Using Repayment Data to Test Across Models of Joint Liability Lending

Christian Ahlin and Robert Townsend*

Revised October 2003

Abstract

Various theories have arisen to explain why joint liability group-based lending can be an improvement over traditional individual-based lending. Here we exploit the idea that if a model were true, the repayment rate would vary in a systematic way with various covariates. The paper develops the implications of four representative and oft-cited models of joint liability lending for repayment and derives new ones. The models agree on some dimensions and conflict on others. For example, we find that several models imply that higher correlation of output can raise the observed repayment rate, and in some the ability to act cooperatively leads to lower repayment rates. The empirical part uses survey data from 262 Thai joint liability groups of the Bank for Agriculture and Agricultural Cooperatives (BAAC) and from 2880 households of the same villages. Nonparametric, univariate tests and multivariate logits are used to evaluate the predictions of the models for repayment. We find that the Besley and Coate model stressing unofficial sanctions is strongly supported in the more rural, poorer region of Thailand covered by the data. In the more prosperous region, closer to Bangkok, support is found for the Ghatak model of adverse selection. There is also evidence that cooperation lowers, and correlation raises, repayment rates.

*We thank Francisco Buera, Jonathan Conning, Steve Levitt, Derek Neal, Sombat Sakuntasathien, seminar participants at Chicago, Southern California, Vanderbilt and at NEUDC 2001, ESSFM 2002, the 2002 European Economic Association meetings, and LACEA 2003 for valuable input. Financial support from the National Institute of Health and the National Science Foundation (including its Graduate Research Fellowship Program) is gratefully acknowledged. All errors are ours.

1 Introduction

Joint liability lending is a potential breakthrough strategy in economic development. International conferences and a proliferation of such lending contracts in a wide range of countries are evidence of this. The hope is that this tool will allow credit to be extended to impoverished borrowers lacking physical collateral. For example, without land title, borrowers cannot take out individual loans. The premise of group, joint liability lending is that if one borrower cannot repay a loan, then other members of a joint liability group will do so. This type of contract can be used to lend to new or expanded enterprise. Economic development will follow, or so the story goes.

In turn, various theoretical papers have been written to explore the key mechanism that gives group loans an advantage over individual loans. Specifically, these papers pinpoint conditions under which joint liability contracts are optimal relative to individual liability contracts. But they take different stands on the underlying economic environment and the problem which groups are imagined to try to overcome. These obstacles include moral hazard, monitoring, adverse selection, and limited enforcement, among others. Thus we have in hand a variety of logical possibilities that might account for the use of joint liability contracts.

The empirical side of research in joint liability lending has lagged relatively far behind. A few evaluation studies do exist. They offer mixed results. More to the point, there is little empirical work that views the data through the lens of theory.[1] This paper attempts bridge the gap between the theoretical and empirical work.

Our approach, naturally enough, is to use the explicit structure suggested by the different models to distinguish them in the data. Specifically, we use as springboards to the data four unique and widely cited papers. Two of these papers highlight moral hazard problems which joint liability lending and monitoring can mitigate: Stiglitz (1990) and Banerjee, Besley, and Guinnane (1994). One focuses on an environment of limited contract enforcement and the remedy of village sanctions: Besley and Coate (1995). The fourth shows how adverse selection of borrowers can be partially overcome by joint liability contracts: Ghatak (1999).

All four models are rich in predictions regarding the determinants of the group repayment rate. We examine the predictions both of variables already included in the models as published, and also with variables we can introduce in a general way. For example, the interest rate is a key variable in all four models, while loan size appears only in one, and correlation of borrower output appears in none. In our approach, we introduce loan size and correlation into the models where this can be done with generality, and then explore the effects of all three variables on repayment rates. Other variables considered in some if not all the models, or introduced in this paper, include borrower productivity, screening ability, the ease of monitoring, the degree of cooperation, the availability of outside additional credit, and penalties for default. In considering repayment predictions, we discard the lender's zero-profit condition imposed in all of the models except Besley and Coate. The reason has to do with the lending institution in our data, discussed in more detail in section 2.1.

Our findings offer general support for the four types of models under consideration: human capital increases repayment and there is some evidence that a higher interest rate decreases repayment. More interesting perhaps are the findings that distinguish the models. The screening model of Ghatak does best in the wealthier, central region in the prediction that the level of the joint liability payment will decrease repayment, the loan size has a positive, then negative effect on repayment, and that covariability in borrower outcomes will increase repayment. The limited enforcement model of Besley and Coate does best in the poorer Northeast in its prediction that village penalties will increase repayment. (This appears to be the first strong evidence for village-level sanctions as a force for repayment.) The results on cooperation support in part the prediction of Banerjee et al and Besley and Coate that repayments should decrease with cooperation. The greater the amount of sharing, and to a lesser degree the higher is the fraction of family-related members, in a group, the lower are repayment rates. This result should serve to challenge, or refine, the notion that groups succeed because of their ability to access and make use of social collateral.

Indeed the paper can be viewed as a critique of the presumed premise that there is a unified force, invariate over regions or customers, that can be captured in a fixed formula by altruistic, or profit maximizing, lenders. Instead policy advice on the targeting of lending would need to be informed by the interaction of theory with data that we propose here.

Again, most of the literature focuses on conditions under which joint liability contracts are optimal relative to individual liability contracts, typically with an endogenous, market-clearing interest rate. For example, in Stiglitz (1990) and in Ghatak (1999), an increase in the degree of joint liability allows profit-maximizing lenders to lower the interest rate and induce safer project choice or draw in safer borrowers. In a competitive equilibrium, lenders still make zero profits but borrower welfare is enhanced through joint liability. Direct tests involve relating the prevalence of joint liability versus individual liability contracts or other outside options against the covariates suggested by the models. In a companion paper, Ahlin and Townsend (2003), we use this direct approach to test predictions of Holmström and Milgrom (1990), the related Prescott and Townsend (2002), and Ghatak (1999). We find, consistent with the theory, that intra-village wealth heterogeneity predicts group, joint liability contracts, and further that there is a U-shaped relationship of group borrowing with household wealth. We also find strong evidence for adverse selection, and distinguish this finding from one for moral hazard. Curiously, we do not find that positive correlation in project returns is a force for individual, relative performance contracts, but that it does positively predict group contracts relative to all other options.

In this paper we adopt an indirect, but equally telling, approach. Specifically, we test the models' implications for borrower repayment rates, *given* the joint liability contract is in use. This exploits the idea that if a model were true, the repayment rate would vary in a systematic way with various covariates. We thus use observed repayment rates as the key dependent variable. The probability of repayment plays a fundamental role in each model's setup and results, and is therefore a useful key for unlocking and examining the mechanics of each of the models. We therefore turn our attention from contract choice per se to those internal mechanics. That is, in this paper we take as given that joint liability contracts are optimal and are what we observe, and focus on the models' implications for repayment.

Apart from choice of contract, there is also the decision of the agents whether or not to borrow at all, and if so, with whom and how much. Three of the four models do not deal at all with selection of agents into borrowing groups or loan size. An important exception is the Ghatak model, where agents choose between borrowing and an outside alternative. While the original model does not allow loan size to vary, here we extend it by allowing loan size to be determined in part by borrower choice.

Though tempted, we do not try other major innovations on the model front. That is, we accept for now that the current models have their limitations or shortcomings. For example, the models are static and involve borrowing groups of fixed size (two). Our goal here instead is to evaluate these current, widely-used theories by a confrontation with the data. Hopefully the insights provided can be used in future research, including the construction of revised models.

2 Overview

2.1 Background on the BAAC

The Bank for Agriculture and Agricultural Cooperatives is a government-operated development bank in Thailand. It was established in l966 and is the primary formal financial institution serving rural households. By its own estimates, it serves 4.88 million farm families, in a country with just over sixty million inhabitants, about eighty percent of which live in rural areas. In the data here, BAAC loans constitute 34.3% of the total number of loans, but we include in this total loans and reciprocal gift giving from friends, relatives, and moneylenders (see Kaboski and Townsend 1998). Indeed, commercial banks in the sample here have only 3.4% of total loans, and provide loans to only about 6% of the household sample. Occasionally a village will have established a local financial institution, but typically these are small and constitute on average only 12.8% of total loans. Informal loans, though 39.4% of the total, are also small in size.

The point then is that the BAAC faces little competition from other financial intermediaries, especially those capable of generating large loans. It is thus not realistic or desirable to impose a zero profit constraint as if markets were in competitive equilibrium. Many BAAC branches do not make profits, that is, cannot and do not adjust their lending to the local environment and the local clients. Indeed the BAAC as a whole receives a non-trivial government subsidy.

The point is two-fold. First, we see little variation in interest rates across the joint liability groups of our sample. There is an exogenous, pre-specified, unified national schedule mapping loan size into interest rates. For example in l997, at the time the data used here were collected, all loans under 60,000 baht carried a 9% interest rate, while loans between 60,000 baht and 1,000,000 baht charged 12.25% interest rates. Thus, except for the highest loan amounts and any exceptions to the policy, we should see virtually no variation.

The second point is that in this regulated context, though competing for deposits, the BAAC charges low, below-market interest rates on its loans. Its subsidy dependency index of 35%, as estimated by Yaron (Townsend and Yaron 2001), is the amount that would be necessary to raise the average on-lending rate in order to break even. That is, under its charter the BAAC is responsible for the well-being of farmers and those in rural areas, and it carries out that responsibility by charging a lower interest rate to small clients. Note that is the opposite of what one might have anticipated – smaller loans must surely be more costly to administer and hence should carry higher rates.

We are thus dealing with a bank that does not attempt to break even by adjusting interest rates based on risk or other group and location specifics. Interestingly, the BAAC interest rate policy was changed subsequent to the collection of our data, after the Asian crisis and with the advice of outside agencies. The changes specify higher rates for riskier borrowers according to a formula based on the number of past defaults. The latter would make interest rates a monotone increasing function of default, rather than having defaults increasing with the interest rates, as predicted by all the models here. That is, one could not identify from the positive association of interest and defaults either of these two scenarios. But note again that this new policy was implemented well after the data we use were collected. Juxtaposition of the more recent policy with the old, initial policy only reaffirms the peculiar, if exogenous, nature of the latter. Further, to be safe we weight the lowest rate much more than the highest rate in the group when constructing a group average interest rate – the highest rate very well may reflect a previous penalty.

Loan size is determined in part by BAAC policy as well. Initial loans are small. Farmers work their way up the ladder toward larger loans as they gain seniority, so to speak. The BAAC sets the maximum loan size for any farmer to an estimated 60% of the revenue sale of crop, though of course farmers are free to borrow less. This can dramatically limit loan size for subsistence farmers and those who eat much of their crop. Thus it is plausible that much of the sample is credit-constrained in the usual sense. Loans can also be larger if the government has targeted a particular area for expansion, or if the government wishes to be lenient to those experiencing adverse events (see Townsend and Yaron 2001 for examples). The point then is that there is some exogenous policy variation in loan size across borrowers groups. On the other hand loans can depend on credit officer assessment of the client and on good repayment histories (a feature not found in the theory we test). Loan size would then increase with assessed safety, and hence decrease with the observed, ex post probability of default. This potential property of the data would make it hard to provide convincing support for a (different) theory predicting that higher loan sizes raise repayment rates, but would leave open the possibility of convincing evidence for theories predicting the opposite.

The BAAC requires some kind of collateral for all loans, but it allows smaller loans to be backed with social collateral in the form of joint liability. Thus loans underwritten by a BAAC group do not in principle require land or other physical collateral, only the promise that individual members be jointly liable. Loans larger than 50,000 baht must be backed by an asset such as land. Any particular loan is classified as a group-guaranteed or individual loan, and the appropriate collateral box checked off on the loan form. In practice, however, the BAAC asks about individual landholdings and may even require the deed for "safekeeping". Indeed, the BAAC will give a farmer two to three opportunities to repay before restricting loans to that farmer, and ultimately to the rest of the group. Legal proceedings can be implemented as well, against the defaulting member or other members of the group. Thus repayment by some members for other members may be seen as a last resort and the likelihood that the group will have to pay rather than the defaulting member is seemingly mitigated by that member's landholdings. We can thus take the degree of joint liability to be proportional to the fraction of the group which are landless.[2]

We emphasize that the BAAC is not a universal bank. BAAC clients are more educated and wealthier than the typical rural household for example, particularly so for those taking out individual loans. However, this paper does not seek to explain among all rural households of the sample who borrows and who does not. We also leave aside almost entirely decisions about whether to borrow from the BAAC as an individual or with a group (decisions examined in Ahlin and Townsend 2003), and whether to borrow from commercial banks or other lenders instead of or in addition to the BAAC. Rather, with one exception, this paper follows the models in taking as given the selection of some of the rural population into BAAC groups and then focusing on the potential inner workings of those groups themselves. The major exception is our examination of Ghatak's adverse selection model, with its implication that group members are more risky than those who take the outside option.

2.2 Overview of theories and the empirical strategy

The key to understanding each of the four types of models is, naturally enough, the derivation of the probability that the group will repay its loan, or equivalently, the residual probability that the group will default. This is also the probability as a function of observables of whether a particular group in our sample would have defaulted on its obligations to the outside lender, the BAAC. The determinants of these repayment rates differ rather radically across the models.

Stiglitz (1990) is representative of moral hazard models. That is, the agents in a joint liability group receive a loan and then take an action which determines repayment, an action that is not seen by the outside lender. In Stiglitz that action is the choice of the riskiness of the investment project financed with the loan. A conflict of interest arises, because the borrower only pays off the loan when the project succeeds. This gives the agent a greater incentive to choose risky projects. But in a joint liability group, the borrower with a successful project may have to repay another member's loan, if another member has a failed project. This causes each member to care a little more about the safety of projects chosen. Specifically one enumerates the utility consequences of members jointly choosing safe or risky projects and derives an indicator function for the choice of safe projects. A so-called Switch Line characterizes the locus of indifference. That indicator function, or Switch Line, is the key determinant of repayment rates.

