has some initial wealth, W, that can be used as collateral but not to finance the project, so that the project can only be undertaken with loan contract $K(r, C)$, where r is the interest rate and C is the collateral requirement. In the analysis that follows, we assume that the contractual terms are fixed. This assumption is appropriate if we are interested in the responses to the introduction of collateral by an experimenting lender focused on gauging the behavioral effects

[3]Moreover, while Allen (2016) considers the effect on strategic default, the current paper considers the effect on effort diversion

[4]γ_i can also be interpreted as a fixed wage per unit of time (effort). Thus, γ_i can reflect the availability of other wage-earning opportunities for the farmer.

of collateral in a joint liability environment.[5] In section 2.4, we relax this assumption and allow the interest rate to adjust to meet the zero-profit condition of the lender. We abstract away from strategic default considerations, by assuming the borrower will always repay her loans if the project generates sufficient funds. This assumption is consistent with the sunflower contract farming scheme familiar to farmers in the experimental set-up described below.

Finally, we assume that household preferences can be captured by utility function $u_i(W+\pi_i)$, where π_i represents household income, and we assume that $u_i'(W+\pi_i)>0$, and $u_i''(W+\pi_i)<0$. In what follows, we assume that the household maximizes expected utility $\mathbb{E}\,U(e_i|r,C)$, by choosing an effort level, and taking the contract $K(r,C)$ as given.

2.2 Individual lending: Collateral, moral hazard and credit market participation

First, we consider the case of an individual-liability loan contract, wherein the agent must borrow the full investment amount from the lender in order to finance the project. Moreover, the borrower is only responsible for repaying her own loan, i.e. there is no joint liability. Assembling the assumptions listed above, the agent's optimization problem can be written as follows:

$$\begin{aligned} \max_{0\leq e_i\leq \bar{e}_i} \quad & \mathbb{E}\,U_i^I(e_i|r,C) = p(e_i)u_i(W+\bar{X}-(1+r)+\gamma_i(\bar{e}_i-e_i)) + (1-p(e_i))u_i(W-C+\gamma_i(\bar{e}_i-e_i)) \\ \text{subject to:} \quad & \\ & \mathbb{E}\,U_i^I(e_i|r,C) - u_i(W+\gamma_i\bar{e}_i)\geq 0 \end{aligned} \tag{1}$$

Assuming that the participation and the time constraints do not bind, the optimal effort level is determined by the first-order condition:

$$\begin{aligned} & p'(e_i^*)(u_i(W+\bar{X}-(1+r)+\gamma_i(\bar{e}_i-e_i^*)) - u_i(W-C+\gamma_i(\bar{e}_i-e_i^*))) \\ & \qquad = p(e_i^*)\gamma_i u_i'(W+\bar{X}-(1+r)+\gamma_i(\bar{e}_i-e_i^*)) + (1-p(e_i^*))\gamma_i u_i'(W-C+\gamma_i(\bar{e}_i-e_i^*)) \end{aligned} \tag{2}$$

The condition says that at the optimum, the marginal benefit of effort due to an increase in the probability of success should equal the marginal opportunity cost of effort. For a risk-neutral borrower, this condition reduces to:

$$p'(e_i^*)(W+\bar{X}-(1+r)+C) = \gamma_i \tag{3}$$

[5] We maintain this assumption in part to match the experimental games, where simplicity was key. In the empirical analysis, we are able to isolate the behavioral impact of collateral from its mechanical impact on expected profits.

Given that $p''(e_i) < 0$, it's trivial to show that $\frac{de^*}{dC} > 0$ and $\frac{de^*}{dr} < 0$, which is intuitive and consistent with previous results in the literature (e.g. Ghatak and Guinnane, 1999). In the extreme case that a loan is fully collateralized ($C = (1 + r)$), expression (5) reduces to $p'(e_i^*)(\bar{X} + W) = \gamma_i$. Hence, under the strong assumption of risk neutrality, an undercollateralized loan contract always results in the borrower exerting less effort when compared to the case of full collateralization (or, equivalently, self-financing).

Considering the more general case of risk-averse borrowers, we use the implicit function theorem to derive an expression for the effect of collateral on optimal effort.

$$\frac{de_i^*}{dC} = -\frac{p'(e_i^*)u_i'(B) - (1 - p(e_i^*))\gamma_i u_i''(B)}{p''(e_i^*)(u_i(A) - u_i(B)) - \gamma_i^2(p(e_i^*)u_i''(A) + (1 - p(e_i^*))u_i''(B))}, \tag{4}$$

where $A = W + \bar{X} - (1 + r) + \gamma_i(\bar{e}_i - e_i^*)$ and $B = W - C + \gamma_i(\bar{e}_i - e_i^*)$. In equation 4, while the numerator is positive, the sign on the denominator is ambiguous. Hence, while risk neutrality guarantees that collateral always has a positive effect on effort, this is not ensured when agents are risk averse. However, we can ensure a positive collateral effect on effort by assuming that the cost of effort, γ_i, is sufficiently low.[6]

Next, consider the effect of collateral on credit market participation. First, define the optimized utility function as $V_i^I(r, C) = \mathbb{E}\, U_i^I(e_i^*|r, C)$. Now, using the envelope theorem, we can show that $\frac{\partial V_i^I}{\partial C} = -(1 - p(e_i^*))u_i'(W - C + \gamma_i(\bar{e}_i - e_i^*)) < 0$. This finding implies that under an individual-liability loan contract with a fixed interest rate, collateral is always non-desirable for the borrower.[7] This result is intuitive, as from the borrower's perspective, there are no direct or indirect benefits of collateral, which shifts risk onto the borrower. It is purely a cost, and this cost will be higher for more risk-averse individuals. Furthermore, define $\widetilde{\omega}_i$ such that $V_i^I = u(\widetilde{\omega}_i)$, i.e. $\widetilde{\omega}_i$ is the reservation income that makes the borrower indifferent between taking the loan or not. Given that $u(\widetilde{\omega}_i)$ is a monotonic transformation of $\widetilde{\omega}_i$, it is also true that $\frac{\partial \widetilde{\omega}_i}{\partial C} < 0$. Hence, as the collateral level increases, the agent would need a lower subsistence wage to still be enticed to borrow. Hence, assuming some distribution of ω_i across the population (perhaps reflecting different wage-earning opportunities for farmers), credit market participation is unambiguously decreasing in the collateral level.

2.3 Joint liability group lending

Here, we consider a joint liability model, in which a group consists of two agents. Moreover, since this paper is concerned with the effect of collateral on moral hazard, borrowers are randomly assigned to each other. Furthermore, borrowers simultaneously and non-cooperatively choose a level

[6]Moreover, if agents with a higher γ_i do not borrow, we may also ensure that $\frac{de_i^*}{dC} > 0$ for borrowers.

[7]For a risk-neutral borrower, this result is an artifact of our assumption that the interest rate is fixed and hence lender expected profits are increasing in collateral. In section 2.4, where we allow the interest rate to adjust, collateral may increase utility for a risk-neutral borrower.

of effort. Hence, the solution is characterized by a two-person Nash equilibrium. These assumptions are common in the literature on joint liability group lending (e.g. Ghatak and Guinnane, 1999; Laffont and Ray, 2003). In this paper, we add the possibility that the joint liability contract requires monetary collateral, denoted C, as before. In particular, monetary collateral is a dollar amount pledged by each borrower that will be seized by the lender or other group members if the borrower cannot repay. We also assume that the collateral is individual, in that a group member's collateral can be seized only if that individual cannot repay. This is in contrast to group-level collateral, under which the bank will seize the collateral of every group member if the group cannot pay, regardless of whether some individuals fully paid their share. While VFT uses group collateral in its actual credit groups, we have chosen to focus on individual collateral, as group collateral simply pre-finances a portion of joint liability and does not by itself fully resolve the moral hazard and free-riding problem that accompanies joint liability contracts. That is, group collateral is forfeited based on aggregate group performance, whereas the individual collateral we consider is forfeited solely based on individual performance. The latter thus supplies an undiluted effort incentive to the individual.

As shown by Besley and Coate (1995), joint liability group lending works in large part because of the social collateral the exist between borrowers. In particular, social collateral is represented by the social relationships put at risk by entering into a joint liability contract. The social cost of defaulting on one's share of a joint liability loan can take several forms in real life. For example, other group members may impose costs on the non-paying member, such as refusing to do business with her. Other forms include shame, social exclusion and public humiliation. For ease of analysis, we express the damage of being socially sanctioned as a monetary-equivalent cost. This cost depends on the amount the individual defaults to her group in the event that her project fails ($d = 1+r-C$) and on the extent of her social linkages or connections to others in the group, denoted λ_i. Note that an individual who is socially disconnected cannot be damaged by social sanctions, whereas a well-connected individual has much to lose. Formally, we write the cost of social sanctions as a smooth function $S(d, \lambda_i)$, with $S(0, \lambda_i) = S(d, 0) = 0$, and $\frac{\partial S}{\partial d}, \frac{\partial S}{\partial \lambda_i} \geq 0$.

Note that the cost of social sanctions does not have to be symmetric within a group. For example, it is possible that one borrower has a lot of social collateral to lose from reneging on the contract, while the other has none. Finally, we assume that joint liability is complete, that is, a borrower cannot choose to cover only a portion of her partner's loan. Whereas some models in the literature allow for partial joint liability (as in Allen, 2016; Ghatak, 1999; van Tassel, 1999), the idea of all-or-nothing joint liability is consistent with practices among most MFIs.

Now, consider the payoff of borrower i when entering into a joint liability group lending contract with borrower j. Note that in the case of two borrowers, there are four different outcomes and thus four different payoffs for borrower i:

1. Both borrowers have a successful project: $\pi_{ss} = (\bar{X} - (1+r) + \gamma_i(\bar{e}_i - e_i))$

2. Borrower i succeeds, borrower j fails: $\pi_{sf} = (\bar{X} - 2(1+r) + C + \gamma_i(\bar{e}_i - e_i))$

3. Borrower i fails, borrower j succeeds: $\pi_{fs} = (-S(1+r-C, \lambda_i) - C + \gamma_i(\bar{e}_i - e_i))$

4. Both borrowers fail: $\pi_{ff} = (-C + \gamma_i(\bar{e}_i - e_i))$

Borrower i's optimization problem now becomes:

$$\begin{aligned} \max_{0 \leq e_i \leq \bar{e}_i} \quad & \mathbb{E}\, U_i^J(e_i|r, C, \widetilde{e}_j) = p(e_i)\left[\tilde{p}_g(\tilde{e}_j)u_i(W + \pi_{ss}) + (1 - \tilde{p}_g(\tilde{e}_j))u_i(W + \pi_{sf})\right] \\ & \qquad + (1 - p(e_i))\left[\tilde{p}_b(\tilde{e}_j)u_i(W + \pi_{fs}) + (1 - \tilde{p}_b(\tilde{e}_j))u_i(W + \pi_{ff})\right] \\ & subject\ to: \\ & \quad \mathbb{E}\, U_i^J(e_i|r, C, \widetilde{e}_j) - u_i(\omega_i) \geq 0 \end{aligned} \tag{5}$$

Here, $\widetilde{e}_j$ represents the effort level exerted by borrower j, and $\tilde{p}_s(\tilde{e}_j) = p(\tilde{e}_j|s_i = g)$, $\tilde{p}_b(\tilde{e}_j) = p(\tilde{e}_j|s_i = b)$ is the conditional probability of success for borrower j given a good or a bad state, respectively, for borrower i. Note that in addition to having a negative effect on the payoff under failure (π_{fs} and π_{ff}), collateral also has a positive effect on the success payoff (π_{sf}), showing that collateral has a dual incentive effect under joint liability by acting as both a stick and a carrot, whereas under individual liability, collateral only acts as a stick. Note also that if outcomes are perfectly positively correlated ($\tilde{p}_g(\tilde{e}_j) = 1$ and $\tilde{p}_b(\tilde{e}_j) = 0$), problem 5 reduces to the individual-liability problem. This illustrates the idea that joint liability only works when outcomes are imperfectly correlated, i.e. joint liability provides mutual insurance against default for both borrowers.