Banerjee, Besley, and Guinnane (1994, hereafter BBG) is representative of how costly monitoring may help to overcome the same moral hazard problem. More precisely, costly verification of actions is necessary to implement penalties. The conflict of interest between a borrowing member and the outside lender falls on the second monitoring member who is otherwise responsible for paying off the loan. More precisely, at an increasing cost of effort, the monitoring member can inflict yet higher penalties on the borrowing member in the event of default, giving the borrowing member an incentive to choose a safer project. On the margin, with the incentive thus internalized, the marginal cost of increased monitoring is equated to the marginal benefit of increased monitoring, namely the decreased likelihood of facing the joint liability payment at the endogenously chosen level of project risk. This first order condition or Monitoring Equation is the key to the characterization of repayment rates.

Ghatak (1999) is representative of models with an adverse selection problem. Again, investment projects differ in their likelihoods of success, but an agent here cannot choose his project type. That is, some agents are inherently more risky than others, but the outside lender cannot discern who is who. Thus a common interest rate will have to cover (at a given outside subsidy) the overall level of risk in the pool of borrowers, with high risk borrowers in effect cross-subsidized by safer ones. In fact with an outside, if low, return option, safe borrowers will drop out of the pool, leaving an otherwise riskier overall set, and in Ghatak, a higher equilibrium rate is the result. In this context, local knowledge about the characteristics of other borrowers and joint liability gives each member an incentive to match with a similar risk type. As Ghatak shows, this would allow a lower interest rate. Here though we focus on the selection equation which determines the cut-off risk type, below which safe potential borrowers choose the outside option and do not participate. The repayment rate of any particular group is, in so far as the lender or econometrician is concerned, the average across risk types of those left in the borrowing pool. This Selection Equation then is the key to characterizing the model's implications for observed default as a function of observables.

The Besley and Coate (1995, hereafter BC) model of strategic default or limited enforcement is distinctly different from the others in that there is no moral hazard and no adverse selection problem. Rather, joint liability members are endowed with a uniform risky project financed with loans. Further, while each other model assumes repayment always occurs if the borrower's project is successful, in BC borrowers choose whether or not to repay based on ex post project outcomes. Here the incentive to repay depends on the outcome of other group members and on presumed official and unofficial penalties for default. Both types of penalties are assumed increasing in project outcome. Thus can one partition the space of joint project outcomes with a Default Curve, below which the group will opt not to repay. This is the key to repayment in the model; that is, the probability of repayment is the likelihood that project outcomes fall in the region above the curve.

The Switch Line in Stiglitz, the Monitoring Equation in BBG, the Selection Equation in Ghatak, and the Default Curve in BC are thus the sources of restrictions on the data. For example in Stiglitz one can characterize how the Switch Line, or point of indifference in project choice, will move with observables such as the interest rate, loan size, and joint liability payment. That is, a change in the interest rate will be associated with a change in the utility return from choosing the safe project, and similarly for the risky project, and the movement in the difference in utilities between these two will move the point of indifference. Thus the key to whether increasing interest rates will raise or lower the repayment rates, ceteris paribus, lies in the derivative of a utility difference. We show in fact that the derivative with respect to the interest rate, can be signed uniformly negatively under mild, non-parametric restrictions, for example, that utility be concave and that both projects have expected returns that are concave in the amount of capital loaned. The order of magnitude of the (negative) derivative can vary however, so there should be no presumption at this level that the frequency of repayment rates should fall uniformly, that is, linearly with the interest rate. Likewise, the derivative depends non-parametrically not only on preferences and technology but also on other variables, such as loan size and joint liability payment. Repayment probabilities are not linearly additive in the covariates given the structure of the model.

We take some liberty in modifying the models when this can be done with minimal assumptions, in order to test unexamined dimensions. In the Stiglitz model, for example, one can sign the effect on repayment of a certain zero-one conceptual experiment, of allowing joint liability borrowers to play non-cooperatively.[3] The requirement that joint project choices be a Nash equilibrium among borrowers places an additional term in the equation of indifference. Indeed we show it pushes the project Switch Line downward, so that risky projects would be chosen more often, ceteris paribus. One can also introduce productivity differences across groups. On the assumption that the production function can be decomposed multiplicatively into a piece related to the risk factor and a piece related to productive inputs, say loaned capital and human capital, we are able to sign the derivative of the utility difference with respect to human capital. Similarly, one can allow project returns to be correlated, parameterize the degree of that correlation, take a derivative, and determine that correlation in returns actually increases the likelihood of repayment.

This same strategy is applied to the other models. In BBG the riskiness of the project is determined by the Monitoring Equation. Thus we can see how riskiness will change with movement in the joint liability payment, for example, by totally differentiating that equation with respect to both the probability of success, call it p, and the degree of joint liability, call it q. Increasing q increases the benefit of monitoring without affecting the cost of monitoring, that is, of implementing a given project choice. Thus repayment rates are increasing in q. Increasing the interest rate r, however, leaves the benefit of monitoring unchanged while increasing the cost of monitoring. That is, more monitoring effort must be exerted to enforce a given project choice, since the higher interest rate skews the borrower's incentives toward risky choices. Repayment rates thus decrease with r. For both of these results, it is sufficient to assume that the cost of monitoring is convex, that the expected project return is concave in p, and that the expected return is increasing in p at a rate which is less than the interest rate, so that the borrower is tempted to take a risky project.

Similarly, in BC the Nash equilibrium of the repayment game determines the critical values of income from the project returns, which determine whether the group will pay off their loans. These critical values form the Default Curve in the space of joint project returns. Below the Default Curve, the cost of repayment, the interest rate, is higher than the benefit, avoiding official and unofficial penalties. Conversely, above the Default Curve, repayment does happen because increased penalties mean benefits of repaying are higher than costs. Thus the probability of repayment is moved up or down by variation in interest rates, in official and unofficial penalties, and in the ability to play cooperatively, since these all shift the Default Curve. It is also affected by productivity differences and correlation across project returns, which leave the Default Curve unaffected but shift the probability mass enclosed by it.

In Ghatak, one differentiates with respect to covariates such as the interest rate the critical cutoff probability that determines the pool of residual risky borrowers. The average risk in the residual pool, which determines the expected repayment rate of the group we observe, moves in the same direction as the cutoff probability that determines the pool.

Table 2.2a summarizes the results of this exercise; the details are contained in section 3. As is evident, some of the predictions are common across the models. Increased interest rates lower the probability of repayment, and increased productivity raises that probability, for example. If any of the models are to have some validity, these should be found in the data. There are also implications that are peculiar to specific models. An increased cost of monitoring lowers the repayment rate in BBG, for example. Similarly, increased unofficial penalties and an enhanced possibility for screening raise the probability of repayment in the BC and Ghatak models, respectively. Each of these can seen as a crucial test of these models, separately.

We emphasize however the lines in Table 2.2a which reveal sign reversals across the

Table 2.2a - Repayment Implications

Entries with a '‡' are the result of our own extensions of the authors' original models.

Variable	Effect on Repayment			
	Stiglitz	BBG	BC	Ghatak
interest rate r	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
loan size L	$\downarrow$	$\downarrow^{\ddagger}$	no pred.	$\nearrow\searrow^{\ddagger}$
liability payment q	$\downarrow^{a}$	$\uparrow$	no pred.	$\downarrow$
productivity H	$\uparrow^{\ddagger}$	$\uparrow^{\ddagger}$	$\uparrow^{\ddagger}$	$\uparrow^{\ddagger}$
screening	no pred.	no pred.	no pred.	$\uparrow$
positive correlation	$\uparrow^{\ddagger b}$	no pred.	$\downarrow^{\ddagger}$	$\uparrow^{\ddagger}$
cost of monitoring	no pred.	$\downarrow$	no pred.	no pred.
cooperative behavior	$\uparrow^{\ddagger}$	$\downarrow^{\ddagger c}$	$\downarrow^{\ddagger d}$	—
outside credit options	$\downarrow^{\ddagger e}$	$\downarrow^{\ddagger}$	no pred.	no pred.
official penalties	no pred.	no pred.	$\uparrow$	no pred.
unofficial penalties	no pred.	no pred.	$\uparrow$	no pred.

[a] Under assumption A3, section 3.1

[b] All correlation results rely on general, symmetric parametrizations of the correlation.

[c] If $M'(c) \leq 1$.

[d] If $c_u(Y, \Lambda) \geq \Lambda$.

[e] The outside credit results assume some similarity between primary and outside lenders.

models. An increased joint liability payment increases repayment in BBG, for example, but decreases repayment in Ghatak. The intuition is that increased joint liability raises the marginal benefit of monitoring in the BBG model, making increased monitoring and reduced risk worth while. But in Ghatak an increase in the joint liability payment makes borrowers pay more on average, at a given interest rate. This makes the outside option more attractive, increasing the risk of the residual pool. Likewise, cooperative behavior increases repayment in the Stiglitz model but lowers repayment in BBG and BC. Under moral hazard, Nash non-cooperative behavior makes it harder for members jointly to choose the safe project. But under costly enforcement, ex ante cooperative agreements can mitigate the threat that especially severe unofficial penalties will be implemented ex post, making default more likely.

Our empirical strategy thus focuses on testing in various ways whether or not the particular covariates, vector $X = (X_1, ..., X_j, ..., X_M)$, move monotonically with repayment history R. As noted, the key objects coming from the theories are the probabilities of repayment for group g[4] as functions of covariates, $P(R^g = 1|X^g)$.[5] A different approach from this paper's would be to test across the models using maximum likelihood estimation. That is, one could parameterize preferences, utility functions, the distributions of shocks, the values of project risk, and so on, then maximize the likelihoods for each model separately by choice of these parameters. One attractive feature of this approach is that the likelihoods for each model are identical up to the function $P(R = 1|X)$:

$$\prod_{g=1}^{G} P(R^g = 1|X^g)^{R^g}[1 - P(R^g = 1|X^g)]^{1-R^g}. \quad (1)$$

Note[6] however that the sign restrictions inherent to each model would be loaded automatically into the probabilities and in a sense forced onto the data. Though it would be possible to compare likelihoods across non-nested models as in Vuong (1989), for example, we prefer here to get a direct look at the monotonicities as predicted by the models.

Our first approach to testing the monotonicity predictions is the most structural. It involves making two simplifying assumptions on the models themselves. First we assume that for each model, $P(R^g = 1|X^g)$ can be written as a function $P(\beta' X^g)$, where β is an $Mx1$ vector of parameters and X^g is an $Mx1$ vector containing group g's values for the M covariates. Clearly this restricts the covariates to enter repayment probabilities as a linear combination while leaving the function P unrestricted. This is the single-index model, studied by Ichimura (1993) among others, and potentially computationally complex to estimate. Our second assumption is that $P = \Lambda$, that is the probability function is logistic. This is the logit model, easily estimated by maximum likelihood. Of course, since our data on repayment R are binary-valued, expected repayment equals the probability of repayment – $E(R^g|X^g) = 1 * P(R^g = 1|X^g) + 0 * P(R^g = 0|X^g)$ – and so we are finding the covariates which make for expected repayment.

The second, bivariate approach is the least structural – namely a simple test of means. We order each of the covariates X_j in the data X_j^g across groups g from low to high, pick an intermediate cutoff value, say $\hat{X}_j$, and then test whether the means of the repayment variable are significantly different across groups with values above and below $\hat{X}_j$, and if so with what sign. For robustness, we move the cutoff value across the ordered domain from low to high, forming all possible two-bin partitions, with the requirement that we have a minimal sample size in each bin and that we do not put into separate bins observations that have equal values for the covariate. The latter requirement is especially necessary for discrete-valued covariates, such as indices of sharing within the group.

The third approach is also bivariate and flexible: locally linear non-parametric regressions (see Cleveland 1979 and Fan 1992). These regressions calculate an expected repayment rate at each value X_j^g of the covariate X_j using only the 80% of the sample closest to X_j^g. That is, with a local neighborhood centered at a value in the domain of the covariate, with a width large enough to capture 80% of the sample, we compute fitted values from a weighted least squares regression, using the tri-cube weighting function (see Cleveland 1979). The conditional expected values are plotted in figures with bootstrap standard error bands.

In many instances, the two univariate approaches, tests of means and locally linear regressions, are consistent with the multivariate logits. However, this is not the case for all variables. To sort these cases out, our final approach involves the same locally linear regressions, but with linear multivariate controls. That is, we assume a partially linear model – where all regressors but one affect p linearly, and the remaining regressor's effect can take any smooth shape. We estimate this model using Yatchew's (1998) differencing method for estimating and removing the linear regressors' effects, then using the local linear regression to plot the residual relationship. Almost without exception, these tests confirm the results of the multivariate, logit specification.

3 Theories and Implications

In this section we turn to the specific setups of the four models and demonstrate their repayment implications. We adopt common notation wherever possible. All the models have in common that there are two members of the single group considered, and the framework is always static. Both members of a group face the same contract terms.[7] Three of the models restrict attention to binomial output distributions, while the fourth, BC, allows for more general distributions.

3.1 Moral Hazard: Stiglitz 1990

Stiglitz shows how joint liability lending can alleviate the moral hazard issues involved in lending to those with no collateral, and thus limited liability. In this context, when project choice is unobservable the borrower has incentives to choose a high-risk project, since this lowers expected interest payments. Joint liability can increase group incentives for safe project choice by making a borrower willing to encourage a partner to choose a safer technology. There is a drawback though: joint liability contracts introduce greater variance in payoffs than would be observed under individual liability. Stiglitz shows in his main result that this effect is second-order and there is some positive degree of joint liability that increases borrower welfare, holding lender profits constant.

In this section we justify the basic predictions of the Stiglitz model for repayment contained in column one of table 2.2. Each borrower receives a loan L and chooses a risky or safe project, producing output $Y(p_R, L)$ with probability p_R or $Y(p_S, L)$ with probability p_S, respectively. The complementary probabilities result in zero output. By assumption, $0 < p_R < p_S < 1$, and the safe project gives higher expected output:

$$p_S Y(p_S, L) > p_R Y(p_R, L). \tag{A1}$$

The lender is implicitly assumed able to observe success or failure of a project, but not project choice or the amount of output.[8] Further, the lender can recover nothing from a borrower that fails. Assuming repayments are linear in loan size, any permissible contract can thus be characterized by an amount rL paid by a borrower upon success, and an additional amount qL paid by that borrower upon his own success and his partner's failure. Let U be utility of consumption, strictly increasing and concave, and twice continuously differentiable. Normalize $U(0) \equiv 0$. Expected utility of a borrower who chooses technology i and whose partner chooses technology j, call it V_{ij}, can be written (under independent returns):

$$V_{ij}(r, L, q) = p_i p_j U[Y(p_i, L) - rL] + p_i(1 - p_j)U[Y(p_i, L) - rL - qL] - v(L),\ i, j \in \{R, S\}. \tag{2}$$

The first term represents the expected payoff from both borrowers succeeding, while the second represents the expected payoff from borrower i succeeding and borrower j failing. The third term represents the effort cost as a function of L.

The ability of the two borrowers to make a binding agreement on project choice is seen as key to mitigating the moral hazard problem. Restricting attention to symmetric choices, the pair will choose safe projects if and only if this gives them each higher expected utility. Each borrower thus chooses a project with success rate

$$p = p_R + (p_S - p_R)1\{V_{SS}(r, L, q) \geq V_{RR}(r, L, q)\}, \tag{3}$$

where $1\{\cdot\}$ represents the indicator function. This equation makes clear that if $\partial V_{SS}/\partial X > \partial V_{RR}/\partial X$ for some parameter X, then the repayment rate p is increasing in X, in the sense that there may exist a cutoff value for X above (below) which safe (risky) projects are chosen. This is the basis for our strategy for determining effects on repayment.

The paper uses a graphical representation called the "**Switch Line**", a (typically non-linear) curve along which borrowers are indifferent between safe and risky projects. Along the Switch Line, it must be that $V_{SS} = V_{RR}$; equivalently, using equation 2,

$$\begin{aligned} p_S^2 U[Y(p_S, L) - rL] + p_S(1 - p_S)U[Y(p_S, L) - rL - qL] = \\ p_R^2 U[Y(p_R, L) - rL] + p_R(1 - p_R)U[Y(p_R, L) - rL - qL]. \end{aligned} \tag{4}$$

Figure 1 pictures the Switch Line in (r, L) space, under the premise that both higher loan sizes and higher interest rates make risky projects more attractive relative to safe.[9]

If equation 4 is to be satisfied, it must be true that

$$Y(p_R, L) > Y(p_S, L). \tag{A2}$$

That is, a risky project must deliver more when successful than a safe one. Otherwise it has no redeeming feature in comparison.[10] This assumption leads easily to the following lemma, important for later repayment results:

Lemma 1. *Under assumption A2, $U'[Y(p_S, L) - rL - qL] > U'[Y(p_R, L) - rL - qL]$, for any $q \geq 0$.*

Proof: It follows from assumption A2 and the concavity of U.

We will sometimes invoke another substantive assumption when exploring determinants of the repayment rate:

$$p_S(1 - p_S) \geq p_R(1 - p_R). \tag{A3}$$

This ensures that safe projects involve opposite borrower outcomes, and thus payment of qL, more often than risky projects do.[11]

3.1.1 Checking r, L, q, and outside options

Stiglitz further assumes that the expected utility of the risky project increases faster in loaned funds than that of the safe project, at least at $q = 0$:

$$\frac{\partial\{p_S U[Y(p_S, L) - rL]\}}{\partial L} < \frac{\partial\{p_R U[Y(p_R, L) - rL]\}}{\partial L}. \tag{A4}$$

This assumption guarantees that an increase in L increases the relative attractiveness of risky projects, for q small enough.

Proposition 1. *Under assumption A2 and for q small enough, the group repayment rate is lower for groups with higher r. Under assumption A4 and for q small enough, the group repayment rate is lower for groups with higher L or more outside borrowing options (under the same r and q). Under assumptions A2 and A3, the group repayment rate is lower for groups with higher q.*

Proof. For details, see Ahlin and Townsend (2002). It is straightforward to show that $(\partial V_{SS}/\partial r)|_{q=0} < (\partial V_{RR}/\partial r)|_{q=0}$ using lemma 1. Assumption A4 is equivalent to $(\partial V_{SS}/\partial L)_{q=0} < (\partial V_{RR}/\partial L)|_{q=0}$. The continuous differentiability of U makes these inequalities true for q in a neighborhood of zero. Outside borrowing options in general increase L, so the result is the same as long as r and q are the same under the outside lender.[12] Finally, lemma 1 and assumption A3 are sufficient to show that $\partial V_{SS}/\partial q < \partial V_{RR}/\partial q$. ■

The intuition for proposition 1 is that increases in L make risky projects relatively more attractive by assumption A4; and since outside borrowing options simply increase L, the same result applies. Increases in r hurt safe projects relatively more because safe projects lead to paying interest more often and in times of lower output. Finally, since the joint liability payment is paid more often (under assumption A3) and during times of lower income under safe project choice, the safe payoff is hurt more by an increase in q. The r and L results are clear from Figure 1, while the q result would be represented by shifting the Switch Line left as q increases.

3.1.2 Subtracting cooperation

In a departure from the Stiglitz model, assume borrowers cannot mutually enforce technology choices and will both choose safe projects only if neither can gain by deviation to a risky project. Such a Nash equilibrium where both choose safe projects exists when $V_{SS} \geq V_{RS}$. This is a stronger condition than $V_{SS} \geq V_{RR}$ of the cooperative case when $q, L > 0$, since

$$V_{RS} - V_{RR} = p_R(p_S - p_R)\{U[Y(p_R, L) - rL] - U[Y(p_R, L) - (r+q)L] \equiv \Delta(r, L, q) > 0. \quad (5)$$

The non-cooperative repayment probability is, using equation 5,

$$p = p_R + (p_S - p_R)1\{V_{SS}(r, L, q) \geq V_{RS}(r, L, q) = V_{RR}(r, L, q) + \Delta(r, L, q)\}, \quad (6)$$

instead of as in equation 3.

Proposition 2. *The group repayment rate is higher for groups acting cooperatively.*

Proof. Comparing equations 6 and 3 gives that every (r, L, q) leading to $p = p_S$ under non-cooperation leads to $p = p_S$ under non-cooperation, but there are some (r, L, q) combinations leading to $p = p_S$ under cooperation but $p = p_R$ under non-cooperation. ■

Graphically, any (r, L) combination on the cooperative Switch Line satisfies $V_{SS} = V_{RR} < V_{RS}$, and thus leads to $p = p_R$ under non-cooperation. From any such point, r must be lowered to raise $V_{SS} - V_{RR}$ (and lower Δ) so that $V_{SS} \geq V_{RS} = V_{RR} + \Delta$ can hold. Thus the Switch Line for non-cooperative groups is shifted down as compared to the cooperative Switch Line, as in Figure 1, and there is a region of (r, L) space that leads to $p = p_S$ under cooperation and $p = p_R$ under non-cooperation.[13]

3.1.3 Adding borrower productivity

We next examine differences in borrower productivity, writing output as a function of an additional factor, H: $Y(p, L, H)$. We assume output separability:

$$Y(p, L, H) = Y(p, 1, 1)F(L, H), \tag{A5}$$

where $F(1, 1)$ is normalized to one and F is assumed strictly increasing in both arguments. With this assumption, we can show the following.

Proposition 3. *Under assumptions A1, A2, and A5, for q small enough, the group repayment rate is higher for more productive groups (groups with higher H).*

Proof. For details, see Ahlin and Townsend (2002). One can show that $(\partial V_{SS}/\partial H)|_{q=0} > (\partial V_{RR}/\partial H)|_{q=0}$ using lemma 1 and the two assumptions. The continuous differentiability of U makes these inequalities true for q in a neighborhood of zero. ■

This result holds because safe projects have higher expected returns (assumption A1), and thus due to separability (assumption A5), higher expected marginal product in H. In addition, the safe project payoff is augmented in times of lower output than the risky project payoff. Graphically, higher H leads to a higher Switch Line.

3.1.4 Adding correlation

A final modification to the model introduces correlation in borrower output realizations.[14] Let the joint probability distribution for the returns of a borrowing group choosing projects that succeed with probability p_i and p_j be

	j Succeeds (p_j)	j Fails ($1 - p_j$)
i Succeeds (p_i)	$p_i p_j + \epsilon$	$p_i(1 - p_j) - \epsilon$
i Fails ($1 - p_i$)	$(1 - p_i)p_j - \epsilon$	$(1 - p_i)(1 - p_j) + \epsilon$

Note that $\epsilon = 0$ is the zero-correlation case assumed thus far. It can be verified that $\epsilon > 0$ implies positive correlation and $\epsilon < 0$ negative correlation.[15] Further, one can show that any joint distribution of output that preserves p_i and p_j, respectively, as the individual probabilities of success, must take this form.[16]

Implicitly, ϵ could in theory be different for each (p_i, p_j) combination. As before, suppose groups make symmetric project choices, either safe or risky. This gives rise to two distributions, with potentially different correlation structures: $\epsilon(p_R, p_R)$ and $\epsilon(p_S, p_S)$. These values need not be the same, if for example there are different degrees of covariance across safe and risky projects. In this section, however, we use assumptions to tie $\epsilon(p_R, p_R)$ and $\epsilon(p_S, p_S)$ to a single underlying parameter that reflects the degree of symmetric correlation. The first variation is the simplest:

$$\epsilon(p, p) = \epsilon, \quad p \in \{p_R, p_S\}. \tag{A6}$$

This adds the same probability mass to the events where both succeed and fail, whether the projects are safe or risky. The second variation is

$$\epsilon(p, p) = \rho * p(1 - p), \quad p \in \{p_R, p_S\}. \tag{A7}$$

Assumption A7 ensures that both the safe and risky joint project distributions have the same *correlation coefficient*, equal to ρ, as straightforward calculation verifies.[17]

Denote the two values for $\epsilon(p_S, p_S)$ and $\epsilon(p_R, p_R)$, ϵ_S and ϵ_R, respectively. Payoffs (gross of the cost of effort) now equal:

$$V_{kk} = (p_k^2 + \epsilon_k)U[Y(p_k, L) - rL] + [p_k(1 - p_k) - \epsilon_k]U[Y(p_k, L) - (r + q)L], \qquad (7)$$

for $k \in \{R, S\}$. The probability of success is still as in equation 3, with V_{SS} and V_{RR} defined in equation 7.

Proposition 4. *Under assumption A2 and the type of covariance expressed in assumption A6, or under assumptions A2 and A3 and the type of covariance expressed in assumption A7, the group repayment rate is higher for groups with higher project return correlation (higher ϵ or ρ).*

Proof. For details, see Ahlin and Townsend (2002). It is easy to show that $(\partial V_{SS}/\partial \epsilon) > (\partial V_{RR}/\partial \epsilon)$ using assumption A2 and the concavity of U. The same can be said of $(\partial V_{SS}/\partial \rho) > (\partial V_{RR}/\partial \rho)$ under the additional assumption A3. ■

The intuition for proposition 4 is that correlation shifts weight from the state in which a borrower is successful and his partner fails to the state in which both borrowers are successful. This shift is more valuable with the safe project, since output is lower and marginal utility higher there. Graphically, groups with higher correlation will have higher Switch Lines. This somewhat surprising result contrasts with the assumptions of the empirical literature, which typically assumes it is bad for repayment. However, this model makes clear that correlation can tilt payoffs in favor of safe projects.

3.2 Moral Hazard: Banerjee, Besley, Guinnane 1994

BBG also focus on the moral hazard problem engendered by lending to borrowers lacking collateral under a limited liability constraint. As in Stiglitz, the borrowers' key choice is whether to engage in risky or safe projects. They tackle a larger question than we are concerned with in this paper, examining cooperatives that can internally lend some of their own funds as well as borrow from an outside source. We modify their model by shutting down internal lending options exogenously (as does the majority of the micro-credit literature) and only consider capital as coming from an outside source.[18] In this section, we present the details of the model crucial to understanding the repayment determinants and justify the basic predictions of the BBG model contained in column two of table 2.2.

BBG consider groups of two risk-neutral agents, in which only one borrows and the other cosigns and monitors. This asymmetry captures the idea that at any given time, only some members of a typical group will want loans, while all members remain liable for these loans. The monitor first chooses a level of (costly) monitoring effort, then the borrower makes his project choice based on the penalty that may be imposed on him. The greater is the monitoring effort, the greater the penalty that can be imposed.

The borrower receives one unit of capital and chooses a project indexed by $p \in [\underline{p}, 1]$, where $\underline{p} > 0$. The project return is $Y(p)$ with probability p and zero otherwise. The lender offers a debt contract, collecting r from the borrower when his project is successful and q from the cosigner otherwise. The borrower's payoff (gross of any penalties) is thus $p[Y(p) - r] = E(p) - pr$, where $E(p) \equiv pY(p)$ is the expected output of project p. It is assumed that

$$0 < E'(p) < r \quad and \quad E''(p) \leq 0. \tag{A8}$$

Assumption A8 guarantees[19] that safer projects have higher expected output. The socially optimal choice is thus the safest project, $p = 1$, since this maximizes expected surplus. However, since $E'(p) < r$, the borrower's payoff $E(p) - pr$ is decreasing in p. So $p = \underline{p}$ is privately optimal. We also assume E twice continuously differentiable.