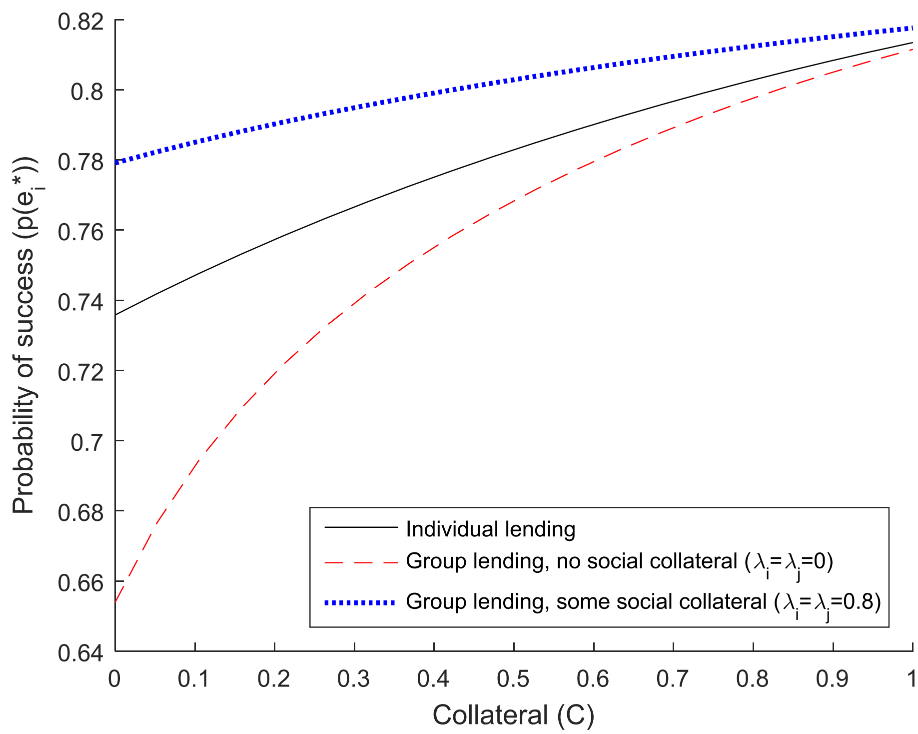
2.3.1 Effect of collateral on optimal effort

Assuming that the participation constraint and the time constraint do not bind, the optimal effort for agent i is the solution to the following first-order condition:

$$\begin{aligned} p'(e_i^*)\left[\tilde{p}_g(\tilde{e}_j)u_i(W + \pi_{i,ss}) - \tilde{p}_b(\tilde{e}_j)u_i(W + \pi_{i,fs}) + (1 - \tilde{p}_g(\tilde{e}_j))u_i(W + \pi_{i,sf}) - (1 - \tilde{p}_b(\tilde{e}_j))u_i(W + \pi_{i,ff})\right] \\ = \gamma_i p(e_i^*)\left[\tilde{p}_g(\tilde{e}_j)u_i'(W + \pi_{i,ss}) + (1 - \tilde{p}_g(\tilde{e}_j))u_i'(W + \pi_{i,sf})\right] \\ + \gamma_i(1 - p(e_i^*))\left[\tilde{p}_b(\tilde{e}_j)u_i'(W + \pi_{i,fs}) + (1 - \tilde{p}_b(\tilde{e}_j))u_i'(W + \pi_{i,ff})\right] \end{aligned} \tag{6}$$

Note that the marginal benefit and cost of effort now depends on the effort exerted by the other group member ($\tilde{e}_j$). A similar condition can be derived for borrower j. Assuming that both group members do not act cooperatively and cannot anticipate their partner's response, the optimal effort by each borrower is the solution to the two-person Nash equilibrium. Denote this equilibrium by $\left\{e_i^{**}(r, C, e_j^{**}),\ e_j^{**}(r, C, e_i^{**})\right\}$. In contrast to individual lending, where optimal effort only depends

Figure 1: Effect of collateral on effort and project success



on one's own characteristics, effort now also depends (exogenously) on the partner's optimal response. As can be seen from equation 6, in addition to the direct effect of collateral on effort, collateral now has an indirect effect through the effort exerted by the partner.

Since no closed-form solution for $e_i^{**}(r, C, e_j^{**})$ exists, we study the problem numerically. Specifically, we assume that $u_i(\pi_i) = \frac{1}{1-\alpha_i}{\pi_i}^{(1-\alpha_i)}$, $p(e_i) = 1 - \frac{1}{e_i+1}$, and $S(d, \lambda_i) = \lambda_i d$[8]. Here, α_i is the coefficient of relative risk aversion (CRRA). We also assume that project outcomes are statistically independent $(p(\tilde{e}_j|s_i = g) = p(\tilde{e}_j|s_i = b) = p(\tilde{e}_j)$.

The red dashed line in Figure 1 illustrates the effect of collateral on the success probability of a borrower when both group members are socially disconnected $(\lambda_i, \lambda_j = 0)$. The same relationship for an individual borrower is also shown for comparison (black solid line). We note that under the assumption of no social collateral, the success probability (and thus effort) is lower under a joint liability group lending contract than under an individual contract. This result is consistent with the idea that joint liability, by itself, entails more moral hazard than an individual-liability contract

[8]Default numerical parameters are: $\bar{X} = 2.5$, $r = 0.2$, $W = 1.5$, $\bar{e} = 15$, $\gamma_{i,j} = 0.1$, $\lambda_{i,j} = 0.6$, $\alpha_{i,j} = 1.5$

for a given interest rate, as a borrower is no longer solely responsible for her own outcome[9]. The blue dotted line in Figure 1 shows the effect of collateral on the success probability when social connectedness is high ($\lambda_i = \lambda_j = 0.8$) and clearly illustrates that joint liability group lending results in higher effort levels when group members are socially connected. Borrowers, fearful of needing to have their friends and relatives cover their loans, supply a higher level of effort than they would under individual lending.

Moreover, Figure 1 suggests that collateral has a positive effect on effort under all contracts, with the strongest marginal effect found when the collateral level is zero and social connectedness is low. These results indicate that collateral may be particularly useful in group lending contracts when there is a lack on social collateral in the group.

These results suggest that collateral may be an effective instrument for boosting effort and thus reducing moral hazard under a joint liability contract. But under what conditions will collateral be the most effective at incentivizing higher effort? To explore this question, we numerically solve the model to calculate the effect of imposing a 20% collateral requirement for various combinations of the parameters. Figures 2a and 2b show the effect of a 20% collateral requirement on the success probability for combinations of $\{\lambda_i, \lambda_j\}$and $\{\alpha_i, \alpha_j\}$, respectively.

First, financial collateral is more effective at incentivizing higher effort when both borrowers feel less burdened by having the other group member cover their loan (lower social linkages). This result is consistent with the idea that social collateral is partially a substitute for monetary collateral. In particular, if λ_i is high, the incentive effect of financial collateral is partially outweighed by the reduction in social collateral $S(d, \lambda_i)$, since d is a negative function of C.

While much of our later analysis will focus on the symmetric case in which both borrowers are equally socially connected, Figure 2a offers important insights on the asymmetric case as well. Note that an individual who is well connected (e.g., $\lambda = 1$), and hence personally responsive to joint liability incentives, responds more robustly to individual collateral the less well-connected her partner is. This behavior reflects the fact that individual collateral helps resolve a commonly heard complaint about joint liability loans, namely, that it exposes those with high social collateral to the free-riding behavior of those without it. By incentivizing effort supply by low social collateral borrowers, individual collateral increases expected returns for high social collateral and provokes them to supply a matching effort increase.

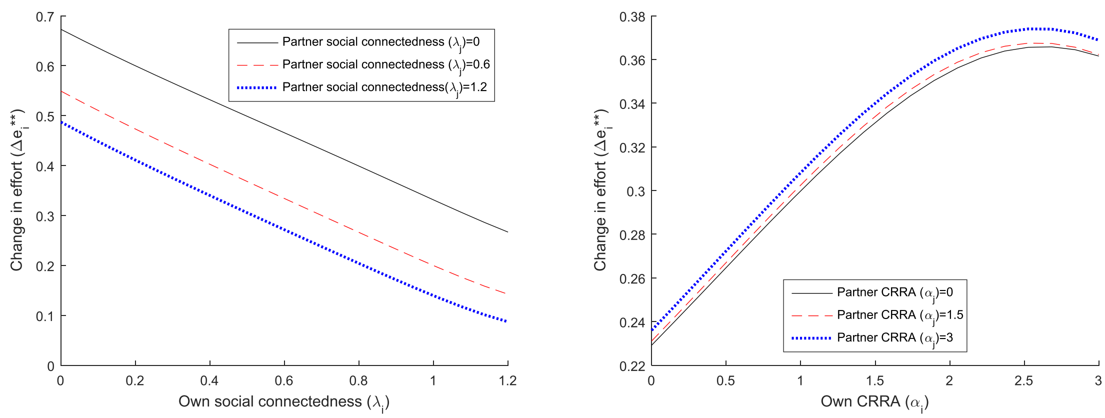
Next, the collateral effect is increasing in the level of own risk aversion, which is driven by the fact that a very risk-averse borrower will supply more effort in order to avoid losing her collateral. Moreover, the effect depends strongly on own risk aversion, but very little on the partner's risk aversion. This suggests that from a lender's perspective, the effect of a collateral requirement

[9] This result holds when the interest rate is fixed or when the borrower is risk averse. As we show in section 2.4, when the borrower is risk neutral and the interest rate is allowed to adjust to reflect the higher repayment rate under group lending contracts, the probability of success is the same under joint liability as under individual lending. This result is consistent with the findings in Ghatak and Guinnane (1999).

Figure 2: Impact of a 20% collateral requirement on optimal effort

(a) Impact by social connectedness

(b) Impact by risk aversion



would not depend on the heterogeneity in risk preferences among group members.

Figure 2 thus suggests that the effect of a modest (20%) collateral requirement on optimal effort is positive, and that the incentive effect is strongest for risk-averse borrowers with low social connectedness. In the econometric analysis in section 4, we test these hypotheses using data from the experimental games.

2.3.2 Effect of collateral on credit market participation

In Section 2.2, we showed that under an individual loan contract, collateral would never be desirable by the borrower (assuming a fixed interest rate), and thus a collateral requirement would always reduce credit market participation. Does this also hold under joint liability group lending? Define $V_i^J = \mathbb{E}\, U_{JL,i}(e_i^{**}|r, C, \tilde{e}_j^{**})$ and $\widetilde{\omega}_i$ such that $V^J = u(\widetilde{\omega}_i)$, i.e. $\widetilde{\omega}_i$ is the reservation income that makes the borrower indifferent between taking the loan or not. Since $sign(\frac{\partial \widetilde{\omega}_i}{\partial C}) = sign(\frac{\partial \hat{U}_{JL,i}}{\partial C})$, $\frac{\partial V^J}{\partial C}$ can be interpreted as the effect of collateral on (latent) credit market participation. Assuming statistically independent outcomes, we have:

$$\begin{aligned}\frac{\partial V^J}{\partial C} &= p(e_i^{**})(1 - p(\tilde{e}_j^{**}))u_i'(\pi_{i,sf}) \\ &\qquad - (1 - p(e_i^{**}))\left[p(\tilde{e}_j^{**})u_i'(\pi_{i,fs})(1 - S_i'(q)) + (1 - p(\tilde{e}_j^{**}))u_i'(\pi_{i,ff})\right] \\ &\qquad + \frac{\partial p(\tilde{e}_j^{**})}{\partial C}\left(p(e_i^{**})\left[u_i(\pi_{i,ss}) - u_i(\pi_{i,sf})\right] + (1 - p(e_i^{**}))\left[u_i(\pi_{i,fs}) - u_i(\pi_{i,ff})\right]\right) \qquad (7)\end{aligned}$$