If the monitor can impose a penalty c, say, then he can implement project choice p if and only if the following incentive constraint is satisfied:

$$E(p) - pr \geq E(\underline{p}) - \underline{p}r - c. \tag{8}$$

The left side is the payoff at p, while the right side is the deviation payoff, which includes setting $p = \underline{p}$ and incurring penalty c. This inequality defines a function $c(p, r)$ which gives the minimum penalty c needed to enforce a given probability of success:

$$c(p, r) = E(\underline{p}) - E(p) + r(p - \underline{p}). \tag{9}$$

Note that $c(\underline{p}, r) = 0$ and

$$c_p(p, r) = r - E'(p), \tag{10}$$

which is strictly positive by assumption A8. Thus the monitor must threaten a higher penalty to enforce a safer project choice.

The monitoring that enables a penalty of c to be inflicted on the borrower costs $M(c)$ to the monitor. We assume M to be strictly increasing and convex, and twice continuously differentiable. The monitor's problem can be written as the choice of p that maximizes payoff

$$(1 - p)(-q) - M[c(p, r)]. \tag{11}$$

This payoff includes the joint liability payment q paid with probability $(1 - p)$ (when the borrower fails), and monitoring costs of implementing p.[20] Maximization of payoff 11 yields the first-order condition

$$q = M'[c(p, r)]c_p(p, r). \tag{12}$$

We call this the **Monitoring Equation**. Here q represents the return to monitoring, since this is the payment that can be saved if the borrower succeeds. The right-hand side represents the costs of monitoring. These are affected both by how costly it is to increase penalties, $M'(c)$, and by how acute the moral hazard problem is, that is, how sharply penalties must increase to induce the borrower to choose a safer project, $c_p(p, r)$.[21] Repayment predictions are derived by totally differentiating the Monitoring Equation with respect to p and the determining factor.

Equation 12 is graphed in Figure 2 (using solid lines and equation 10 for $c_p(p, r)$). The left-hand side is a horizontal line at q. The right-hand side is a strictly increasing, not necessarily linear function that crosses q exactly once. This intersection gives the unique equilibrium p.[22]

3.2.1 Checking r and q

Groups with higher degrees of joint liability q exhibit higher probabilities of repayment p. This effect is represented in Figure 2 by an upward shift of the horizontal line. A higher interest rate r, on the other hand, leads unambiguously to a lower repayment rate p, shifting up the sloped curve in Figure 2. This is because a higher interest rate raises the monitor's marginal cost of increasing p, by tilting borrower incentives further toward risky projects.

Proposition 5. *Under assumption A8, the group repayment rate p is higher for groups with higher joint liability payment q and lower interest rate r.*

Proof. For details, see Ahlin and Townsend (2002). Total differentiation of the Monitoring Equation gives that $\partial p/\partial q = 1/[M''(c)c_p^2 + M'(c)c_{pp}]$, which is strictly positive since M is strictly increasing and convex; $c_p = r - E'(p)$, strictly positive by assumption A8; and $c_{pp} = -E''(p)$, positive by assumption A8. Similar calculations show $\partial p/\partial r = -[M''(c)c_p c_r + M'(c)c_{pr}]/[M''(c)c_p^2 + M'(c)c_{pp}] < 0$. ■

Interestingly, the prediction on q is opposite that of the Stiglitz model (see proposition 1). BBG emphasize the fact that greater liability engenders more intense group pressure to perform well. The joint liability payment creates no adverse incentives since the monitor always is able to make the payment. Stiglitz, on the other hand, accounts for the fact that the joint liability payment is like an additional tax on success, since it is paid only when the borrower who pays it is successful.

3.2.2 Checking cost of monitoring

Cost of monitoring affects repayment probabilities exactly as q does, at least when we consider proportional shifts. Assume that the monitor faces cost of monitoring

$$M(c) \equiv \kappa * m(c), \ \kappa > 0. \tag{A9}$$

Proposition 6. *Under assumptions A8 and A9, the group repayment rate is higher for groups with lower cost of monitoring (lower κ).*

Proof. If one defines $\hat{q}$ as q/κ, then the Monitoring Equation holds with $\hat{q}$ in place of q and m in place of M. Proposition 5 then gives that $\partial p/\partial \hat{q} > 0$ (since m inherits the properties of M). Finally, $d\hat{q}/d\kappa < 0$. ■

3.2.3 Adding L and outside options

Here we let successful output depend on loaned capital L as in Stiglitz. We again rely on assumption A5 of section 3.1.3 to break Y multiplicatively into components relating to probability p and loan size L, modified here to suppress the argument H:

$$Y(p, L) = Y(p, 1)F(L),$$

where $F(1)$ is normalized to 1. We also assume F is strictly increasing and concave, twice continuously differentiable, and $F(0) = 0$. We continue to let $E(p) \equiv pY(p,1)$, so that expected output satisfies

$$pY(p,L) = pY(p,1)F(L) = E(p)F(L). \tag{13}$$

The amount due by the borrower upon success is now rL, while the amount due from the monitor when the borrower fails is qL. The analogue to assumption A8 is now

$$0 < E'(p)F(L) < rL \quad and \quad E''(p) \leq 0. \tag{A10}$$

This ensures that $p = 1$ is socially optimal but $p = \underline{p}$ is privately optimal.[23] The minimum penalty needed to enforce a project choice p is, exactly analogous to equation 9,

$$c(p,r,L) = F(L)[E(\underline{p}) - E(p)] + rL(p - \underline{p}). \tag{14}$$

Finally, the modified Monitoring Equation is

$$qL = M'[c(p,r,L)]c_p(p,r,L). \tag{15}$$

Proposition 7. *Under assumptions A5 and A10, the group repayment rate is lower for groups with higher L or more outside borrowing options (under the same r and q and the same joint liability group).*

Proof: see Appendix A.

Intuitively, a higher loan from the lender has two opposite effects. It increases the monitor's liability and thus his payoff to monitoring. It also increases the expected interest cost to the borrower more than his expected output, giving him greater incentive for risky project choice. The latter effect dominates, leading to lower probability of success. Outside credit options tend to increase L and thus have the same effect.

3.2.4 Adding borrower productivity

Here we introduce an additional factor of production called H, but consider loan size fixed as in previous sections. The amounts owed by borrower and monitor are thus r and q, respectively. As in section 3.2.3, we use assumption A5 of section 3.1.3 to write $pY(p,H) = E(p)G(H)$, where G is assumed strictly increasing and differentiable.

The analogue to assumption A8 is now

$$0 < E'(p)G(H) < r \quad and \quad E''(p) \leq 0. \tag{A11}$$

This ensures that $p = 1$ is socially optimal but $p = \underline{p}$ is privately optimal.[24] The minimum penalty needed to enforce a project choice p is, exactly analogous to equation 9,

$$c(p,r,H) = G(H)[E(\underline{p}) - E(p)] + r(p - \underline{p}). \tag{16}$$

The monitor's first-order condition becomes

$$q = M'[c(p,r,H)]c_p(p,r,H). \tag{17}$$

Proposition 8. *Under assumptions A5 and A11, the group repayment rate is higher the higher is borrower productivity H.*

Proof. For details, see Ahlin and Townsend (2002). Total differentiation of Monitoring Equation 17 and use of equation 16 and assumption A11 give that $\partial p/\partial H = -[M''(c)c_p c_H + M'(c)c_{pH}]/[M''(c)c_p^2 + M'(c)c_{pp}] > 0$. ■

Just as in Stiglitz, higher productivity increases the payoff of safe projects relative to risky projects, because safe projects have higher expected returns (assumption A11), and thus due to separability (assumption A5), higher expected marginal product in H. The moral hazard problem is softened, making monitoring more effective.

3.2.5 Adding cooperation

In this section we assume the monitor and borrower can enforce any joint agreement on project choice *costlessly*, as in Stiglitz. They will thus maximize the sum of payoffs.[25] The problem becomes to choose p in order to maximize

$$E(p) - pr - (1-p)q,$$

the sum of net payoffs of the borrower and monitor. To facilitate comparison with equation 12 of the non-cooperative case, the first order condition can be written

$$q = r - E'(p). \tag{18}$$

Compare this to Monitoring Equation 12, with $c_p(p, r)$ substituted in from equation 10:

$$q = M'[c(p, r)][r - E'(p)]. \tag{19}$$

The comparison evidently hinges on whether $M'(c)$ is greater than or less than one. If it is less than one, the non-cooperative upward sloping curve in Figure 2 is lower than the cooperative one, and the resulting p is higher under non-cooperation.

Proposition 9. *Under assumption A8, the group repayment rate is lower for groups that can cooperate and enforce side-contracts if $M'(c) < 1$ and higher for groups that can enforce side-contracts if $M'(c) > 1$.*

Proof. For details, see Ahlin and Townsend (2002). Using equations 18 and 19, respectively, the cooperative repayment rate satisfies $E'(p) = r - q$, while the non-cooperative repayment rate satisfies $E'(p) = r - q/M'(c)$. The result follows from the concavity of E. ■

The cooperative setup is isomorphic to the non-cooperative case where $M(c) = c$ and thus $M'(c) = 1$. Here the monitor can apply penalties that affect the borrower's payoff at a one-for-one cost to the monitor's own payoff. This results in maximization of joint surplus, just as in the cooperative case. If the marginal cost of penalizing is less than (greater than) one, then the monitor monitors more than (less than) in the surplus-maximizing case, and non-cooperation results in a higher (lower) repayment rate.[26]

This prediction (under $M(c) < 1$) is counter to that of the Stiglitz model, where cooperation enables the group to circumvent free-riding of one member on his partner's safe behavior. Here, non-cooperative behavior brings the monitor to use cheap penalties to enforce a higher probability of repayment than is optimal from the group's perspective. The common idea that social capital leads to better-behaving groups may thus be turned on its head. Lenders may even prefer groups with less social capital if this translates into less ability to collude.

3.3 Strategic Default: Besley, Coate 1995

In BC, project choice is fixed and homogeneous across borrowers, but the lender cannot fully enforce repayment. Borrowers decide whether or not to repay after realizing project returns, by comparing the repayment amount with the severity of penalties imposed by the lender and perhaps the community. BC show that joint liability can increase repayment rates relative to individual liability, but may not in the absence of sufficiently strong social penalties. In this section, we present the details of the model crucial to understanding the repayment determinants and justify the predictions of the BC model contained in column three of table 2.2.

Each borrower takes out a loan and owes a gross interest payment of r. Borrower returns are realized as two independent draws from the distribution defined by $F(Y)$, which is assumed strictly increasing over its support $[0, Y_{max}]$, and then repayment decisions are made non-cooperatively.[27] Joint liability implies that if the lender does not receive the full amount $2r$ from the group, he imposes an *official penalty* of $c^o(Y_i)$ on each borrower $i \in \{1, 2\}$. It is assumed that

$$c^o \textit{ is continuous, strictly increasing, unbounded, and } c^o(Y_i) < Y_i \textit{ when } Y_i > 0. \quad \text{(A12)}$$

In other words, the lender penalizes more severely when output is higher, but never as severely as outright confiscation.

It is useful to define a function

$$\underline{Y}(r) \equiv (c^o)^{-1}(r). \tag{20}$$

By construction, $c^o[\underline{Y}(r)] = r$. Thus for $Y \geq \underline{Y}(r)$, the borrower would repay r rather than incur official penalties, since $c^o(Y) \geq r$. For $Y < \underline{Y}(r)$, the borrower does better keeping r and incurring penalty $c^o(Y)$, since $c^o(Y) < r$. It is not difficult to show that assumption A12 implies $\underline{Y}$ is continuous, strictly increasing, and that $\underline{Y}(r) > r$ when $r > 0$.

There are also unofficial penalties, imposed by the jointly liable borrower and the community on a borrower who decides to default when his partner decides to repay. In particular, the *unofficial penalty* on a delinquent borrower who realized output Y_i and decreased his partner's payoff by Λ_j is $c^u(Y_i, \Lambda_j)$.

$$\Lambda_j \equiv min\{c^o(Y_j) - r, r\} \tag{21}$$

is derived as follows. If j ultimately decides to bail out his partner, he loses r relative to the case where i repaid; if he decides not to repay at all, he saves his own debt of r but loses $c^o(Y_j)$. His loss is just the minimum since he will choose the cheaper option. It is assumed that the the delinquent borrower is punished more the more he lowered his partner's payoff and the more output he realized:

$$c^u(Y_i, \Lambda_j) \text{ is continuous and strictly increasing in } Y_i \text{ and } \Lambda_j, \text{ for } \Lambda_j, Y_i \geq 0. \tag{A13}$$

Further, penalties are not imposed if the output realization was minimal or if the jointly liable borrower was not hurt by his partner's default.

$$If\ \Lambda_j \leq 0 \text{ or } Y_i = 0, \text{ then } c^u(Y_i, \Lambda_j) = 0. \tag{A14}$$

One can define $\hat{\underline{Y}}(r, Y_j)$ (analogously to $\underline{Y}(r)$) as the minimum output level for borrower i to be willing to repay r, given his partner realized output Y_j. It differs from $\underline{Y}(r)$ in that it accounts for *both* official and unofficial penalties. $\hat{\underline{Y}}(r, Y_j)$ is defined implicitly, to satisfy

$$r = c^o(\hat{\underline{Y}}) + c^u[\hat{\underline{Y}}, \Lambda(r, Y_j)]. \tag{22}$$

At $\hat{\underline{Y}}$, it is equally costly to pay r and to suffer official and unofficial penalties. Above $\hat{\underline{Y}}$, official and possibly unofficial penalties increase, making it strictly better to pay r; below $\hat{\underline{Y}}$, the reverse is true. It is not difficult to show that assumptions A13 and A14 imply that $\hat{\underline{Y}}$ is continuous and decreasing in Y_j, strictly so iff $Y_j \in (\underline{Y}(r), \underline{Y}(2r))$ (since $\Lambda_j = c^o(Y_j) - r$ there); and that $\hat{\underline{Y}}(r, Y_j) \leq \underline{Y}(r)$, strictly so iff $Y_j > \underline{Y}(r)$ (since $\Lambda_j > 0$ there).

The subgame perfect equilibrium[28] of the game results in default in two circumstances only: when both borrowers realize $Y_i < \underline{Y}(r)$, $i = 1, 2$, or when one realizes output $Y_j \in [\underline{Y}(r), \underline{Y}(2r))$ and the other $Y_i < \hat{\underline{Y}}(r, Y_j)$. Repayment occurs otherwise. The repayment rate p then equals

$$p = 1 - [F(\underline{Y}(r))]^2 - 2 \int_{\underline{Y}(r)}^{\underline{Y}(2r)} F(\hat{\underline{Y}}(r, Y)) dF(Y). \tag{23}$$

The squared term is the probability that both borrowers realize output below $\underline{Y}(r)$. The integral represents the probability that one borrower realizes $Y \in [\underline{Y}(r), \underline{Y}(2r))$ and the other below $\hat{\underline{Y}}(r, Y)$; the term is multiplied by two to account for the same scenario with the borrowers' identities reversed.

The set of joint output realizations leading to default, the Default Region, is pictured in Figure 3, in which $a \equiv \underline{Y}(r)$, $b \equiv \underline{Y}(2r)$, and Y_{max} is normalized to one. Repayment happens for all joint output realizations in the unit square except those falling in box A and in some parts of the AB boxes. In particular, there is a curve running through the AB boxes and the point (a, a), symmetric about the 45-degree line, below which repayment does not happen (the dashed curve here). This curve represents $\hat{\underline{Y}}(r, Y)$, and thus its placement depends on unofficial penalties; the stronger they are, the lower it is.[29]

3.3.1 Checking r

Equation 23 can be differentiated to see that p decreases with r. Differentiability is not needed, however, as can be seen with the following graphical argument using Figure 3. An increase in r strictly increases $\underline{Y}(r)$ and $\underline{Y}(2r)$ (a and b) on the graph and shifts upward the $\hat{\underline{Y}}$ curves. The new Default Region strictly contains the old one, and thus the probability of default is higher. The intuition is that higher r raises the cost of repayment without affecting (or even lowering, in the relevant range of output) the cost of default.

Proposition 10. *Under assumptions A12, A13, and A14, the group repayment rate is lower for groups with higher r.*

Proof. For details, see Ahlin and Townsend (2002). This follows from the fact that $\underline{Y}$ and $\hat{\underline{Y}}$ are strictly increasing in r (at least in the relevant region for the latter). ■

3.3.2 Checking official and unofficial penalties

Not surprisingly, repayment improves as the severity of either kind of penalty increases. Stiffer penalties raise the cost of default and do not affect the cost of repayment.

Proposition 11. *Under assumptions A12, A13, and A14, the group repayment rate is higher for groups with stronger official or unofficial penalties.*

Proof. For details, see Ahlin and Townsend (2002). It is straightforward to show that stronger official penalties lead to lower $\underline{Y}$ and $\hat{\underline{Y}}$ cutoffs, while stronger unofficial penalties lower $\hat{\underline{Y}}$ cutoffs. ■

Referring to Figure 3, stronger official penalties lower a, b, and the $\hat{\underline{Y}}$ curves. Stronger unofficial penalties leave a and b unchanged but lower the $\hat{\underline{Y}}$ curves. Either way, the new Default Region is strictly contained in the old one, and thus the probability of default is lower.

3.3.3 Checking borrower productivity

As in the other models, more productive groups repay more frequently. Here, higher output raises both kinds of penalties and thus the cost of default, without affecting the cost of repayment r. Consider groups 1 and 2, identical except that output is distributed according to F_1 and F_2, respectively. Let group 2 borrowers' output distribution first-order stochastically dominate that of group 1 borrowers: $F_1(Y) \geq F_2(Y)$ for all Y. Graphically, both groups have the same Default Region, but differ in the probability of falling in this region.

Proposition 12. *Under assumptions A12, A13, and A14, the group repayment rate is higher for more productive groups, where higher productivity means first-order stochastic dominance.*

Proof: see Appendix A.

The intuition of the proof is to transform the problem from physical-output space, in which both groups have the same Default Region but different probability mass assigned to this region, to percentile-output space, over which both groups have the same probability measure. However, the region of default in percentile-output space for group 2 is contained by the region of default for group 1 (and strictly so if $F_1[\underline{Y}(r)] > F_2[\underline{Y}(r)]$).

3.3.4 Adding cooperation

Assume borrowers can costlessly enforce agreements among themselves. Since utility is transferable, they will maximize the sum of payoffs and repay iff

$$c^o(Y_i) + c^o(Y_j) \geq 2r. \tag{24}$$

In words, repayment is optimal exactly when the sum of official penalties is greater than the group's total debt.

An indifference curve in joint output space can be found by rearranging condition 24 at equality and using the definition of $\underline{Y}$ as $(c^o)^{-1}$: $Y_j = \underline{Y}[2r - c^o(Y_i)]$. The indifference curve clearly goes through $(0, \underline{Y}(2r))$, $(\underline{Y}(r), \underline{Y}(r))$, and $(\underline{Y}(2r), 0)$ (respectively, $(0, b)$, (a, a), and $(b, 0)$ in Figure 3). It is strictly decreasing, because c^o is strictly increasing, and symmetric about the 45-degree line due to borrower symmetry. An example (under linear official penalties) is the dash-dotted line in Figure 3. Below this line is the cooperative Default Region. Using the indifference curve equation, the graph, and exploiting borrower symmetry, the cooperative repayment rate, p_c, can be written

$$p_c = 1 - [F(\underline{Y}(r))]^2 - 2\int_{\underline{Y}(r)}^{\underline{Y}(2r)} F[\underline{Y}(2r - c^o(Y))]dF(Y), \tag{25}$$

very similar to equation 23 for the repayment rate without cooperation, call it p_{nc}. Subtracting one from the other gives

$$p_{nc} - p_c = 2\int_{\underline{Y}(r)}^{\underline{Y}(2r)} \{F[\underline{Y}(2r - c^o(Y))] - F[\hat{\underline{Y}}(r, Y)]\}dF(Y). \tag{26}$$

Equation 26 reveals that the effect of cooperation on repayment depends on how severe are the unofficial penalties that cooperation renders unused. If unofficial penalties are severe, the cutoff $\hat{\underline{Y}}(r, Y)$ is low and $p_{nc} > p_c$; and vice versa. An example of the former case is pictured in Figure 3, the dotted curve representing the boundary of the non-cooperative Default Region under severe penalties. But note that this curve drops to $(b, 0)$, which is impossible (as argued in section 3.3). In order to make it possible, we weaken assumption A14 in a benign way:

$$If\ \Lambda \leq 0,\ then\ c^u(Y, \Lambda) = 0. \tag{A15}$$

The sole difference is that under assumption A15, unofficial penalties may be imposed even on a borrower who realizes zero output.[30][31] It thus allows the possibility that the cutoff $\hat{\underline{Y}}(r, Y)$ may reach zero, since even at zero output, unofficial penalties may exceed r.

Proposition 13. *Under assumptions A12, A13, and A15, the group repayment rate is lower for groups acting cooperatively if* $c^u(Y, \Lambda) > \Lambda$ *for all* $Y \geq 0$ *and* $\Lambda > 0$ *and higher for groups acting cooperatively if* $c^u(Y, \Lambda) < \Lambda$ *for all* $Y \geq 0$ *and* $\Lambda > 0$.

Proof. For details, see Ahlin and Townsend (2002). Setting $c^u(Y_i, \Lambda_j) = \Lambda_j = c^o(Y_j) - r$ in equation 22 (which defines $\hat{\underline{Y}}$) gives that $\underline{Y}[2r - c^o(Y_j)] = \hat{\underline{Y}}(r, Y_j)$ for $Y_j \in (\underline{Y}(r), \underline{Y}(2r))$. Thus $p_c = p_{nc}$, from equation 26. Similarly, if $c^u(Y_i, \Lambda_j) > \Lambda_j$, $p_{nc} > p_c$; and the inverse. ■

Thus, very similar to BBG (see section 3.2.5), cooperation decreases repayment if unofficial penalties are severe. Proposition 13 rests on the fact that the cooperative setup is isomorphic to the non-cooperative case where $c^u(Y, \Lambda) = \Lambda$, under which the unofficial punishment for default fits the damage from default exactly. If the penalty is more severe, there are output realizations where the sum of official penalties on the group would be less than $2r$, yet the low-output partner repays to avoid the unofficial penalties. Under cooperation, however, the low-output borrower could instead compensate his partner directly for his loss Λ, leaving some surplus to be split as the group defaults. Again, the common idea that social capital leads to better-behaving groups may thus be turned on its head.

3.3.5 Adding correlation

Finally, we examine how correlation between borrower project returns affects repayment. This is an easier task in the other models, where output takes on one of two values. Here, borrower returns are distributed according to some general distribution function, F. Thus there are a multitude of ways to introduce correlation. We aim for as general an approach as possible.

Recall that the support of F is $[0, Y_{max}]$; here we normalize Y_{max} to 1. Let f be the density associated with F, and assume it is continuous and strictly positive on its support. In the baseline BC model, returns are independent across borrowers and thus the joint density function is $f(Y_i)f(Y_j)$. In this section, we are interested in constructing a generalized joint density function $\phi(Y_i, Y_j)$ that preserves the unconditional output distributions but allows for correlation. The restrictions this places on $\phi(Y_i, Y_j)$ make this a potentially complicated task. To simplify, we first parametrize $\phi(Y_i, Y_j)$ in the following way:

$$\begin{aligned}\phi(Y_i, Y_j) = {} & f(Y_i)f(Y_j)+ \\ & \kappa[g(Y_i, Y_j) - \int_0^1 g(Y_i, Y_j)dY_i - \int_0^1 g(Y_i, Y_j)dY_j + \int_0^1 \int_0^1 g(Y_i, Y_j)dY_i dY_j].\end{aligned} \tag{27}$$

This is a useful parametrization in that it allows us to reframe our choice of $\phi(Y_i, Y_j)$ as a choice of positive integer κ and function $g(Y_i, Y_j)$, which must only satisfy continuity. It is also perfectly general, as we now show.

Lemma 2. *Every continuous joint density $\phi(Y_i, Y_j)$ that preserves f as the unconditional density for Y_i and Y_j can be written as in equation 27 for some continuous function $g(Y_i, Y_j)$ and some integer κ arbitrarily close to zero. Every continuous function $g(Y_i, Y_j)$ generates, through equation 27, for κ close enough to zero, a continuous joint density $\phi(Y_i, Y_j)$ that preserves f as the unconditional density for Y_i and Y_j.*

Proof: see Appendix A.

This lemma thus allows us to parametrize $\phi(Y_i, Y_j)$ without loss of generality and to generate all permissible such joint densities. For ease of exposition, define

$$\gamma(Y_i, Y_j) \equiv g(Y_i, Y_j) - \int_0^1 g(Y_i, Y_j)dY_i - \int_0^1 g(Y_i, Y_j)dY_j + \int_0^1 \int_0^1 g(Y_i, Y_j)dY_i dY_j, \tag{28}$$

so that $\phi(Y_i, Y_j) = f(Y_i)f(Y_j) + \kappa\gamma(Y_i, Y_j)$. Essentially, $\gamma(Y_i, Y_j)$ is the added (or subtracted) mass, relative to the zero-correlation case, at a point (Y_i, Y_j). Note that it must add zero net mass to any horizontal or vertical slice of the unit square. If it added more, say, then the particular Y_i or Y_j value corresponding to the horizontal or vertical slice would have increased in probability mass, altering one borrower's unconditional distribution of output.[32] Of course, in any given slice of the square, some segments may be raised and others lowered, but the net addition along the slice must be zero. The form $\gamma(Y_i, Y_j)$ takes guarantees this property holds for any choice of continuous $g(Y_i, Y_j)$.

Lemma 2 makes clear that there are many ways to introduce correlation; all that is required is a continuous function $g(Y_i, Y_j)$. Our approach is to parametrize $g(Y_i, Y_j)$ as generally as possible, while imposing some structure on the correlation in the form of symmetry.[33] Consider sets $\{\alpha_1, \alpha_2, ..., \alpha_N\}$ and $\{\beta_1, \beta_2, ..., \beta_N\}$, where each $\alpha_k, \beta_k > 0$, and assume

$$g(Y_i, Y_j) = -\sum_{k=1}^{N} \beta_k |Y_i - Y_j|^{\alpha_k}. \tag{A16}$$

This formulation of the basic correlation structure $g(Y_i, Y_j)$ has the nice property that it subtracts mass in proportion to some polynomial function of the distance between two returns. The more disparate the output realizations, the more mass is subtracted, while if they are identical, clearly no mass is subtracted: $g(x, x) = 0$. Intuitively, and as we will show formally, this should lead to positive correlation. Assumption A16 encompasses very simple examples like absolute difference $-|Y_i - Y_j|$ and squared difference $-(Y_i - Y_j)^2$. More generally, we conjecture that it can approximate to an arbitrary degree of accuracy any continuous function $Z(|Y_i - Y_j|)$ that is monotonically decreasing in $|Y_i - Y_j|$. This therefore appears to be a general way of introducing symmetric correlation.