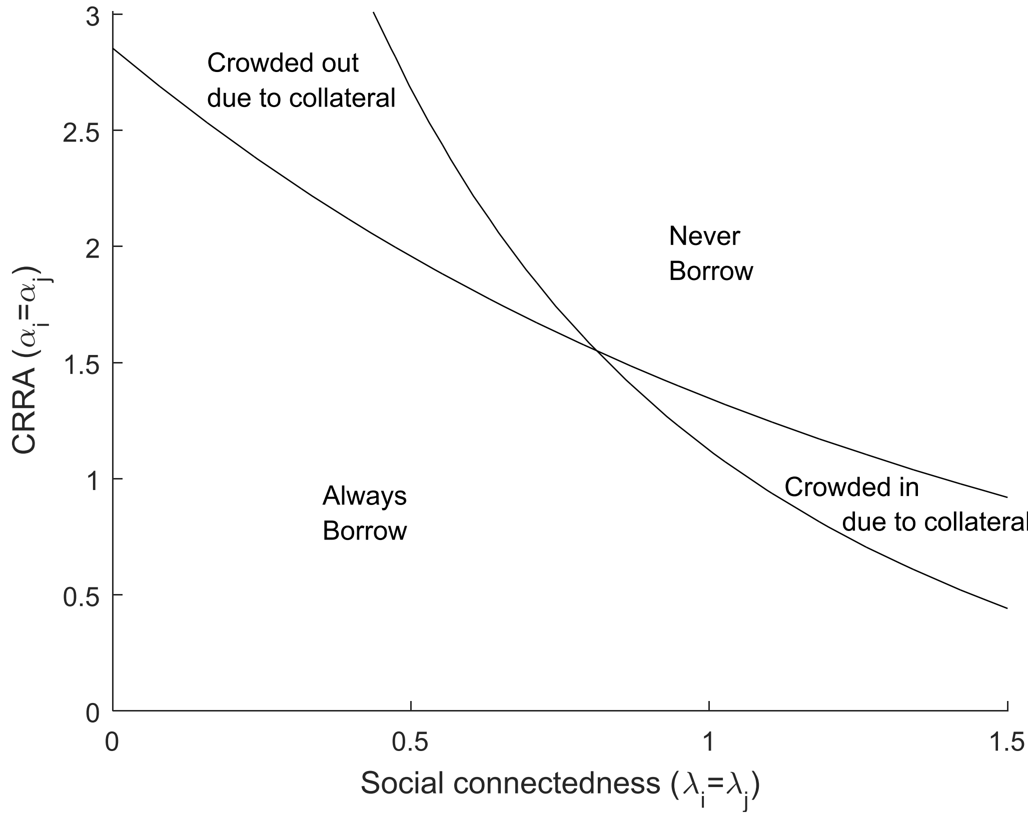
The first term is always positive and represents the positive direct effect of collateral on (latent) credit market participation, in that a higher collateral level means that the borrower has to cover less of the partner's loan when the partner fails (the carrot effect). The second term represents the direct collateral burden when the borrower fails and is similar to the collateral effect under individual lending (the stick effect). While this effect is generally negative, there is a possibility that it could be positive if $\partial S(d_i, \lambda_i)/\partial d_i$ is sufficiently large[10]. The third term represents the indirect effect of collateral, through an increase in effort by the partner, on (latent) credit market participation. Assuming $\frac{\partial p(\tilde{e}_j^{**})}{\partial C}$ is positive, which is consistent with the numerical analysis above, this term is positive. Hence, under joint liability group lending, it is possible that introducing a collateral requirement may in fact increase (latent) credit market participation. In particular, whether or not a borrower views the collateral requirement as desirable depends on the relative magnitude of the positive direct and indirect effects to the direct negative effect. Note that if $\partial S(d_i, \lambda_i)/\partial d_i$ is sufficiently large, all three effects are unambiguously positive, which would guarantee that $\frac{\partial V^J}{\partial C} > 0$. Moreover, in the case of no social connectedness ($\lambda_i = 0$), the negative direct effect is identical to that under individual lending and does not depend on the partner's effort.

While the above analysis shows that a collateral requirement may increase credit market participation, it does not tell us how collateral would alter the composition of borrowers. In particular, it does not allow us to characterize the types of people who are crowded out or crowded in due to collateral relative to the people who always borrow or never borrow. To do this, we numerically characterize the parameter space under which the borrowing constraint in equation 5 ($\mathbb{E}\, U_{JL,i}(e_i^{**}|r, C, \tilde{e}_j^{**}) - u_i(\omega_i) \geq 0$) holds. Specifically, Figure 3 plots the borrower participation constraint in $\alpha_i - \lambda_i$ space under no collateral and under a 20% collateral requirement, assuming both group members are identical ($\alpha_i = \alpha_j$ and $\lambda_i = \lambda_j$)[11]. Figure 3 shows that highly risk-averse, highly socially connected individuals will choose not to enter the credit market in the absence of a collateral requirement. This result stems from the fact that borrowing involves some level of risk relative to the zero-risk fallback option, and that the level of risk increases when there is a large amount of social collateral at stake. Furthermore, when introducing a 20% collateral requirement, the borrower participation constraint curve flattens, implying that a group of highly risk-averse people with low social connectedness will now exit the credit market due to collateral, while a group of highly socially connected people with medium CRRA will enter the market. As the analytical results demonstrated, the collateral burden will be greater for individuals who are poorly connected and these people are thus more likely to be crowded out due to collateral. On the other hand, if there is already a large amount of social connectedness within the group, a monetary collateral requirement will mitigate some of the social collateral burden, which serves to crowd in this group of people. This analysis thus demonstrates that the introduction of a collateral requirement

[10] For example, if social collateral is particularly burdensome to a borrower, the mitigation of social collateral through an increase in monetary collateral could make the borrower better off.

[11] The parameter values used in the numerical analysis are the same as those used previously.

Figure 3: Credit market participation with and without 20% collateral

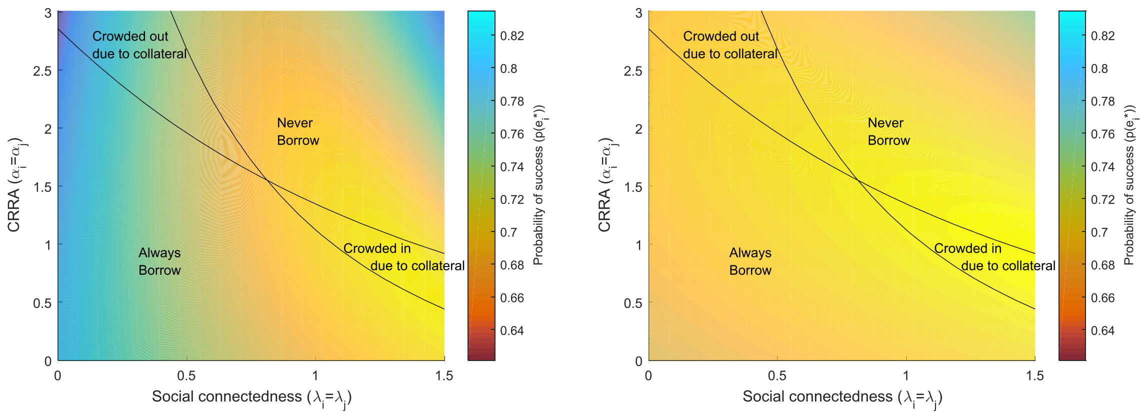


would likely change the composition of borrowers in favor of more socially connected and less risk-averse people. However, whether a collateral requirement changes the overall rate of credit market participation depends on the initial composition of borrowers and is thus an empirical question.

Next, we study whether the selection effect of collateral is adverse or advantageous for lenders. In particular, Figures 4a and 4b plot the optimal effort level (transformed into probability of success) under no collateral and under a 20% collateral requirement, respectively. As shown in section 2.3.1, collateral has a positive effect on effort over the entire parameter space, particularly for individuals with low levels of social connectedness. Moreover, the people who are crowded in due to collateral supply higher effort than the people crowded out due to collateral. Hence, our model predicts that a collateral requirement will not only reduce moral hazard but will also change the composition of borrowers in favor of more high-effort individuals, thus reducing adverse selection.

Figure 4: Probability of success in risk aversion/social connectedness space

(a) No collateral (b) 20% collateral



2.4 Optimal contracts

The preceding analysis has demonstrated that a 20% collateral requirement can reduce moral hazard and adverse selection in joint liability group lending, assuming an exogenous interest rate. The assumption of a fixed interest rate is appropriate if we are interested in the short-run behavioral response to the introduction of collateral by an experimenting lender[12]. Moreover, the assumption of a fixed collateral requirement is consistent with existing contracts offered by VisionFund Tanzania. However, in the long run, the interest rate and the collateral requirement will endogenously adjust to either maximize the welfare of borrowers subject to a zero-profit condition of the lender under perfect competition, or to maximize profit in the case of a monopolistic lender.

The following section relaxes the assumption of a fixed interest rate and characterizes a credit market equilibrium where lenders face perfect competition. We then study optimal contracts by solving for the collateral requirement that maximizes the borrower's value function. Specifically, the bank's zero-profit condition under individual liability is as follows:

$$p(e_i^*)r + (1 - p(e_i^*)(C - 1) = r_0 \tag{8}$$

where r_0 is the lender's required return on capital. Under a joint liability contract, the zero-profit condition is:

[12]We also fixed the interest rate in the model in order to provide testable predictions for the experimental games, in which the interest rate was held fixed. Fixing the interest rate in the games was done to maintain simplicity, and is consistent with the setup in most other experimental studies in the literature.

$$\left[1-(1-p(e_i^{**}))\left(1-p(e_j^{**})\right)\right]r+(1-p(e_i^{**}))\left(1-p(e_j^{**})\right)(C-1)=r_0 \tag{9}$$

As before, we assume that the borrower does not take into account the effect of her effort on the interest rate. Thus, the FOCs given by equation 4 and equation 6 for individual liability and joint liability, respectively, are unchanged. Solving for r and substituting into the FOCs yields indirect expressions for optimal effort under individual lending ($e_i^*(r_0, C)$) and under joint liability $\left\{e_i^{**}(r_0, C, e_j^{**}),\ e_j^{**}(r_0, C, e_i^{**})\right\}$. Since closed-form solutions for optimal effort do not exist, we instead solve for $e_i^*(r_0, C)$, $e_i^{**}(r_0, C, e_j^{**})$ and $e(r_0, C, e_i^{**})$ numerically and plot the results against key parameters.

The numerical results showing the effect of collateral on optimal effort, assuming the interest rate is allowed to adjust, can be found in Appendix A.1. The results change minimally relative to those derived assuming a static interest rate environment. In particular, the direction of the effects is the same, and the magnitude of the collateral effect on effort is slightly stronger when the interest rate is endogenous. This is intuitive, as an increase in the collateral requirement will result in a decrease in the interest rate, which further increases optimal effort.

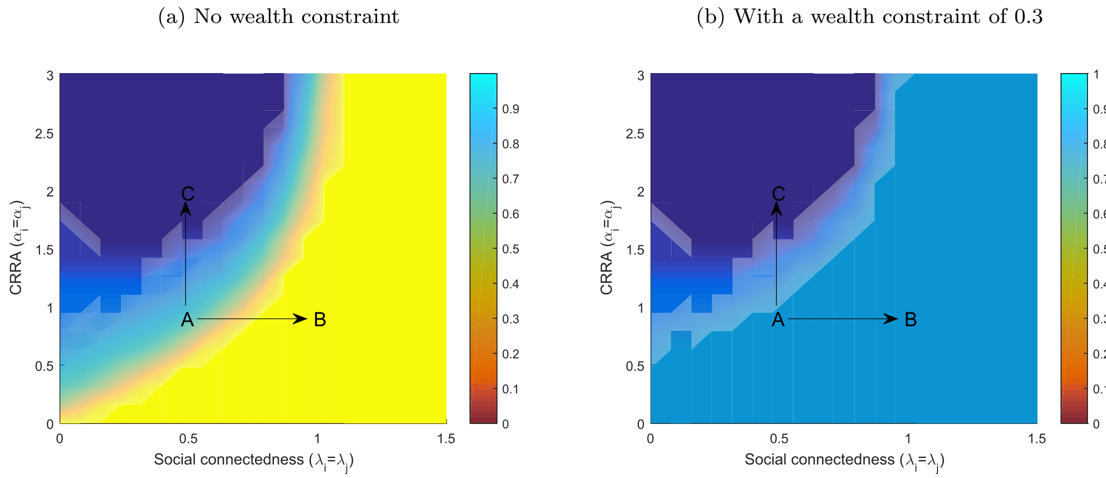
To study optimal collateral under joint liability, first consider the value function for borrower i, assuming that r is set endogenously: $V_i^J = \mathbb{E}\, U_{JL,i}(e_i^{**}|r_0, C)$. We can then maximize the value function by choosing an optimal level of collateral, under the assumption that both group members are identical[13]. We run the analysis both with and without a wealth constraint ($C \leq 0.3$) in order to study both the unconstrained optimal collateral level and a more realistic scenario where farmers have limited wealth to pledge[14].