Transforming the $g(Y_i, Y_j)$ of assumption A16 into $\gamma(Y_i, Y_j)$ using equation 28 gives

$$\gamma(Y_i, Y_j) = \sum_{k=1}^{N} \beta_k [\frac{Y_i^{\alpha_k+1} + (1 - Y_i)^{\alpha_k+1} + Y_j^{\alpha_k+1} + (1 - Y_j)^{\alpha_k+1} - 2/(\alpha_k + 2)}{\alpha_k + 1} - |Y_i - Y_j|^{\alpha_k}]. \tag{29}$$

This is the actual mass that will be added (or subtracted) at each point (Y_i, Y_j).[34] For the simple cases of absolute difference and squared difference, $\gamma(Y_i, Y_j)$ boils down to

$$Y_i^2 - Y_i + Y_j^2 - Y_j + 2/3 - |Y_i - Y_j|, \quad \textit{and} \quad Y_i^2 - Y_i + Y_j^2 - Y_j + 1/2 - (Y_i - Y_j)^2,$$

respectively.

We next calculate the covariance under $\phi(Y_i, Y_j) = f(Y_i)f(Y_j) + \kappa\gamma(Y_i, Y_j)$, using expression 28 for $\gamma(Y_i, Y_j)$ and carrying out some detailed integration, and find it equal to

$$Cov(Y_i, Y_j) = \kappa \sum_{k=1}^{N} \frac{\alpha_k \beta_k}{2(\alpha_k + 1)(\alpha_k + 2)(\alpha_k + 4)}. \tag{30}$$

As expected, the covariance is strictly positive, since $\alpha_k, \beta_k > 0$, and directly proportional to κ. Thus κ parametrizes the intensity of covariance.

Proposition 14. *Under assumptions A12, A13, A14, and A16, if unofficial penalties are severe enough, the group repayment rate is lower for groups with higher covariance of returns (higher κ).*

Proof: see Appendix A.

The intuition is simple: increased correlation makes it more likely that when one borrower realizes low returns, the other does also, and thus repayment for each other and (more importantly) pressure on each other become less likely. Graphically, the groups have the same Default Region in Figure 3, but different probability mass assigned to this area depending on the intensity of correlation. As unofficial penalties get more intense, in the limit only box A of Figure 3 results in default. Higher correlation increases the probability of falling into box A, since $|Y_i - Y_j|$ is on average smaller in that box than in the entire unit square.[35]

3.4 Adverse Selection: Ghatak 1999

Ghatak shows how joint liability can take advantage of the information borrowers have about each other, but the outside lender does not have, to draw into the market relatively safe borrowers who would be excluded under individual liability contracts. The model is similar to those of Stiglitz and BBG, except that riskiness of borrower projects is exogenous, while the decisions of whether to borrow and with whom are endogenized. With respect to matching, Ghatak shows that borrowers form homogeneous groups. Given this, he shows that joint liability effectively varies the interest rate by risk of borrower, reducing the cross-subsidization from risky to safe borrowers.

In this section we justify the basic predictions of the Ghatak model for repayment contained in column four of table 2.2. There is a continuum of risk-neutral, potential borrowers. Each is endowed with one unit of labor and one project indexed by some $p \in [\underline{p}, 1]$. The project requires one unit each of capital and labor. It pays off output $Y(p)$ with probability p and gives zero output otherwise. By assumption,

$$pY(p) = E, \quad \forall p \in [\underline{p}, 1]. \tag{A17}$$

Thus agents differ only in the second moment of the output distribution. The higher is an agent's probability of success p, or 'risk-type', the lower is his risk (measured by variance, for example). There is a density $g(p) > 0$ of borrowers at each type $p \in [\underline{p}, 1]$.

A lender offers a borrower one unit of capital through a joint liability contract. Borrowers form groups themselves, freely observing each other's risk-type. The lender, however, observes neither borrower type nor amount of output, but only whether the project has succeeded or failed.[36] Further, limited liability prevents the lender from receiving any payment from a borrower who fails. Any permissible contract can thus be characterized by an amount r paid by a borrower upon success, and an additional amount q paid by that borrower upon his own success and his partner's failure. A borrower of type p who pairs with one of type p' has expected payoff of

$$E - pr - p(1-p')q. \tag{31}$$

This payoff is increasing in p': all borrowers prefer to be matched with safer borrowers. It increases more steeply in p' the higher is p.[37] Intuitively, safe borrowers benefit relatively more from safe partners because they succeed more often, and are thus in the position of *being able to* bail out their partners more often. Using this insight, Ghatak shows that homogeneous matching is the only equilibrium. From such an equilibrium, no risky borrower would be willing to pay enough to draw a safe borrower away from his safe partner.

Homogeneous matching means the equilibrium payoff of a borrower of type p will be

$$E - pr - p(1-p)q. \tag{32}$$

Note that the derivative of the payoff with respect to p is $-[r + q(1-2p)]$. As long as $q \leq r$, which we assume, this derivative is strictly negative for $p \in [\underline{p}, 1)$. Thus, the safer an agent's type, the lower his payoff from borrowing and undertaking the project. Given outside payoff option $\underline{u}$ requiring one unit of labor only, agents will borrow if and only if payoff 32 is greater than $\underline{u}$. Thus there exists a cutoff type, call it $\hat{p}$, such that borrowers of type $p > \hat{p}$ will pursue the outside option and all others will borrow.[38] Assuming an interior $\hat{p}$, it must satisfy

$$E - \hat{p}r - \hat{p}(1-\hat{p})q = \underline{u}. \tag{33}$$

We call this the Selection Equation.

Unlike the other models, this one does not produce a deterministic probability of repayment p as a function of key variables (r, q, and so on). Rather, it delivers a *range* for the probability of repayment, $[\underline{p}, \hat{p}]$, where $\hat{p}$ is a function of key variables (through equation 33). Our best guess for the repayment rate is then $E(p|p \leq \hat{p}) \equiv \tilde{p}$; $\tilde{p}$ is what enters likelihood function 1 of section 2.2 for this model and is therefore the analog to the deterministic p's of the other models. But since $d\tilde{p}/d\hat{p} > 0$, we need only determine how a given change affects $\hat{p}$ to know how it affects $\tilde{p}$.[39] Thus the Selection Equation is the key to understanding repayment determinants.

3.4.1 Subtracting screening ability

Here we assume that borrowers do not know each other's types, but only their own type and the distribution of types in the population. If they want to borrow, they must join a group without knowing the risk-type of their partner. Let $\hat{p}'$ be the highest value for p satisfying

$$E - \hat{p}'r - \hat{p}'(1-\tilde{p}')q = \underline{u}, \tag{34}$$

where $\tilde{p}' \equiv E(p|p \leq \hat{p}')$. Then $\hat{p}'$ is the cutoff risk-type in equilibrium.[40] To check this is an equilibrium, we verify that everyone is optimizing if the set of borrowers is $[\underline{p}, \hat{p}']$. The payoff for anyone who chooses to borrow in this scenario is

$$E - pr - p(1-\tilde{p}')q.$$

The expression involves $\tilde{p}'$ because this is the expected risk-type of the partner, which must reside in $[\underline{p}, \hat{p}']$.[41] Since this payoff is strictly decreasing in p, there exists a cutoff type, above which agents find the outside option more attractive, and below which agents prefer to borrow. This cutoff is $\hat{p}'$ since $\hat{p}'$ satisfies 34.

It turns out that the removal of the ability to match homogeneously hurts safe borrowers and helps risky ones, since each now effectively matches with an average borrower rather than a similar one. Since the safe borrowers were marginal, they are driven out of the market and the expected repayment rate is lower.

Proposition 15. *Under assumption A17, the expected group repayment rate is higher for groups with the ability to screen.*

Proof. Equation 33, equation 34, and the fact that $\hat{p}' > \tilde{p}'$, respectively, give that

$$E - \hat{p}r - \hat{p}(1-\hat{p})q = \underline{u} = E - \hat{p}'r - \hat{p}'(1-\tilde{p}')q < E - \hat{p}'r - \hat{p}'(1-\hat{p}')q. \tag{35}$$

Recall that the payoff from homogeneous borrowing, $E - pr - p(1-p)q$, is decreasing in p. Applying this fact to (the far left- and right-hand sides of) inequality 35 gives that $\hat{p}' < \hat{p}$. ■

3.4.2 Checking r and q

A higher interest rate or joint liability payment makes borrowing relatively less attractive. Thus the higher a group's r or q, the smaller and more risky the pool from which it is drawn.

Proposition 16. *Under assumption A17, the expected group repayment rate is lower for groups with higher r or q.*

Proof. Total differentiation of Selection Equation 33 gives that $\partial\hat{p}/\partial r = -\hat{p}/[r+q(1-2\hat{p})]$ and $\partial\hat{p}/\partial q = -\hat{p}(1-\hat{p})/[r+q(1-2\hat{p})]$. Both are negative for $q \le r$ and $\hat{p} \in [\underline{p}, 1)$. ■

3.4.3 Adding loan size

Here we introduce as a factor of production loaned capital L. We again use separability assumption A5 of section 3.1.3. It allows us to express expected output as $E\,F(L)$, after some manipulation and use of assumption A17. We assume that F is defined on $\Re_+$, strictly increasing and concave, twice continuously differentiable on $\Re_{++}$, and satisfies Inada conditions. The interest and joint liability payments are now assumed to be proportional to L: rL and qL, respectively. Define $Z(p) \equiv pr + p(1-p)q$ as the unit borrowing cost of an agent of type p, under homogeneous matching. The borrower payoff (under symmetric loan sizes) is then

$$EF(L) - prL - p(1-p)qL = EF(L) - Z(p)L. \tag{36}$$

If we observe an agent borrowing loan size L, we know two things. First, it must be that $EF(L) - Z(p)L \ge \underline{u}$; otherwise this agent would choose the outside option. Rearranging, we know

$$Z(p) \le [EF(L) - \underline{u}]/L. \tag{37}$$

As noted in earlier sections, $Z(p)$ is strictly increasing for $p \in [\underline{p}, 1)$ when $q \le r$. This implies that $p \in [\underline{p}, \hat{p}(L)]$, where $\hat{p}(L)$ solves relation 37 at equality, or rearranging, a familiar Selection Equation:

$$EF(L) - \hat{p}rL - \hat{p}(1-\hat{p})qL = \underline{u}. \tag{38}$$

One can show that the right-hand side of inequality 37 first increases, then decreases in L, implying that $\hat{p}(L)$ does the same. Second, assuming the borrower can always take less (if not more) than what the lender offers,[42] we then know that the borrower's marginal payoff with respect to loan size is not negative. Otherwise, the borrower could have refused some of the loan and increased his payoff. Differentiating payoff 36, we have $EF'(L) - Z(p) \ge 0$, or

$$Z(p) \le EF'(L). \tag{39}$$

Again, since $Z(p)$ is increasing, this implies $p \in [\underline{p}, \check{p}(L)]$, where $\check{p}(L)$ solves relation 39 at equality. The larger the loan L, the tighter the bound of inequality 39 (since F is concave), and hence the lower $\check{p}(L)$. Safer groups face a higher cost of capital and thus prefer smaller loans.

Combining the conclusions of the previous paragraph, observing L tells us that $p \in [\underline{p}, \min\{\hat{p}, \check{p}\}]$ (to avoid clutter we will typically suppress the argument L in writing $\hat{p}$ and $\check{p}$). A little manipulation of the right-hand sides of inequalities 37 and 38 makes clear that the former bound is tighter, implying $\hat{p} < \check{p}$, when

$$[\underline{u} - EF(0)]/E > F(L) - F(0) - LF'(L) \equiv \Gamma(L); \tag{40}$$

and $\check{p} < \hat{p}$ when the reverse inequality holds. One can show that $\Gamma(L)$ is continuous, strictly increasing ($\Gamma'(L) = -LF''(L) > 0$), and $\lim_{L \to 0^+} \Gamma(L) = 0$.[43] Since $\Gamma(L)$ is increasing from zero, equation 40 holds when loan sizes are small enough, as long as $\underline{u} > EF(0)$.

Note that $\underline{u} - EF(0)$ is the difference between the payoff of the outside occupation and the payoff of the borrowing occupation, undertaken without loaned capital (expression 36 at $L = 0$). If these occupations are the same and there is no fixed cost of borrowing, we expect $\underline{u} = EF(0)$. On the other hand, if there is a fixed cost of borrowing, or the outside occupation is different and more profitable in the absence of loaned capital,

$$\underline{u} > EF(0). \tag{A18}$$

This assumption is preferred because if it is not true, *every agent* would choose to borrow, at least a little.[44] This would change the focus of the model from extensive-margin credit rationing to intensive-margin credit constraints.

The $\hat{p}$ and $\check{p}$ curves are pictured in Figure 4. The latter is monotonically declining, since a higher loan size is optimal for a riskier type. The former increases then decreases, peaking at the point of intersection as one can show. If loan sizes are small enough, analysis is straightforward as before. In particular, if condition 40 is satisfied, each borrower has a type drawn from $[\underline{p}, \hat{p}]$, and with $\hat{p} < \check{p}$ each receives a loan smaller than his optimal amount. This is evident because L is optimal for type $\check{p}$, so loans larger than L are optimal for all types below $\check{p}$, including those in $[\underline{p}, \hat{p}]$ (see Figure 4). Since every borrower is constrained under this assumption, a higher loan size means higher payoffs and borrowers being drawn from a larger, safer pool.

Proposition 17. *Under assumptions A5, A17, and A18, and for L small enough (specifically, for L satisfying $\Gamma(L) < [\underline{u} - EF(0)]/E$), the expected group repayment rate is higher for groups with higher L.*

Proof. The expected repayment rate is $E(p|p \leq \hat{p})$, so again we are interested in what happens to $\hat{p}$. Total differentiation of Selection Equation 38 gives that $\partial\hat{p}/\partial L = [EF'(L) - Z(\hat{p})]/[r + q(1-2\hat{p})]$. The denominator is strictly positive for $q \leq r$ and $\hat{p} \in [\underline{p}, 1)$. The numerator is strictly positive since in this range of L, $\hat{p} < \check{p}$ so $Z(\hat{p}) < Z(\check{p}) = EF'(L)$. ■

Thus for small enough loans, expected repayment is increasing in L. When L reaches a threshold so that the reverse of inequality 40 holds, we know $\check{p} \leq \hat{p}$, so observing L tells us that the repayment rate is in $[\underline{p}, \check{p}]$. However, the expected repayment rate is not simply

$E(p|p \leq \check{p})$ under distribution of types g. The reason is that a group of type $p = \check{p}$ would be observed with loan size L as long as they were offered any loan size *greater than* L, while a group of type $p < \check{p}$ is observed with loan size L only if they are offered *exactly* L. This should lead us to upgrade the probability that we are observing a group of exactly type $\check{p}$.[45]

To be more specific, let $h(L)$ be the density of loan offers and $H(L)$ be the associated distribution function.[46] There are two categories of borrowers we might observe with loan size L. The first includes all agents with types $p < \check{p}$ who received a loan offer of *exactly* L, of mass $G(\check{p})h(L)$. These agents accepted the loan offer without modification because L is less than their desired amount. The second includes all agents of type $p = \check{p}$ who received a loan offer greater than L, of mass $g(\check{p})[1 - H(L)]$. These agents were offered more than L but accepted only L, since it is optimal for them. The probability of observing loan size L is then:

$$P(L) = G(\check{p})h(L) + g(\check{p})[1 - H(L)]. \tag{41}$$

This gives rise to a distribution of types conditional on L, call it $P(p|L)$, modified to include a probability mass at $p = \check{p}$. Specifically, using Bayes rule, $P(p|L)$ is zero if $p > \check{p}$, since we know $p \in [\underline{p}, \check{p}]$; $g(\check{p})[1 - H(L)]/P(L)$ if $p = \check{p}$, the numerator representing the chance of observing a group of type $\check{p}$ that was offered a loan size of at least L; and $g(p)h(L)/P(L)$ if $p < \check{p}$, the numerator representing the chance of observing a group of type p that was offered a loan of exactly L. Finally, $E(p|L)$ is the integral $\int_{\underline{p}}^{1} pP(p|L)dp$, where the integration must treat $\check{p}$ as a mass point.

Carrying out this integration gives the expected group repayment rate as a convex combination of $\check{p}$ and $E(p|p \leq \check{p})$ under distribution of types g:

$$E(p|L) = \check{p}\frac{g(\check{p})[1 - H(L)]}{G(\check{p})h(L) + g(\check{p})[1 - H(L)]} + E(p|p \leq \check{p})\frac{G(\check{p})h(L)}{G(\check{p})h(L) + g(\check{p})[1 - H(L)]}. \tag{42}$$

No monotonic result on $E(p|L)$ is available without restrictions on G and H, even though both $\check{p}$ and $E(p|p \leq \check{p})$ are strictly decreasing in L. The reason is that the weight on $\check{p}$, which varies with L, may increase fast enough to offset the declines in $\check{p}$ and $E(p|p \leq \check{p})$ (see Figure 4). Inspection of equation 42 shows that this is most likely as $\check{p}$ approaches a spike in the risk-type distribution or as L approaches a near-zero density point in the loan offer distribution. However, we do know that $E(p|L)$ is *coarsely* decreasing, in the sense that it is bounded by two strictly decreasing functions, both of which converge to $\underline{p}$. The basic pattern is thus that a higher L implies that the group is drawn from a smaller, more risky pool, all of which face a sufficiently low cost of funds.

Proposition 18. *Under assumptions A5, A17, and A18, and for L large enough (specifically, for L satisfying $\Gamma(L) \geq [\underline{u} - EF(0)]/E$), the expected group repayment rate is* coarsely *lower for groups with higher L (in the sense that it is bounded by two strictly decreasing functions that converge to $\underline{p}$).*

Proof. As argued in the text, $\check{p}$ is strictly decreasing in L; hence $E(p|p \leq \check{p})$ is also. Clearly they both converge to $\underline{p}$ as L gets large enough, due to Inada conditions on F. Equation 42 makes clear that $E(p|L)$ is bounded by these two functions. ■

The overall prediction is thus an inverted-U relationship of the expected repayment rate with loan size L (though the second half is not necessarily strictly decreasing); this is pictured in Figure 4. A non-linear pattern will be tested for empirically.

3.4.4 Adding borrower productivity

Here we introduce to the baseline model an additional factor of production called H. The crucial question is, how does H affect the borrowing payoff relative to the outside payoff? To answer this, we use separability assumptions. Assumption A5 of section 3.1.3 enables us, after some manipulation and use of assumption A17, to write $pY(p, H) = E\,G(H)$. G is assumed strictly increasing. The borrower payoff becomes

$$E\,G(H) - [pr + p(1-p)q]. \tag{43}$$

In the same spirit, we assume

$$\underline{u}(H) = \underline{u}\,G(H). \tag{A19}$$

The new Selection Equation, which defines the cutoff borrowing type $\hat{p}$, is

$$E\,G(H) - \hat{p}r - \hat{p}(1-\hat{p})q = \underline{u}\,G(H). \tag{44}$$

Proposition 19. *Under assumptions A5, A17, and A19, the expected group repayment rate is higher for groups with higher H.*

Proof. Total differentiation of Selection Equation 44 gives that $\partial\hat{p}/\partial H = G'(H)(E - \underline{u})/[r+q(1-2\hat{p})]$. This is negative for $q \leq r$ and $\hat{p} \in [\underline{p}, 1)$, since G is increasing[47] and $E > \underline{u}$ (else there could be no borrowers, see Selection Equation 44). ■

Intuitively, increased productivity makes both borrowing and the outside option more attractive. However, the net outside payoff is augmented by $G(H)$, while it is the *gross* borrowing payoff that is augmented by $G(H)$, leaving the net borrowing payoff to be augmented by a factor greater than $G(H)$ (see payoff 43). This makes borrowing relatively more attractive for more productive groups, and the pool they are drawn from is larger and safer on average.[48]

3.4.5 Checking cooperation

Homogeneous groups should emerge whether or not agents are acting cooperatively. This equilibrium is has no desired deviants and is robust to side payments: as argued from the complementarity of risk-types in the payoff function, risky borrowers would not compensate safe borrowers enough to lure them away from safe partners. The only exception could be a coordination failure in a non-cooperative game, but this clearly depends on the formulation of such a game, and it is not robust to renegotiation in the form of the above side payments. Given that homogeneous groups form, the remaining analysis is the same whether groups are cooperating or not: project choice and repayment behavior are exogenous. Therefore, *there is no difference between cooperatively- and non-cooperatively behaving groups.*

3.4.6 Adding correlation

Finally, we add to the baseline model correlation of output between borrowers. As argued in the context of the Stiglitz model, there is a unique way to introduce correlation that preserves the individual probabilities of success for a given pair of borrowers (p, p'). It involves adding probability ϵ to symmetric events and subtracting probability ϵ from asymmetric events (see section 3.1.4 for more detail). However, there are many (p, p') combinations, and each could in theory have its own ϵ: $\epsilon(p, p')$.

We consider the same parametrizations for the function $\epsilon(p, p')$ that we did in the Stiglitz case, both of which treat all project pairings symmetrically in some sense. We assume $\epsilon(p, p')$ to be constant in the analog to assumption A6 of section 3.1.4:

$$\epsilon(p, p') = \epsilon, \ \forall p, p'. \tag{A20}$$

To avoid an essentially technical problem, we modify the support to exclude those with probability of success near 1:

$$\exists \overline{p} \in (\underline{p}, 1), \textit{such that } \forall p \in (\overline{p}, 1], g(p) = 0. \tag{A21}$$

This assumption changes the support from $[\underline{p}, 1]$ to $[\underline{p}, \overline{p}]$, ensuring that all borrowers' face at least some uncertainty.[49]

A straightforward calculation shows that the second assumption, analogous to assumption A7 of section 3.1.4, gives any homogeneous group the same *correlation coefficient* over project returns, equal to ρ:

$$\epsilon(p, p') = \rho * \min\{p'(1 - p), p(1 - p')\}. \tag{A22}$$

This formulation[50] is arguably the most general, being the unique way of affecting each potential group's (appropriately normalized) correlation coefficient symmetrically. Further, ρ can take any value from zero to one.

Given that homogeneous matching still obtains,[51] the new Selection Equation becomes

$$E - \hat{p}r - [\hat{p}(1 - \hat{p}) - \epsilon(\hat{p}, \hat{p})]q = \underline{u}. \tag{45}$$

Proposition 20. *Under assumptions A17, A21, and either A20 or A22, the expected group repayment rate is higher for groups with higher project return correlation (higher ϵ or ρ).*

Proof. Total differentiation of Selection Equation 45 gives that $\partial\hat{p}/\partial\epsilon = q/[r + q(1 - 2\hat{p})]$ under assumption A20 and $\partial\hat{p}/\partial\rho = q\hat{p}(1 - \hat{p})/[r + q(1 - \rho)(1 - 2\hat{p})]$ under assumption A22. These are positive for $q \leq r$, $\hat{p} \in [\underline{p}, 1)$, and $\rho \in [0, 1]$. ■

Intuitively, a positive payoff only occurs when the borrower is successful. Correlation shifts the weight in this state of the world toward the sub-state where the borrower's partner is also successful, away from the sub-state where the borrower's partner fails. Thus it raises the payoff of borrowing for high-correlation groups, and the pool they are drawn from is larger and safer on average.

4 Empirical Results

In this section we discuss our results using data from Thai BAAC groups and the villages where they are located. We discuss the data and sampling in section 4.1 and describe the variables in section 4.2 and appendix tables 4.2a and 4.2b. In section 4.3, we give more detail on the techniques used, and report the cross-tabulation results (summarized in appendix table 4.3a), the logit results (summarized in appendix table 4.3b), and the bivariate and multivariate nonparametric regression results. All the information is summarized, along with the theoretical predictions, in a single appendix table 4.3c, facilitating comparison of the models.

4.1 Data

The data used in this paper are from the Townsend Thai data base, in particular from a large cross section of l92 villages, conducted in May l997. The survey covers two contrasting regions of Thailand. The central region is relatively close to Bangkok and enjoys a degree of industrialization, as in the province of Chachoengsao, and also fertile land for farming, as in the province of Lopburi. The Northeast region is poorer and semi-arid, with the province of Srisaket regarded as one of the poorest in the entire country and the province of Buriram offering a transition as one moves back west toward Bangkok. Each of these two provinces was chosen because at least one county, or amphoe, had been sampled repeatedly in the national level socioeconomic survey, thus allowing some background and comparison for the survey here.

Within each province, twelve subcounties, or tambons, were chosen under a stratified random sampling scheme. The stratification was based on an analysis of satellite imagery that allowed an oversampling of forested zones, to ensure variation in agricultural productivity and the timing of good and bad years. Within each tambon, a cluster of four villages was selected, and within each village fifteen households were administered a Household instrument. There are thus 2280 households in the household data base. We call this instrument the HH survey. Of key importance for the paper here, in each village as many BAAC borrowing groups as possible were interviewed, up to two. In all we have data on 262 groups, 62 of which are the only groups in their respective village. We call this instrument the BAAC survey. Each group designates an official leader, and the leader responded to questions on behalf of the group.

4.2 Variable descriptions

To test the models' predictions involving repayment probabilities, the dependent variable on which we will focus our analysis is a binary dummy from the BAAC survey. It equals one if the BAAC has ever, in the history of the group, raised the interest rate as a penalty for late payment. Twenty seven percent of the groups responded affirmatively. This relatively high figure should not be taken as a mark against the BAAC lending program. Annual default rates are much lower, which is not a contradiction since this asks about default over the entire history of the group (median group age is ten). Further, imposing an interest rate penalty is one of the first remedial actions in a dynamic process the BAAC uses with delinquent group-guaranteed borrowers. This variable thus measures a mild form of default, since repayment ultimately may have occurred. For the empirical tests, we recode this variable to let zero represent default and one represent repayment. The BAAC survey contains another valuable measure of repayment, that is, whether members have ever repaid BAAC loans for another member. However, only about one tenth responded positively to that, so estimates are not as clear and not reported here.

The independent variables used are summarized in Tables 4.2a and 4.2b. Table 4.2a contains several control variables that are not featured in any of the four models.

LNYRSOLD is the log-age of the group. It is crucial to control for the age of the group, because the dependent variable measures whether default has ever happened in the history of the group. If we think of the event as having some probability p of occurring each year, then clearly groups with a longer history have a greater chance of having run into problems. But the effect would be non-linear in age.[52] Results under inclusion of terms for age and age squared, rather than log of age, are similar and not reported here.

VARIBLTY is a village-wide measure of risk. It is equal to the village average of each household's coefficient of variation in next year's expected income. It is not a featured variable in any of the theoretical models, but could readily be introduced. Our measure is taken from the household survey, where households are asked how much they will earn if next year is a good year (Hi), how much if bad (Lo), and how much they expect to earn (Ex). We assume a distribution of income over two of these mass points, Hi and Lo, as do the models. It is not difficult to calculate that the coefficient of variation[53] is equal to

$$\sigma/Ex = \sqrt{Hi/Ex - 1}\sqrt{1 - Lo/Ex}.$$

This quantity is calculated for each villager in the HH survey, and the village average is used. Thus it is a measure of average riskiness of occupation in a given village.

WEALTH is another village average variable. Villagers were asked detailed questions about assets of all types – ponds, livestock, appliances, and so on – as well as liabilities. Date of purchase was used to estimate current value after depreciation. These different types of wealth were aggregated for each villager, then averaged across villagers. The unit of measure is one hundred thousand 1997 Thai baht. We control for wealth so that we do not get confounding effects from other variables that are correlated with wealth. An example of these are the availability of outside borrowing options from commercial banks and village banks, the former being positively correlated and the latter negatively correlated with wealth in the data.

Number of MEMBERS is also controlled for. Groups in our data range in size from five to thirty seven, with eleven being the median. However, each model we consider fixes group size at two. There is theoretical reason to believe group size may affect repayment. As groups increase in size, monitoring may become harder but the social penalties at the group's disposal may also increase. Generalization of the models we consider may be feasible along the dimension of group size, but it is not attempted in this paper.