Figures 5a and 5b show the results of solving for optimal collateral, $C^{**}(\alpha_i, \lambda_i)$, in $\alpha_i - \lambda_i$ space, with and without a wealth constraint, respectively. Our analysis shows that the optimal collateral requirement depends on risk aversion, social connectedness, and the interaction between them. In particular, we find that for a subset of agents with high risk aversion and relatively low social connectedness, a zero-collateral requirement is optimal. For these people, the introduction of monetary collateral does little to mitigate social collateral, and their high level of risk aversion makes collateral particularly costly. On the other hand, the subset of people with high social connectedness or low risk aversion would prefer a 100% collateral requirement, assuming they had sufficient wealth. For individuals with a sufficiently high λ_i, monetary collateral reduces the total collateral burden as social collateral is reduced. Moreover, for less risk averse people, collateral is less costly, so that the benefits of collateral more easily outweigh the costs. Finally, there is a subset of people, formed by a band between the two corner solution regions, who prefer a partial

[13] If the assumption of identical borrowers is relaxed, we will instead need to define and maximize a social welfare function that considers the combined utility of both borrowers.

[14] Obviously, if people have sufficient wealth for a 100% collateral requirement, they would simply self-finance and would not need a loan.

Figure 5: Optimal collateral



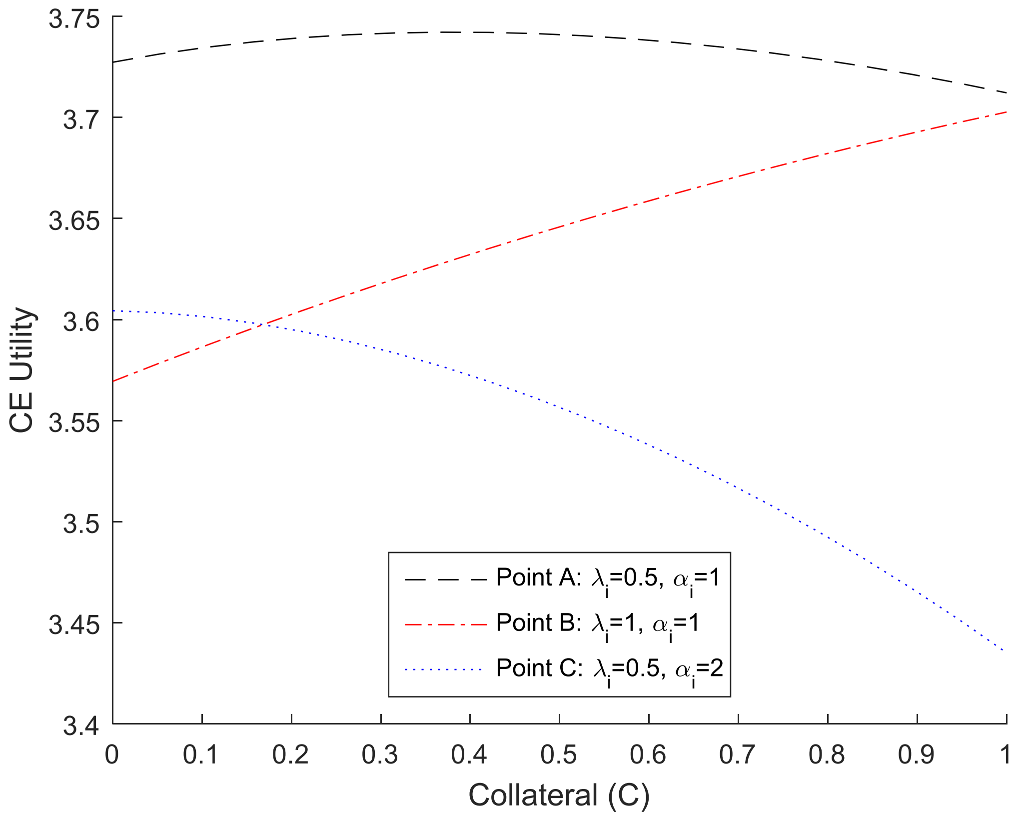
collateral requirement. Figure 5b also demonstrates that the wealth constraint is binding for all individuals whose unconstrained optimal collateral level exceeds the constraint, suggesting that utility is monotonically increasing in collateral up to $C = 0.3$.

To further illustrate the optimality of different collateral levels, Figure 6 plots the value function against collateral for three individuals (A, B, and C) who prefer partial collateral, full collateral, and no collateral, respectively. In particular, person A ($\alpha_i = 1$, $\lambda_i = 0.5$) has relatively low risk aversion and social connectedness and prefers a 40% collateral requirement. Person B ($\alpha_i = 1$, $\lambda_i = 1$) is equally risk-averse but is more socially connected and is thus more heavily burdened with social collateral at $C = 0$. An increase in monetary collateral thus monotonically increases utility, because it relieves the social collateral burden. Finally, person C ($\alpha_i = 2$, $\lambda_i = 0.5$) is equally socially connected relative to person A, but is more risk-averse. Hence, collateral is more costly for person C, to the point where utility is decreasing in C.

It is important to note that while in this section, we have considered the symmetric case in which both partners have the same level of social collateral and risk aversion, the asymmetric case is likely important empirically. As noted in section 2.3.1, the effort effect of collateral is higher for an individual paired with a lower social collateral partner. While we have not formally analyzed contract optimality for the asymmetric case, we would anticipate that value of individual collateral increases for high social collateral individuals when they are paired with a (free-riding prone) low social collateral borrowing partner.

The finding that different individuals prefer different collateral requirements suggests that there might be gains to offering a menu of contracts. In particular, our results indicate that high-CRRA/low-social-connectedness people prefer a zero-collateral contract with a higher interest rate,

Figure 6: Optimal contracts for different borrower types



while people with low risk aversion or high social connectedness would choose a contract with 30% collateral and a lower interest rate. Moreover, offering multiple contracts may enhance welfare by preventing the crowding out of high-risk-aversion/low-social-connectedness individuals. However, these results are only speculative, as there is no guarantee that such contracts are incentive compatible[15].

2.5 Summary of results and hypotheses to be tested

The predictions from the theoretical model are summarized in Table 1. Specifically, the theoretical analysis suggests that adding a collateral requirement to a joint liability group contract may

[15]Deriving the conditions for incentive compatibility would require us to specify a distribution of borrowers in $\alpha_i - \lambda_i$ space or to assume only a limited number of borrower types. Moreover, analyzing contract menus under joint liability is complicated by the fact that individuals within the same group are not identical, which would also affect selection of borrowers into groups. This analysis is beyond the scope of the current paper.

Table 1: Summary of theoretical predictions

Model predictions		Fixed Interest Rate		Endogenous Interest Rate	
		Effort	Participation	Effort	Opt.Collateral
	f	$\frac{\Delta e^*}{\Delta C}$	$\frac{\Delta Q}{\Delta C}$	$\frac{\Delta e^*}{\Delta C}$	C^*
Ind'l liability	f	+	-	+	0
Joint Liability	f	+	?	+	?
	$\frac{\partial f}{\partial \alpha_i}$	+**	-	+**	-
	$\frac{\partial f}{\partial \lambda_i}$	-	+	-	+

Q represents credit market participation, assuming some distribution of people in $\alpha_i - \lambda_i$ space

**Only holds for a sufficiently low level of α

reduce moral hazard (by increasing effort), and that the magnitude of the effect depends on the parameters, including the level of risk aversion and and social connectedness. Moreover, a collateral requirement may also, under certain conditions, increase credit market participation. Whereas under an individual contract, adding a collateral requirement would always reduce credit market participation (assuming a fixed interest rate), this may not be the case under joint liability. Finally, we show that a positive collateral requirement may be optimal for a subset of people.

In the experiment, we will be testing several of these hypothesis. Specifically, we will test the effect of a 20% collateral requirement in joint liability on effort and credit market participation, allowing for interactions with risk aversion and social connectedness. Since the experiment was not set up to test the effect of collateral under individual lending, we cannot test the predictions for individual liability.

3 Experimental Design and Data

To understand the behavioral effects of adding a collateral requirement to a joint liability group contract, we conducted a framed field experiment, in which participants played a series of microfinance games. Except as described in the previous section, these games closely resemble the theoretical framework and allow us to separately identify the impact of dynamic incentives, joint liability and the collateral requirement both on selection and on effort diversion.

The sample consisted of members of joint liability credit groups under VisionFund Tanzania's (VFT) lending program. VFT is one of the largest rural microfinance lenders in Tanzania and has more than 30,000 loans in its portfolio, of which roughly 2,500 are agricultural loans (Mkombozi loans) to smallholder farmers. These loans were originally advertised in select villages within VFT's administrative areas (ADPs), and local representatives held community meetings to provide information about the application process. Community members were then encouraged to submit applications as groups totaling 8-20 people. Once a group had submitted their credit application, a credit officer would screen individual applicants based on factors such as income, intended use of funds, and family relationships. Specifically, in order to qualify for a loan, each applicant had to cultivate a primary staple or cash crop (e.g. rice, sunflower, or maize) and were required to have another source of income, such as cultivation of vegetables, running a small business, or labor work. Also, applicants in the same group could not be from the same immediate family, although we learned from our data that borrowers did not always abide by this rule.

The joint liability clause dictated that the entire group would be responsible for repaying the debt obligation; otherwise, each group member would default and would be denied future access to loans. Hence, while each individual could apply for a separate amount, loan sizes tended to be similar among members of the same group. Some groups were also subjected to a collective savings collateral requirement, under which each member, prior to receiving the loan, had to deposit 20% of the loan amount into a savings account held by VFT. These savings could not be withdrawn by the borrowers until the collective debt had been repaid, and in the case of group default, the bank could seize the savings of all members. As explained in section 2.3, this collective savings requirement is different from the individual collateral requirement analyzed in this paper.

We constructed our sample by randomly selecting among VFT's established credit groups in the administrative areas of Mtinko, Kinampanda and Kisiriri. At the time of the study, there were 77 credit groups in these areas, and out of these, we randomly chose 31 groups for inclusion in our sample. Only groups that had nine or more members were included, and if the group had more than fifteen members, we randomly chose fifteen members. This resulted in a total sample of 305 borrowers[16][17].

[16]Our original sample consisted of 38 groups and 397 participants; however, we decided to drop the data for 7 groups (92 participants). Specifically, we had originally wanted to randomize the order of the games, in order to make our results robust to ordering effects. However, after conducting several sessions with a randomized order, we learned that participants who played the joint liability games first were having trouble comprehending the games due to several new concepts being introduced all at once. Hence, we decided to abandon the random ordering of the games and to exclude these observations from the final sample.

[17]Out of this sample, roughly 80% were subject to the collective savings requirement imposed by VFT. Hence, our population may differ from other populations of microfinance borrowers who have not been selected based on this basis. In particular, prior experience with group collateral may have made the concept of collateral more familiar for study participants. This experience may have also primed them to be favorably disposed to individual collateral, since most respondents reported a favorable impression of group collateral. We can get a small window into whether this real-world selection matters in terms of response to the individual collateral offered in the game. While the subset of game participants whose groups did not have group collateral is smallish (~60), when we interact an indicator variable for this subset with the collateral treatment in the game we find no significant impacts. The insignificant point estimates indicate that those without group collateral experience are slightly less likely to stop borrowing when individual collateral is inserted into the game, and supply slightly more effort in response to the imposition of collateral. While evidence based on this small sample size is not fully convincing, it at least offers some indication

The experiments took place in March and April, 2014 in the rural villages near the town of Singida, Tanzania. Game trials were conducted with graduate students in Davis, CA, and we pretested the experiment with VFT credit groups that were not included in the final sample. The games were organized in sessions, and we invited only members from the same VFT group to join a single session. This is an important feature of our experiment, since it allows us to harness the social connectedness that already exists within real-life credit groups.

The following sections describe the games and the experimental procedures in detail.

3.1 The games

In each session, the participants played a series of four consecutive games, each of which consisted of multiple rounds, where each round represents a lending cycle. Participants were told that they have access to one acre of good-quality sunflower land, but that they do not have sufficient cash to cultivate it unless they take out a loan. In each game and round, players were given the option to take a loan, which would be automatically used to purchase all the inputs required for their plot. For simplicity, the loan amount was fixed at Tsh 200,000 ($125) and the interest rate was 20%, so full repayment equals Tsh 240,000.

If the participant chose to borrow, she would be able to realize a yield at the end of the round. In order to capture all the dynamics of group lending with and without collateral, we assume three states of the world: good, poor and very poor, which corresponds to a sunflower yield of 13 bags, 5 bags or zero bags, respectively. Each bag could be sold for Tsh 40,000, so the associated revenues for each state were Tsh 520,000, Tsh 200,000, and zero, respectively. Note that full individual repayment of the loan was only possible in the good state.

Moreover, each borrower would have to choose between three levels of effort diversion. A lower level of effort diversion was associated with a higher probability of a good yield but also with a lower guaranteed income, that was private and could not be used for loan repayment. This is consistent with the idea that farmers who dedicate less time to their primary farming activities face a higher risk of crop failure as they may be less prepared for adverse events, such as drought, floods or pests. Instead, they can divert their effort towards less risky, but also less productive activities. While in reality, such activities may include anything that yields a positive utility at a low risk, including leisure or wage work, these are represented by wage employment at a local sunflower factory in our experiment.

Table 2 shows the tradeoff between success probability and fixed income for each level of effort diversion. This was phrased to the participants in terms of "farm days", and each borrower would choose either 1, 3 or 5 farm days. The realization of the project outcome for each participant was

that our study population may not be that different from the more general universe of microfinance borrowers who have not been selected based on their willingness to borrow in the presence of group collateral.

Table 2: Tradeoff between fixed income and probability of success for different levels of effort diversion

		Probability of outcome		
Farm Days	Wage Income	Good	Poor	Very Poor
1	Tsh 90,000	40%	30%	30%
3	Tsh 50,000	60%	20%	20%
5	Tsh 0	80%	10%	10%

determined by her drawing a ball from one of three bags, each representing a different number of farm days.

The following sections describe each of the four games in detail.

3.1.1 Games 1 and 2: Individual lending

In the first two games, participants were offered individual lending contracts. In game one, there were no dynamic incentives. As such, this game presents the participants with a choice of different single-period lotteries, each representing a different tradeoff between risk and return, and can thus be used to elicit participants' risk preferences. A framed risk preference game was chosen over a standard unframed game (e.g. Holt and Laury, 2002) for various reasons. First, playing this game first would help familiarize participants with the game structure and would provide risk aversion coefficients specifically relevant to a lending context. Second, the results from this game also allows us to measure the effect of adding a dynamic incentive, as this game is essentially identical to the second game, but without dynamic incentives.

In order to eliminate any potential first-round bias, we had the participants play three rounds of the first game. In each round, the subjects first chose whether or not to borrow. Those electing to borrow would then also choose a level of effort diversion before drawing a ball from a bag to reveal the outcome. An individual i's net payoff in round t, can be expressed as:

$$\pi_{IL,i,t,s} = max(X_{s,i,t} - r, 0) + w_{i,t} \tag{10}$$

Here $X_{s,i,t}$ is the farm revenue for outcome s, r is the interest rate, and $w_{i,t}$ is the wage income. Table 3 shows the net payoff for each choice and each outcome. The last two columns also display the expected payoff and the associated CRRA risk aversion range for each choice. The CRRA upper (lower) bounds are calculated by finding the CRRA coefficient that makes the expected utility, based on the CRRA utility function[18], equal between a given choice and the choice that is only slightly less (more) risky but that yields a lower (higher) return. As expected, not borrowing

[18] $U(c) = \frac{1}{(1-\gamma)c^{(1-\gamma)}}$ if $\gamma > 0$ and $\gamma \neq 1$ and $U(c) = ln(c)$ if $\gamma = 1$, where γ is the CRRA coefficient

Table 3: Payoffs and associated CRRA ranges for various choices in the framed risk preference game

Borrow	Farm Days	Project Outcome	Probability	Net Payoff	Expected payoff	CRRA Range
No	N/A	N/A	100%	120	120	(2.52, ∞)
Yes	1	Good	40%	370	202	(0.89, 2.52)
		Poor	30%	90		
		Very Poor	30%	90		
	3	Good	60%	330	218	(0.37, 0.89)
		Poor	20%	50		
		Very Poor	20%	50		
	5	Good	80%	280	224	(-∞, 0.37)
		Poor	10%	0		
		Very Poor	10%	0		

is the safest option, and for borrowers, riskiness is decreasing in effort diversion.

The second game was identical to the first, except that participants who defaulted in a given round were denied a loan in all remaining rounds. Moreover, participants played this game for seven rounds instead of three.

3.1.2 Games 3 and 4: Joint-liability group lending

In the joint-liability group lending games, participants were first asked to indicate whether or not they wished to borrow. Their decision applied to all rounds, so that switching between borrowing and not borrowing throughout the game was not possible. Those participants choosing to borrow were randomly assigned into groups of either two or three members, depending on the number of total borrowers[19]. Just as in the individual lending games, borrowers would privately choose a level of effort diversion. However, the joint liability clause required success borrowers to cover the loans other group members who were unable to repay their own loans. While the borrowers' choices were private information, their outcomes were revealed to the other group members. This is consistent with reality, in which community members can monitor each other's output but not the level of effort supplied.

The only difference between game 3 and 4 is the addition of a 20% collateral requirement in game 4. In particular, those electing to borrow would have to pledge TSh 40,000 in each round. In order to closely simulate the real effect of collateral, we made the participants complete a simple activity at the beginning of the session, for which they could earn the required collateral amount. This was intended to give the participants a sense of ownership over these earnings, so that the

[19] Allowing the group size to change was necessary in order to ensure that all borrowers were part of a group.

prospect of losing them in the collateral game would closely resemble the risk of losing their own savings.

In all the joint liability games, the net payoff in round t for borrower i is calculated as follows:

$$\pi_{JL,i,t} = max\left(X_{s,i} - r - \frac{1}{\sum_{j=1}^{n} P_j}\sum_{j=1}^{n} max\left(r - (X_{s,j} + C), 0\right), -C\right) + w_{i,t} \tag{11}$$

where $X_{s,j}$ is the farm revenue for group member j, n is number of joint liability group members, C is the required collateral amount (zero in game 3, TSh 40,000 in game 4), and P_i is a binary indicator of partner j's ability to repay her own debt obligation ($P_i = 1$ if $X_{s,j} - r + C \geq 0$ and $P_i = 0$ otherwise).

Just like in game 2, the joint liability games had dynamic incentives. However, the group would only default if the total farm revenue of the group was insufficient to cover the group's debt obligation. Moreover, if the group defaulted, all group members would be excluded from lending in any remaining rounds and would be forced to choose the no-borrow option. To ensure that the dynamic incentives were sufficiently strong, participants played this game for seven rounds.

3.2 Experimental procedures

The sampled members from a single group were all invited to join an experimental session, and we conducted two sessions per day, each lasting between 3 and 3.5 hours. To give the participants ownership of the amount that might be pledged as collateral in game four, we asked them to complete a simple activity at the beginning of the session, for which they could earn Tsh 1,000. This activity consisted of separating maize from beans that had been mixed together in a cup, and those who completed it within five minutes received their winning in cash immediately. Due to the triviality of this task, everyone in the sample successfully completed it and received their TSh 1000.

After being introduced to the basic setup, the participants played the four games described above in the order 1-4[20], followed by a household survey and a social networks survey. All instructions were presented in Swahili with the aid of a posterboard displaying the payoffs and probabilities associated with each choice (see Appendix A.3 for an English version of this board). At the beginning of each

[20] We had originally wanted to randomize the order of the games to make our results robust to the possibility that there was a general trend among participants to increase the effort level as games continued. We hence ran several sessions with the order randomized. Unfortunately, during the sessions where the joint liability games were played first, participants expressed difficulty comprehending the games due to several new concepts being introduced all at once. Hence, we decided to abandon the random ordering of the games and to exclude these observations from the final sample. To test for a possible ordering effect, we instead looked at the average effort level across rounds within the same game (see Appendix A.2 for this analysis). Our analysis shows that overall, and for each game, the number of mean farm days does not significantly increase across rounds. While these results cannot completely rule out an ordering effect, they at least provide some suggestive evidence that participants are not simply increasing their effort level throughout the experiment.

session, participants were provided with game sheets, on which the enumerators would record their decisions, outcomes, payoffs and default status after each round. As part of the introduction, all participants were given a chance to practice drawing balls to familiarize them with the probabilities associated with each choice. Moreover, at the beginning of each game, they would first play one non-incentivized practice round[21], before moving on to the actual game.

To ensure the anonymity of participants' effort diversion choices, we had set up three privacy stations that were each attended by an enumerator. At each station, there were four bags, one for each effort diversion choice and one for the no-borrow decision. Each of the three "borrowing bags" contained ten green, yellow, and red balls, where a green ball indicates a good crop, an orange ball a poor crop, and a red ball a very poor crop. The ratio of green to yellow and red balls in each bag corresponded to the probabilities listed in Table 1. The no-borrow bag contained ten blank balls. A label showing the ratio of balls and the payoffs for each ball color was clearly printed next to each bag.

During the individual lending games, the enumerator would ask before each round whether the participant would like to borrow. If the participant answered affirmatively, she was asked to choose a level of effort diversion and then to draw a ball from the corresponding bag. For the joint liability group games, the participants would make their borrowing decision for the entire game. Those who elected to borrow were then randomly divided into groups of two or three, and were asked to choose a level of effort diversion in each round. In order to ensure that decisions were not affected by a preference for a short playing time, non-borrowers were asked to draw a ball from the no-borrow bag. Moreover, in the group lending games, each borrower received information about the draws of the other group members but not about their effort diversion choices.

In order to incentivize careful game play, we paid participants in cash based on their earnings from a randomly chosen round in a randomly chosen game. The game earnings from the chosen round were divided by a factor of 40 to compute actual cash payouts. If the collateral game was chosen, and the participant had lost her collateral in the selected round, we would collect the Tsh 1,000 she earned at the beginning of the session. Total payouts, including a show-up fee of Tsh 1,000, ranged from Tsh 1,000 ($0.63) to Tsh 13,000 ($6.88), with an average payout of Tsh 5,300 ($3.32).

4 Results

In this section, we first present a summary of the participant characteristics and the raw experiment data to show the effect of the different treatments on borrowing rates and number of farm days. We then proceed to study the data using a simple econometric framework, in which we separately

[21] In the second game, they played two practice rounds to make sure they understood the dynamic incentives.

analyze the effect of the collateral requirement under joint liability on moral hazard, borrowing, and repayment rates.

4.1 Participant characteristics

Table 4 displays the descriptive statistics for the participants in the sample. The average participant is 42 years old, comes from a household of six members, and owns more than 8 acres of land, of which about a third was dedicated to sunflower during the previous season. Note that most participants are literate (96%) and that the gender balance is fairly even (52% males). The use of chemical fertilizer is quite uncommon with only 10% of the sample indicated having used chemical fertilizer during the previous season.

The average VisionFund Tanzania (VFT) credit group size is 12 members, and each member borrows on average slightly less than Tsh 230,000 ($150). The VFT program is relatively new in these areas, with the average participant having borrowed for only less than two seasons. However, almost everybody (97%) expressed an intent to take out another loan in the following season. Finally, only 7% have borrowed money from other sources than VFT, showing the limited access to credit programs among this population.

Based on the choices people made in game 1, we calculate an imputed measure of each participant's CRRA. In particular, we first convert the number of farm days chosen in each round in game 1 to a CRRA value, using the middle point of the risk aversion range associated with each particular choice and assuming that the lower bound is $\alpha_{it} = 0$ and the upper bound is $\alpha_{it} = 3.5$[22]. Hence, the associated levels of risk aversion for 0, 1, 3 and 5 farm days are 3, 1.705, .63 and .185, respectively. We then compute participant i's average level of risk aversion across all three rounds as: $\alpha_i = \mathbb{E}[\alpha_{it}]$.[23]. Our sample has an average CRRA of 0.8, which is similar to that found in unframed lotteries in developing countries (see Cardenas and Carpenter, 2008). Furthermore, based on the responses to the social network survey, we calculate a social collateral index for each individual. In particular, the session social collateral index (SSC Index) is calculated as participant i's average number of "positive" network links towards all the other participants in the same session. A "posi-

[22]Using the mid-point of each range and imposing lower and upper bounds on the CRRA is arbitrary, as we do not know the distribution of CRRAs within each range. As a robustness check, we have also created a binary indicator for above-median CRRA and re-run all the analysis (results available upon request). Both the sign and the significance of the new CRRA variable remains the same in the borrowing regression. Moreover, the other coefficients only change slightly, suggesting that the main findings are robust to this definition. However, in the effort regression, we lose significance on the risk aversion term. This is perhaps not surprising, as the binary indicator suppresses variation, and effectively assumes that a highly risk-averse person behaves in the same way as a slightly risk averse person. We thus prefer to stay with our original specification.

[23]Given the way the experiment was designed, the safest borrowing choice (one farm day) is also the one with highest probability of default. Although there are no dynamic incentives in the first game, it is plausible that participants still have an aversion to defaulting. In particular, if more risk-averse individuals are also more default averse, the distribution of our imputed CRRA measure would be skewed to the left (towards less risk aversion) relative to the distribution of an unframed measure of risk aversion. This, in turn, is likely to understate the effect of risk aversion on effort and borrowing.

Table 4: Summary statistics

Variable	N	Mean	St.Dev
Demographics			
Age	305	41.70	10.38
Head of household	305	0.66	0.48
Male	305	0.52	0.50
Married	305	0.80	0.40
Can read and write	305	0.96	0.20
No. of HH members	303	6.00	2.51
Local leader	305	0.38	0.49
Behavioral parameters			
Risk aversion (CRRA)	305	0.80	0.70
Session Social Collateral Idx	304	0.41	0.28
Agricultural Production			
Total acres planted	304	8.30	10.75
Total acres, sunflower	299	2.80	3.11
Use fertilizer	286	0.09	0.28
Sunflower yield (kg/acre)	237	527.85	290.07
Borrowing			
No. of members in VFT group	301	12.46	2.63
Amount borrowed (Tsh 1,000)	302	229.88	74.94
No. of seasons borrowed VFT	305	1.70	0.84
Apply for loan next season	294	0.97	0.17
Other borrowing	301	0.07	0.26

Table 5: Summary statistics: Experimental games data

	Borrowed	Farm days	Repay
Game 1: Ind'l liability, no dynamic incentives	0.89	3.40	0.73
Game 2: Ind'l liability, w/dynamic incentives	0.86	4.11	0.76
Game 3: Joint liability, no collateral	0.77	4.25	0.95
Game 4: Joint liability w/collateral	0.70	4.43	0.97

tive" link means answering "yes" to either of the first five questions of the social network survey[24]. Our data shows that the average SSC Index is 0.41, with a standard deviation of 0.28. This can be interpreted as the typical person answering 'yes' to an average of 0.41 social networks questions towards all the other participants in the session.

Given that groups were largely self-formed, we would expect to see little cross-group variation in the extent of social connectedness, with most of the variation in social collateral occurring within groups. A simple analysis of variance confirms this expectation, as only 27% of the total variation in session social collateral is across groups. This variation is not randomly generated, thus creating a correlation between our measure of social collateral and individual characteristics such as gregariousness and perhaps social position. However, we can still induce exogenous variation in social collateral within the experimental credit groups, as these were randomly created subsets of the real-life credit groups.

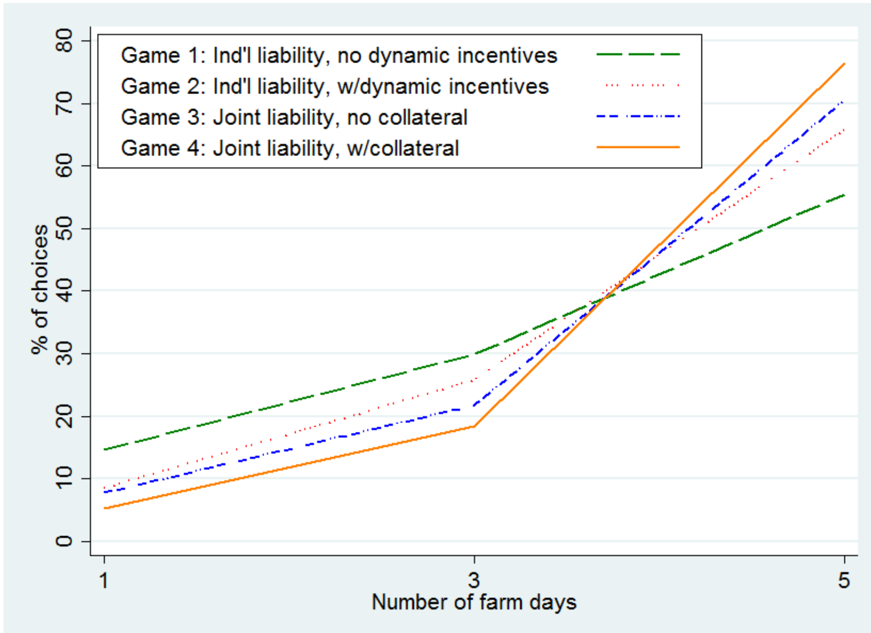
4.2 Distribution of choices

To gain some intuition, consider first a simple summary of the participants' choices. Table 5 reports the rate of borrowing, the mean number of farm days chosen, and the mean repayment rate under each of the four games. We note that the rate of borrowing decreases by almost ten percentage points when adding joint liability and by an additional seven percentage points when also adding collateral. This indicates that on average, both joint liability and the collateral requirement are considered a burden for borrowers, as they now consider the safe no-borrowing option to be relatively more attractive.

Among the people who chose to borrow, the average number of farm days increases with the addition of dynamic incentives, joint liability, and the collateral requirement, in particular by 0.71, 0.14, and 0.18, respectively. These results suggest that each of these contract features induce

[24] A listing of the social networks questions can be found in Appendix A.4. Among these, the first three questions are mutually exclusive (close family, relatives, or friends), while the last two questions are not. Hence, the highest SSC index possible is 3, which corresponds to an individual answering yes to either of the first 3 questions and to both of last two, for every participant in the session.

Figure 7: Connected-line histogram of participant choices among active borrowers in each game.



borrowers to supply more effort and thereby reducing moral hazard.

Finally, the rightmost column shows the conditional repayment rates[25], which are the result of the combined behavioral effect and contractual effect. In particular, we note that average repayment rates are much higher under group lending than under individual lending, mostly due to the insurance effect of joint liability. Moreover, we also note a small increase in repayment rates (two percentage points) when adding collateral to the joint liability contract.

To better see what is driving the change in average number of farm days, we study the distribution of participants' choices for the different games. Figure 7 shows the percentage of borrowers who chose 1, 3, or 5 farm days (represented by a connected-line histogram), in each game. As is clear from Figure 7, the increase in the number of farm days due to dynamic incentives, joint liability, and collateral is due to borrowers shifting away from 1 and 3 farm days towards 5 farm days. In particular, borrowers choose 5 farm days approximately ten percentage points more often under joint liability with collateral relative to when they are under an uncollateralized joint liability contract.

To further understand the effect of the collateral requirement on participants' borrowing and effort diversion choices, consider the transition matrix of choices between game 3 and game 4. Table 6 shows the actual number and percentage of participants choosing not to borrow or 1 through 5

[25]The conditional repayment rate is calculated as the average per-period rate of default among all active borrowers.

Table 6: Transition matrix showing the percentage of participants who made the given choices (on average across all rounds, rounded to nearest integer) between game 3 and game 4

Frequency of obs. (% of row total)		Farm days under JL with collateral						
		Not borrow	1	2	3	4	5	Total
Farm days under JL without collateral	Not borrow	47 (77%)	1 (2%)	0 (0%)	1 (2%)	5 (8%)	7 (11%)	61 (100%)
	1	1 (11%)	3 (33%)	1 (11%)	2 (22%)	2 (22%)	0 (0%)	9 (100%)
	2	2 (40%)	0 (0%)	1 (20%)	1 (20%)	0 (0%)	1 (20%)	5 (100%)
	3	9 (17%)	0 (0%)	1 (2%)	23 (44%)	14 (27%)	5 (10%)	52 (100%)
	4	11 (20%)	0 (0%)	1 (2%)	4 (7%)	16 (29%)	24 (43%)	56 (100%)
	5	12 (10%)	0 (0%)	0 (0%)	3 (2%)	9 (7%)	98 (80%)	122 (100%)
	Total	82 (27%)	4 (1%)	4 (1%)	34 (11%)	46 (15%)	135 (44%)	305 (100%)

farm days (taken as the mean across all rounds and rounded to nearest integer) in the collateralized joint liability game (game 4) conditional on their choice in the uncollateralized joint liability game (game 3). A few observations are worth noting. First, those people who chose to borrow in both games generally increased the number of farm days when the collateral requirement was added, while only a small fraction of borrowers reduced their number of farm days. For example, 37% of those who chose 3 farm days in the uncollateralized game increased the number of farm days in the collateralized game, while only 2% reduced the number of farm days. Second, 35 out of 244 people who borrowed in the non-collateralized game (14%) chose not to borrow when the collateral requirement was added. For these people, the risk of losing their collateral outweighed the added protection of having group members also be subject to the collateral requirement. On the other hand, 14 out of the 61 non-borrowers in the non-collateralized game (23%) switched to borrowing under the collateralized contract. These are likely people who are concerned about the cost of joint liability, but who believed the collateral requirement would help partially offset this cost.

The next sections provide a more rigorous statistical approach to analyze the effect of the collateral requirement on the borrowing decision, the number of farm days, and repayment rates.

4.3 Impact of joint liability and individual collateral on borrowing

Our theoretical model predicts that collateral may have an ambiguous effect on borrowing rates, and that the direction of the effect depends on the level of social connectedness among group members and the level of risk aversion. In particular, the model shows that the effect is more likely to be positive for individuals with a high level of social connectedness and a low risk aversion[26].

To study the effects of the different contractual environments on a subject's decision in the framed field experiment, we estimate the following general model:

$$\begin{aligned} y_{ig} =& \beta_0 + \beta_1 L_g + \beta_2 C_g + \\ & \delta_1 \lambda_i + \delta_2 \alpha_i + \delta_2 L_g \times \lambda_i + \delta_3 L_g \times \alpha_i + \delta_4 C_g \times \lambda_i + \delta_5 C_g \times \alpha_i + \\ & \gamma^{'} \mathbf{X_i} + \epsilon_{ig} \end{aligned} \tag{12}$$

where, y_{ig} is the decision of individual i in game g. The first line gives the main effects of the different contractual treatments, where L_g is a binary variable that takes on the value 1 when the game includes a joint liability contract term and C_g takes on the value 1 for games that further include the individual collateral and liability component. The second line allows for investigation of heterogeneous impacts suggested by the theoretical model summarized in Table 1 above, specifically the interaction between the contract terms and individual risk aversion (α_i) and social connectedness (λ_i). Finally, the last line of 12 contains additional control variables[27] and the error term. In what follows, we will investigate both average treatment effects by ignoring the terms in the second row, as well as exploring heterogeneous treatment effects.

We first focus on the decision whether or not to borrow for the entrepreneurial project. For this decision, we define the dependent variable to be between 0 and 1. For games 3 and 4 with joint liability clauses, subjects had only a single decision to make at the beginning of the game: join a borrowing group or not. For these games, the dependent variable is strictly binary. In game 2, the individual borrowing game, the individual decided at the beginning of each round whether or not to borrow. For this game, the dependent variable is the fraction of rounds for which the individual chose to borrow when he or she was creditworthy.

Finally, since borrowing decisions for this game were made prior to the random credit group assignment, we use as the measure of social connectedness the session social collateral index. As explained above, the session social collateral variable measures the strength of an individual's social connection with other subjects in her experimental session. We would anticipate that an individual with a high level of session social collateral would be more likely to borrow as she would expect any random pairing of herself with other session members would match her with someone she knows and trusts.

While our regression strategy will allow us to determine how the impacts of the contractual treatment differ for well-connected versus less well-connected individuals, note that the level of social connections was not exogenously generated and is liable to correlation with unobserved individual

[26]For a particularly high level of social connectedness, higher risk aversion is also associated with increased borrowing.

[27]Included control variables are listed in the footnote of Table 7.

propensities and characteristics. Care should be taken not to use the estimated coefficients from regression 12 to infer the impact that an exogenous increase in social connectedness (*i.e.*, an increase not generated by the same naturally occurring data generation process that created the observed distribution of λ_i in the population) would have on subject behavior.

Table 7 gives the regression estimates for the borrowing linear probability model. Column 1 shows the simple average treatment effects (controlling for the variables listed in the bottom of the table). As can be seen, shifting from an individual loan contract to a joint contract lowers loan demand by 11 percentage points. Adding an individual collateralized liability element to the joint liability contract further reduces demand by another 7 percentage points. While these are large impacts, it is important to remember that the interest rate (and loan offer) was identical across contracts in the game, whereas that is unlikely to be the case in the real world.

Columns 2 and 3 of Table 7 explore the extent to which these average effects are driven by heterogeneous responses. Column 2 looks at whether the risk averse are more sensitive to the introduction of the collateral requirement and whether the socially better connected are less sensitive to the introduction of joint liability. Both hypotheses are borne out by the data. For the socially well connected ($\lambda > 1$), the depressive effect of joint liability on loan demand almost disappears. We further see that the more risk averse not only demand fewer loans in general, but, contrary to expectations, are not estimated to be any further discouraged by the individual collateral requirement.

Column 3 in the table adds additional interactions to further explore impact heterogeneity, adding interactions between joint liability and risk aversion, and social connectedness and the collateral requirement. As can be seen, these additional interactions do not turn up anything of statistical significance, although high levels of social connectedness reduce the discouraging effect of collateral on loan demand, as the theory predicts. This impact modifier just misses statistical significance at conventional levels. More generally, and as would be expected given their collinearity with the included variables, these additional interaction terms cloud the impacts of the interaction terms in column 2.

4.4 Impact of joint liability and individual collateral on effort supply and moral hazard

In this section, we estimate the effect of the different contractual treatments on effort supply and moral hazard. We employ the same general regression framework used in the analysis of borrowing decisions (equation 12 above). The dependent variable for the analysis in this section is defined as the number of workdays per week the subject chose to allocate to the loan-financed entrepreneurial activity. As described in section 3.1, the choice of entrepreneurial workdays was discrete and limited to values of 1, 3, or 5 days per week, with any residual time diverted to a safe fallback

Table 7: Borrowing demand under alternative contracts

	[1]	[2]	[3]
Constant	0.96***	1.09***	1.08***
	(0.12)	(0.11)	(0.11)
Joint Liability (L)	-0.11***	-0.16***	-0.12***
	(0.021)	(0.033)	(0.040)
Individual Collateral Required (C)	-0.073***	-0.078***	-0.13***
	(0.023)	(0.030)	(0.044)
Session Social Collateral (λ)		-0.017	-0.016
		(0.034)	(0.034)
$L \times \lambda$		0.12**	0.063
		(0.049)	(0.051)
$C \times \lambda$			0.10
			(0.065)
Risk aversion (α)		-0.13***	-0.12***
		(0.026)	(0.024)
$C \times \alpha$		0.0062	0.016
		(0.036)	(0.039)
$L \times \alpha$			-0.016
			(0.033)
Observations	906	906	906
R^2	0.060	0.12	0.12

Standard errors in parenthesis, clustered at the individual level. The following variables were included as control variables but are not reported: age, head of household, male, married, literate, number of household members, village leader, and total acres. *p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01.

activity. Because individuals made their effort decision *after* the fictive borrowing groups were formed, we can define a social connectedness measure specific to the subject's borrowing group (if they borrowed in the joint liability games). Like the session social collateral index described above, this new group social collateral measure captures how strongly connected the subject is to the others in her or his borrowing group. This measure does not exist for the individual borrowing game and takes on different values for the same individual who chose to borrow in both games 3 and 4. However, the individual's session social collateral measure is a predictor of how connected she would be with any randomly drawn subset of participants with whom she could be paired in a joint liability game. Because our regression model 12 follows standard procedures and controls for the levels-impact-modifying variables – as well as their interaction with the treatments – we will use the general session social collateral measure to control for any impact of high social connectivity on effort supply and interact the group social connectivity measure with the treatment variables themselves.

As with our analysis of the impact of contract terms on borrowing decisions, the first column in Table 8 again presents the average treatment effects across the entire population of participants. As can be seen, the estimated impact of joint liability is positive and statistically significant, boosting effort supplied to the loan-finance entrepreneurial project by about 3%. The further addition of an individual collateral requirement on the joint liability loan contract boosts effort supply by another 5%.

Column 2 looks at the heterogeneity that underlies these average impacts and finds that the positive impact on effort induced by joint liability is driven by those who are socially connected to those in their game borrowing group. Those without social connections ($\lambda_i \approx 0$) do not increase their effort at all to the joint liability clause of the contract, while those with higher levels of social connectivity do substantially increase their effort in response to the joint liability clause. This result is consistent both with the theoretical prediction in this paper and with the finding in Besley and Coate (1995), who show that social collateral among group members can mitigate the negative effect of joint liability on repayments. In conjunction with the previous result, this demonstrates that joint liability is only effective at reducing moral hazard when there is a sufficient level of social collateral in the group.

Turning to risk aversion, we see that the risk-averse supply less effort to the risky entrepreneurial game under all contracts (as we would expect), but that the imposition of a collateral rule increases their supply of effort, albeit in a statistically insignificant fashion. The near risk-neutral person would now be estimated to supply substantially more effort in all games (as the intercept has risen by 0.5 days) and to only meekly respond to the imposition of the collateral rule, as the coefficient on the collateral terms is cut in half and becomes statistically insignificant.

Finally, as with the borrowing regression, when we expand in column 3 to include additional interactions between the treatments and social collateral and risk aversion, the precision of the

Table 8: Effort supply under alternative contracts

	Full sample			Consistent borrowers only		
	[1]	[2]	[3]	[4]	[5]	[6]
Constant	3.75***	4.25***	4.36***	3.62***	4.15***	4.31***
	(0.34)	(0.33)	(0.34)	(0.39)	(0.36)	(0.36)
Joint Liability (L)	0.12*	0.055	-0.10	0.11	0.074	-0.13
	(0.068)	(0.069)	(0.097)	(0.072)	(0.071)	(0.095)
Individual Collateral Required (C)	0.18***	0.094	0.14	0.15***	0.050	0.10
	(0.053)	(0.065)	(0.085)	(0.050)	(0.063)	(0.077)
Session Social Collateral (λ)		0.27	0.27		0.21	0.21
		(0.17)	(0.17)		(0.18)	(0.18)
$L \times \lambda'$		0.14**	0.12		0.12*	0.092
		(0.062)	(0.085)		(0.068)	(0.090)
$C \times \lambda'$			0.040			0.053
			(0.096)			(0.097)
Risk aversion (α)		-0.57***	-0.71***		-0.63***	-0.86***
		(0.12)	(0.13)		(0.15)	(0.17)
$C \times \alpha$		0.12	0.032		0.15	0.032
		(0.099)	(0.11)		(0.091)	(0.087)
$L \times \alpha$			0.23*			0.35**
			(0.14)			(0.14)
Observations	3664	3664	3664	3094	3094	3094
R^2	0.027	0.11	0.12	0.029	0.12	0.13

Standard errors in parenthesis, clustered at the individual level. The first 3 columns use the full sample of borrowers, while the last 3 columns include only those individuals who borrowed in games 2, 3, and 4. An individual is defined to have borrowed in game 2, if he or she chose to borrow in more than 50% of the rounds. See Table 7 for the individual control variables that were included in these regressions but not reported. Round fixed effects are included but not reported. λ' is the group-level social connectedness measure, as described in the text.
*p < 0.10, ** p < 0.05, *** p < 0.01

estimates starts to weaken, as expected. However, in this case, the higher levels of risk aversion significantly boost the effort supply response to joint liability. Moreover, contrary to the predictions of the theoretical model that social connectedness reduces the effect of monetary collateral on effort, the interaction term between the collateral requirement and social collateral is positive and insignificant. This result suggests that monetary collateral does not appear to substitute for social collateral.

The results in columns 1-3 use the data from all participants. However, as discussed in the prior sections, some individuals systematically withdraw from borrowing when new contract terms are imposed. Indeed, the theory above predicts that selection based on imposition of the collateral requirement will be advantageous for the lender, as lower effort types will exit the market. From this perspective, the selection out of borrowing by lower effort types means that the coefficients on collateral terms in columns 1-3 overstate the pure incentive effects of collateral for the fixed group of individuals who borrow under all contracts. To explore this implication of the theory, columns 4-6 replicate the analysis of the first three columns but use the data for only those who borrow in all games. As can be seen, for this subpopulation, collateral has more muted effects, as expected, although the differences are not large.

4.5 Effect on repayments

While the effects of collateral and joint liability on effort diversion are interesting from a theoretical perspective, these numbers are less useful to microfinance practitioners. Lenders are mostly concerned with repayments and may be deterred from lending altogether if expected defaults are sufficiently high. Moreover, increasing repayment rates could also help reduce interest rates in the long run, especially if banks operate in a competitive environment. This, in turn, would increase expected incomes for borrowers and could enhance credit market participation.

To study the effect of collateral on repayments, we use the estimated coefficients and the contract features for each game to simulate expected repayment rates for an average person, with and without the collateral requirement, for different levels of group social collateral (λ')[28]. However, while we preferred a linear model in section 4.4, due to the easier interpretation of the coefficient estimates, we here estimate an ordered probit model (based on the specification in table 8, column 3), as the predicted probabilities can be directly applied to the game structure, allowing us to simulate repayments[29].

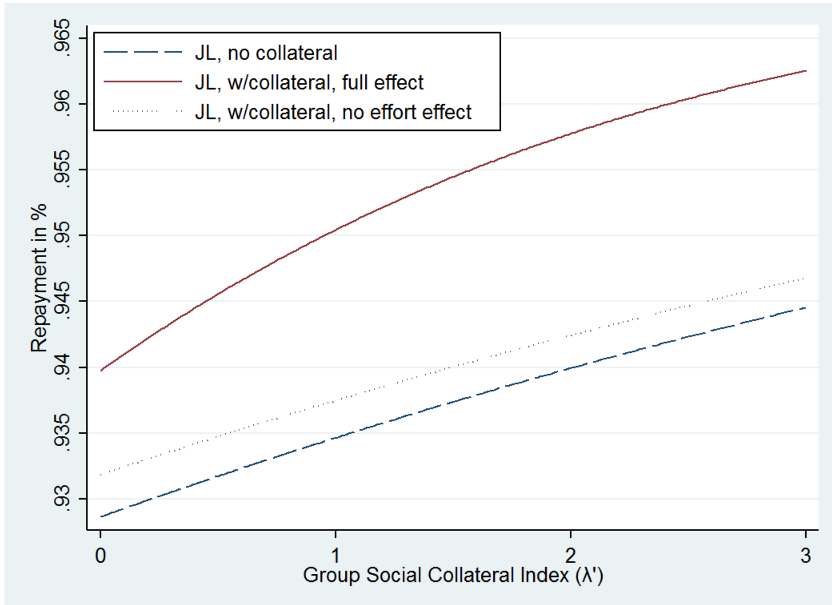
Figure 8 shows how expected repayments vary with the level of social collateral in the group for a joint liability contract without collateral (blue dashed line) and with collateral (red solid line). This graph makes it clear that the collateral requirement indeed increases repayments, and that the order of magnitude is roughly one to two percentage points. While this may seem small, it could potentially have large impacts on an MFI's portfolio at risk. For example, a one-percentage point increase in repayment rates could reduce defaults by as much as 20% if repayment rates are currently around 95%. Furthermore, note that the effect of collateral on repayments is stronger for more socially connected individuals, which is consistent with the results in Table 8.

It is further possible to decompose the total effect of the collateral requirement into a "contract

[28]The obvious way to study the effect on repayments would be to directly estimate model 12 using the repayment status in each round where the participant was creditworthy as the dependent variable. However, since repayments are determined, in large part, by the random draws of each group member, it is a rather noisy signal. Hence, the coefficients from running this regression have larger standard errors, and the only significant coefficient in this regression is joint liability, which has a large positive effect on repayments, as would be expected. These regression results are available from the authors upon request.

[29]The results from estimating this ordered probit model are qualitatively similar to those presented in table 8, in that the sign and significance levels of the coefficients are mostly the same, with a few minor exceptions. The ordered probit results are available upon request.

Figure 8: Simulated repayment rates



effect" and an "incentive effect". The "contract effect" represents the direct impact on repayments due to the transfer of a portion of the liability from the lender to the borrower, but given the same level of effort. This effect is represented by the green dotted line, which shows that only a slightly larger fraction of groups are able to repay as a direct consequence of having a "collateral cushion". The difference between the red solid line and the green dotted line is the "incentive effect", which represents the increase in repayments due to higher induced effort. As is clear from the graph, the incentive effect largely accounts for the increase in repayments due to a collateral requirement.

5 Conclusion

Joint liability group lending has historically been viewed as the holy grail of microfinance, with a plethora of research demonstrating the advantages of joint liability in reducing moral hazard and adverse selection. Yet, several papers have also shown that there are important limitations to the effectiveness of joint liability, and recent empirical evidence has failed to demonstrate a clear advantage of joint liability contracts relative to those relying on individual liability. While some microfinance lenders have taken to requiring collateral that is held against the joint liability, this paper has examined a genuinely hybrid contract in which joint liability is mixed with individual collateral that is forfeited if the individual cannot pay her share of the joint loan.

Theoretically, we demonstrate that the hybrid contract that adds a modest individual collateral to a joint liability contract reduces moral hazard by both increasing the cost of default and by reducing the expected amount that borrowers will have to cover for defaulting group members. In that sense, collateral is acting as both a stick and as a carrot in a joint liability contract. Through a similar mechanism, we also show that adding collateral may have positive selection effects for the lender, in that high-effort people are crowded in due to collateral, while lower-effort people are crowded out. Our analysis of optimal contract terms reveals that some level of individual collateral is preferred by a wide range of borrower types.

We also test the hypotheses from this theoretical model using a framed field experiment in rural Tanzania. Specifically, we find that introducing a modest (20%) monetary collateral requirement to a joint liability contract reduces moral hazard (effort diversion) among borrowers and helps reduce defaults by approximately 15-20%, depending on the level of social connectedness among group members. Moreover, while collateral results in lower credit market participation overall (7%), this effect vanishes for socially well-connected individuals.

Our findings have several important implications both for the welfare of farmers and for microfinance practitioners. First, our findings suggest that MFIs could reduce default rates by introducing a modest individual collateral requirement, specifically in areas where people have sufficient wealth to afford the collateral amount. Second, for a segment of the population, specifically those who are well socially connected or are less risk averse, a collateral requirement is optimal from a social perspective. Third, the reduction is default rates may entice MFIs to expand lending to areas where they otherwise would not lend, thus increasing the welfare of farmers who previously had no access to credit. Finally, while the experimental results assume that the interest rate is exogenous, in reality, lenders will likely reduce interest rates in response to an increase in repayments, particularly in a competitive lending environment. This could help further increase the welfare of farmers.

Finally, while these results were found in a lab-in-the-field setting, we have strong reasons to believe they may also be valid in a real-world setting. First, the process by which borrowers self-selected into the credit groups we used in our sample is similar to that used by most other MFIs, including the Grameen Bank. Second, we show that real-world social connectedness explains choices in the games consistent with theory and results from other empirical studies using survey data, suggesting that game behavior is driven by individual traits. Finally, the characteristics of our sample participants are similar to those of many smallholder farmers in sub-Saharan Africa and other parts of the developing world[30].

[30]While VisionFund Tanzania is a faith-based NGO (Christian), they do not discriminate based on the religion of their borrowers. Hence, the composition of their clients would be similar to that of other non-faith-based MFIs.

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A Appendix

A.1 Numerical simulation results of endogenous interest rates

Figure 9: Effect of collateral under group lending with different levels of social collateral, assuming the interest rate is endogenous

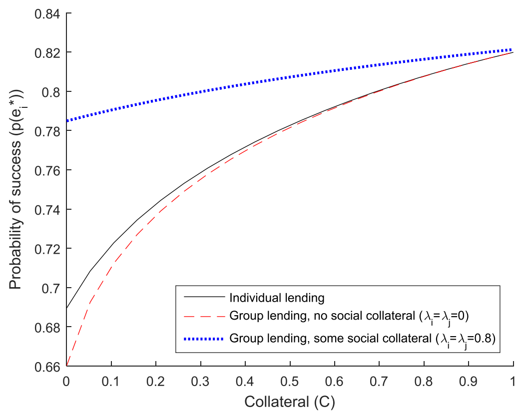


Figure 10: Effect of a 20% collateral requirement on optimal effort under various sets of parameters, assuming the interest rate is endogenous

(a) (b)

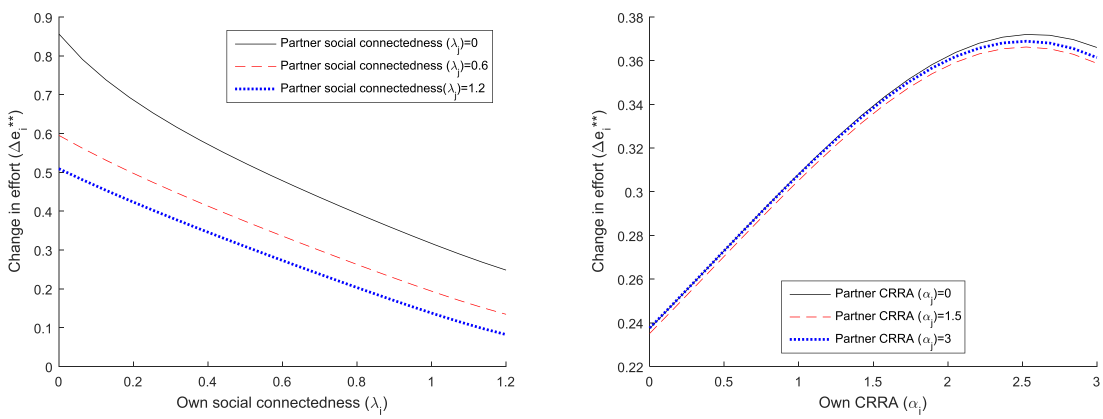
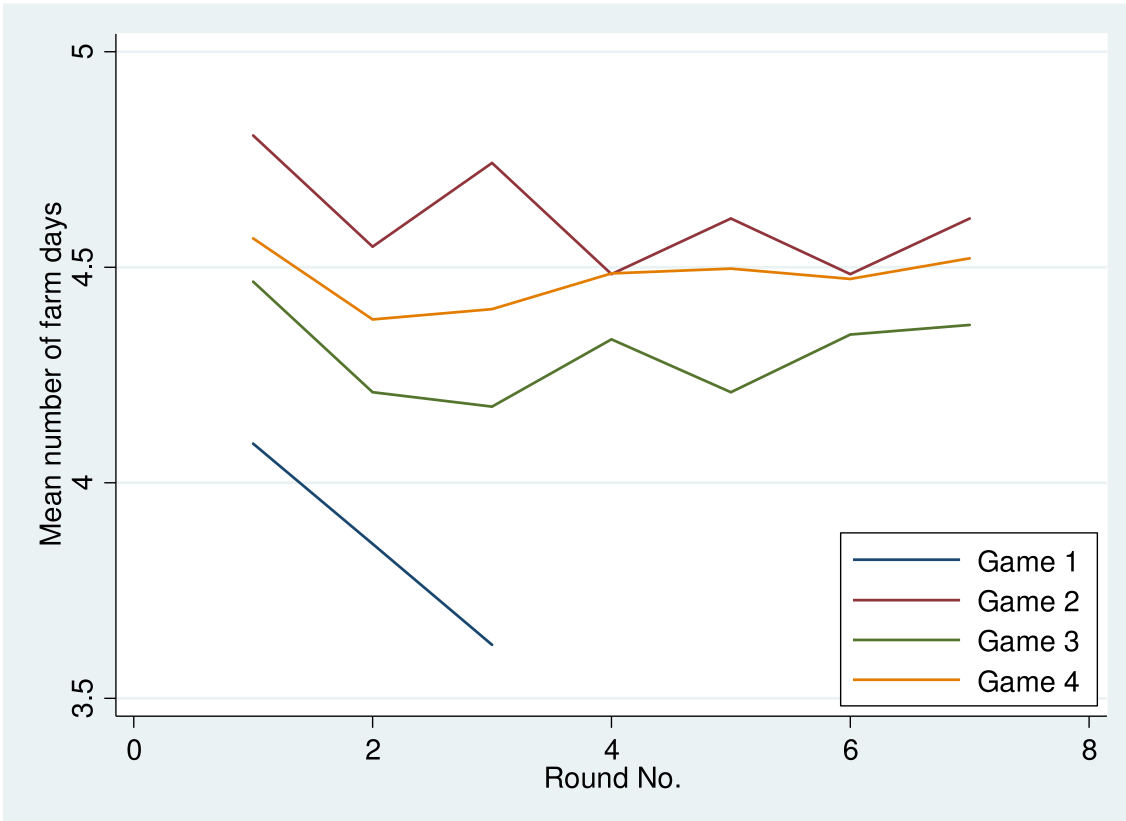


Figure 11: Farm days across rounds by game



A.2 Ordering effects

In order to test for possible ordering effects, we have looked at the average effort level across rounds within the same game. To avoid survival bias, we only included individuals, for whom we observe an effort choice in all possible rounds. In addition to plotting the average number of farm days against rounds (Figure 11), we also regressed the number of farm days on round number to look for any general trends (Table 9). This analysis shows that overall, and for each game, the number of mean farm days does not significantly increase across rounds. The only trend we find is a significant decrease in the number of farm days over the three rounds in game 1. While these results cannot completely rule out an ordering effect, they at least provide some suggestive evidence that participants are not simply increasing their effort level throughout the experiment.

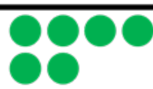
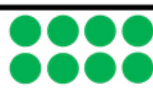
Table 9: OLS Regression of farm days on rounds

	[1]	[2]
Round no.	-0.010	
	(0.0069)	
game=2	0.77***	0.41**
	(0.14)	(0.17)
game=3	0.46***	-0.023
	(0.081)	(0.13)
game=4	0.64***	0.13
	(0.077)	(0.12)
game=1 × Round no.		-0.23***
		(0.054)
game=2 × Round no.		-0.030
		(0.019)
game=3 × Round no.		-2.4e-15
		(0.010)
game=4 × Round no.		0.0050
		(0.0092)
Constant	3.88***	4.33***
	(0.076)	(0.12)
Observations	3394	3394
R^2	0.038	0.043

The depending variable is the number of farm days. Standard errors in parenthesis, clustered at the individual level. The sample is limited to those individuals for whom we observe an effort choice in all possible rounds.

*p $<$ 0.10, ** p $<$ 0.05, *** p $<$ 0.01

A.3 Posterboard

		Sunflower revenue (Tsh):	Net profit after repaying loan (Tsh):	Wage income (Tsh):	Total income (Tsh):
Not borrow:				120,000	120,000
		520,000	280,000	90,000	370,000
		200,000	0	90,000	90,000
		0	0	90,000	90,000
		520,000	280,000	50,000	330,000
		200,000	0	50,000	50,000
		0	0	50,000	50,000
		520,000	280,000	0	280,000
		200,000	0	0	0
		0	0	0	0

A.4 Social networks questions

1. Are any of these people in your closest family (spouse, children, parents)?
2. Are any of these people a close relative (aunt/uncle, cousin, niese/nephew)?
3. Which of these people do you consider to be your close friends?

4. Which of these people have you spoken to in the past week (except for today[31])?
5. Which of these people would you feel comfortable leaving your child with?
6. Which of these people did you NOT know well before joining the credit group?

[31]We included this wording so as not to count people who had spoken to each other only because they were participating in our experiment together. For example, people might have talked to each other merely because they had been seated next to each other in the room.