Key variables explicitly included in some or all models are the interest rate r, loan size L, and joint liability payment q. Data on groups' loan sizes and interest rates come from a BAAC survey question asking about the highest and lowest loan size and interest rate experienced by any member of the group over the past year. We take these high (hi) and low (lo) figures and use a weighted average $(lo + 0.1 * hi)/1.1$. The high end is only slightly weighted since the upper tail is often quite long and unrepresentative of the group as whole.

Our strategy for proxying the degree of joint liability q exploits the compromise the BAAC makes between individual liability and joint liability. One option the BAAC has toward the end of the process of reclaiming a delinquent loan is to seize assets of the borrower or guarantors, most often land. This fact leads to some variation in the actual degree of liability. If all group members own land, then there is less of a chance that a guarantor will in the end have to pay rather than the borrower himself, since the BAAC can take his land. If on the other hand some members of the group are landless, then the effective degree of joint liability can be thought of as higher, since it is more likely a guarantor will have to repay if a landless borrower defaults. Thus our approach will be to proxy joint liability by a group characteristic available from the BAAC survey, namely the percent of the group who do not own land. This is a clear source of variation and also measures the likeliness of having to pay for a defaulting member, given the BAAC can confiscate land of defaulters.

Productivity shifters include AVGLAND, the average amount of land per group member, measured in rai,[54] and EDCATION, average educational attainment in the group. EDCATION was constructed as follows. The leader was asked to classify each member into one of four categories: no schooling; some schooling, but below P4; P4; and higher than P4 schooling. The majority of borrowers have P4 schooling, the minimum level required by the Thai government. Our measure attempts to summarize this information, but in a necessarily somewhat arbitrary way. It is equal to 1*(Pct of group with some schooling, but below P4) + 3*(Pct of group with P4 schooling) + 5*(Pct of group with higher than P4 schooling). The exact specification of this seems to make little difference in the empirical results.

Next are two dummy variables from the BAAC survey associated with screening, SCREEN and KNOWTYPE. For KNOWTYPE, groups were asked if members know the quality of each other's work. This speaks to the assumption of Ghatak's model that borrowers know each other's types, which is a necessary prerequisite for screening to occur. For SCREEN, groups were asked whether there are borrowers who would like to join their group but cannot. In the Ghatak model, every group except those of type $p = \underline{p}$ has riskier types below them who would like to move up to safer partners. Thus if groups are sorting under the mechanism specified in the model, they should answer yes. This dummy then measures the degree to which groups are actually screening.

Measures of covariance are included next. COVARBTY is a village-level measure taken from the HH survey. Villagers were asked which of the previous five years were the best and worst economically, respectively. Our variable is constructed as the probability that two respondents chosen at random from the same village reported the same year as worst. If N_v is the number of villagers in village v and s_{vy} is the share of villagers in village v who named year y as the worst, this probability is equal[55] to

$$\frac{(\sum_{y=1}^{5} s_{vy}^2) - 1/N_v}{1 - 1/N_v}.$$

Our second proxy for covariance is a measure of occupational homogeneity from the BAAC survey, equal to the probability two randomly chosen group members have the same occupation. It is constructed exactly the same as above. Clearly, this should be positively associated with covariance of output in the group. A cautionary note is that it can also be a measure of the cost of monitoring, those of the same profession being easier to monitor.

Cost of monitoring is further measured by the percent of the group living in the same village, LIVEHERE, and the percent of group members who have a close relative in the group, RELATPCT, both from the BAAC survey. Recall that the model that focuses on cost of monitoring, BBG, inextricably ties monitoring to imposing penalties, making the degree of relatedness a mixed signal. It can also be thought of as a measure for cooperation.

Further measures of cooperation are captured by variables, SHAREREL and SHAREUNR, measuring sharing; a poll of villagers in the HH survey, BCOOPPCT; and JOINTDCD, which counts the number of key productive decisions on which some subset of the group, rather than the individual farmer, has the final say. To construct the sharing variables, we utilize six yes/no questions asked each group in the BAAC survey: whether sharing of rice, helping with money, helping with free labor, coordinating to transport crops, coordinating to purchase inputs, and coordinating to sell crops has occurred in the past year. In our measure, we exclude the sharing of rice, since this may indicate not only sharing but a regional character reflected in the predominance of rice farming. The index is thus the number of yes responses to the remaining five questions. These should be correlated with the degree to which the group can make binding agreements. The same set of questions was asked twice, regarding relatives and non-relatives, respectively, within the group. These lead to SHAREREL and SHAREUNR, respectively.

BCOOPPCT comes from a poll of villagers in the HH survey. Each is asked which village in his tambon (subcounty) enjoys the best cooperation among villagers. The percentage of villagers in the HH survey naming the village in which a group is resident is the measure we use. Finally, JOINTDCD counts the number of the following three decisions on which some or all group members, as opposed to the individual farmer, have the final say: which crops to grow, pesticide and fertilizer usage, and production techniques. Thus it is intended to capture joint choice of project, as is assumed in Stiglitz's model of cooperation.

Measures of outside borrowing opportunities are captured in the variables PCGMEM and CBANKMEM, taken from the HH survey.[56] They give the percent of villagers in the group's village who are members of a production cooperative group (PCG) or commercial bank, respectively. PCGs are village-run organizations that collect regular savings deposits from members and offer loans after a member has met some threshold requirement involving length of membership, amount deposited, or both. Often the maximum available loans from these institutions are small, possibly one fifth the size of BAAC loans, and the interest rates are similar or slightly higher (see Kaboski and Townsend, 1998). There do exist PCGs large enough to offer loans as large as BAAC loans. Occasionally joint liability is used with these loans.[57] Commercial banks are conventional lenders, requiring collateral. We restrict attention to these two non-BAAC lenders because they probably offer contracts closest to that of the BAAC. Of the two, PCG loans are much closer to BAAC group loans than are commercial bank loans.

A more indirect measure of outside loan options, BINSTPCT, comes from a poll of villagers in the HH survey. Specifically, it is the percent of villagers in the tambon (subcounty) naming the group's village best in terms of availability and quality of institutions. This refers at least in part to lending institutions; thus this captures outside loan availability.

The measure probably also captures to some degree the legal infrastructure, which is related to the official penalties the BAAC can impose on borrowers.

Finally, official and unofficial penalties are proxied by BINSTPCT, described in the preceding paragraph, and SNCTIONS, respectively. SNCTIONS comes from the HH survey and is constructed from a question asking villagers what the penalties for default on their current loans are. We use the percent of loans in the village that have penalties extending beyond the direct participants in the loan agreement. Specifically, we count loans for which the borrower reports that under default, he cannot borrow again from this lender *and other* lenders, or that reputation in the village is damaged. This captures very directly a form of unofficial penalties – denial of future credit – that extends not only beyond the BAAC's power to punish, but also the power of the group members themselves.

4.3 Nonparametric and logit results

First we report on some simple non-parametric comparisons that give evidence on how the repayment rate varies with each independent variable separately. Logit results are then reported. Both are done for the whole sample of BAAC groups, as well as by region.[58]

Each non-parametric comparison is performed across two subsamples that partition the whole sample, one with high values of a given independent variable and the other with low values. If the repayment rate varies monotonically with this independent variable, we should expect to find differences in average repayment rate across the subsamples.[59]

There is inherent arbitrariness in setting the cutoff value of the independent variable that will partition the sample into groups with high and low values, with obvious exceptions such as dummy variables. To address this, we perform the comparison using *all* two-subsample partitions that satisfy two conditions. First, since the partition must divide groups based high and low values of the independent variable, we only consider partitions in which every group in one subsample has a *strictly* higher value for the independent variable than every group in the other subsample.[60] Second, we only consider partitions that leave at least fifteen groups in each subsample. The number fifteen is arbitrary, but setting a minimum subsample size ensures some chance for significant mean differences across subsamples in each partition.

Results of the comparisons are listed in Table 4.3a. The first two columns give the results when considering the northeast groups only, the second two give those of the central groups, and the third two give the results for the whole sample. For each of these samples, there are two columns. The first contains the percentage of partitions in which the high subsample yielded significantly *higher* mean repayment rates at a 90% confidence level; the second contains the percentage of partitions in which the high subsample yielded significantly *lower* mean repayment rates at a 90% confidence level. Partitions that produce the first or second of these results give evidence that the repayment rate is monotonically increasing or decreasing, respectively, with the independent variable. The final three columns of the table record the total number of partitions for each sample satisfying the two criteria we imposed, as stated above.

These comparisons are all univariate in the sense that the sample is partitioned based on high and low values of a single independent variable. In principle, it would be possible and desirable to partition using multiple independent variables, in order to identify partial effects. However, the number of combinations of tests and the data requirements grow very quickly as the number of independent variables grows, so we report here the simple univariate comparisons.

Logits allow us to add a multivariate dimension at the expense of the simplifications mentioned in section 2.2. Results on all variables simultaneously are listed in Table 4.3b. There are 219 groups included in the regression incorporating both regions; 43 are excluded for missing data. There are 130 observations in the regression restricted to the northeast region, and 89 observations in the regression restricted to the central region.

A summary of predictions from the nonparametric tests and the logits is contained in Table 4.3c. There, we also attempt to summarize empirical findings in the literature on repayment, namely Wydick (1999), Sharma and Zeller (1997), Zeller (1998), and Wenner (1995). For details on the studies reviewed, see appendix E of our earlier working paper, Ahlin and Townsend (2002). When existing studies conflict, we use two arrows. If of equal length, the two arrows indicate relatively equal evidence for both signs; if unequal, the longer one represents the effect with more evidence behind it.

The final columns of Table 4.3c reproduce Table 2.2a, which summarizes the theoretical predictions of the four models. For more details on the predictions, see section 3 and Table 2.2a.

Our own results are summarized in the first three columns. The three columns represent results from the northeast region sample, the central region sample, and the combined sample, respectively. The pre-comma entry of each column represents the nonparametric, mean-comparison results of Table 4.3a. If 80% or more of the partitions showed means significantly different at 90%, three arrows are used; if 50% or more showed means significantly different at 90%, two arrows are used; if 20% or more showed means significantly different at 90%, one arrow is used. Otherwise the empty set symbol $\emptyset$ is used. The post-comma entry of each column represents the logit results of Table 4.3b. A coefficient different from zero at 15%,[61] 10%, and 5% significance is represented by one, two, and three arrows, respectively. A coefficient not different from zero at any of these significance levels is represented by $\emptyset$. In both the nonparametric and logit cases, the arrows point up if mean repayment was increasing in the independent variable and down if the reverse was true.

The final four columns summarize the theoretical predictions. Note that in most cases, the predictions are put on the same row as the thematic group heading, rather than on the row of the variables themselves. This is because we often use multiple variables to proxy what in the models is a single concept. The theoretical predictions do not vary across the different proxies. The exceptions to this rule in the table are the control variables, about which the models by definition have no predictions,[62] and the category including penalties for default. Since both the theory and our data do distinguish between official and unofficial penalties for default, we list the predictions for both proxies.

The chart treats existing empirical literature similarly. If evidence was found on a variable very similar to one we use, it is reflected on the same line as our variable. If evidence was found on variables that we do not use but serve as proxies for the same concepts we examine, it is reflected on the same line as the group heading. In some cases, the literature has examples of both.

In analyzing the results, we focus primarily on whole-sample results, since they contain the most data. Only if interesting and significant differences emerge from the regional results are they noted.

Of the **control variables**, LNYRSOLD performs utterly predictably with a significant negative correlation with repayment. This is clearly because our dependent variable involves default at any time in the history of the group, which is more likely for older groups. None of the others show up significantly in the whole-sample regressions except MEMBERS, which is negative in the nonparametric tests but insignificantly positive in the logit. To reconcile this difference of outcome, we look at the results of two locally linear regressions. The first involves MEMBERS as the independent variable and repayment as the dependent variable. In the second, we use the differencing method of Yatchew (1998) to remove the linear effect of all regressors except MEMBERS on repayment; we then take these residuals and relate to the number of MEMBERS using the locally linear regression.

The particular local linear regression technique we use is similar to Lowess (see for example Cleveland 1979 and Fan 1992). For each unique value of the independent variable, we calculate a fitted value of the dependent variable from a weighted least squares regression on a "nearby" subset of the total sample. Thus the choices are weights for the regression and a bandwidth which determines the subsample. The bandwidth $h(x)$ is set for each unique value x of the independent variable to ensure inclusion of the 80% of the data whose values x_g are closest to x.[63] The weighting function is the tri-cube weighting function:

$$w_g = (1 - (\frac{|x - x_g|}{1.0001h(x)})^3)^3.$$

This function places more weight on observations located more closely to x. Standard errors at 90% confidence are calculated using the bootstrap method, that is, recreating 1000 samples from the original sample by sampling with replacement, and calculating the fitted values for each unique value x of the *original* sample, using the same technique described above on each of the bootstrapped samples. For each value x, the confidence interval is the 51st and 950th smallest fitted value from these samples.

The multivariate version adds an initial step: ordering the observations by the focal variable and differencing (we use optimal fifth-order differencing, according to Yatchew 1998). The linear coefficients on the remaining regressors are then calculated using ordinary least squares. From these residuals are calculated as the dependent variable minus the predicted contribution from the non-focal variables. These residual are then regressed in the manner above on the focal variable. Bootstrapped confidence intervals are calculated as above. Since our main concern is with the shape (slope) of the functions, we normalize the residuals in each estimate to have mean zero.[64]

The results are plotted in Figure 5. The thrust of these graphs is that the negative correlation appears to be an artifact of the univariate nature of the comparisons. Once we control for the other covariates, albeit in a linear fashion, any hint of a monotonic negative relationship is erased. If anything, the relationship takes on what may an inverted-U shape, which could accord with the idea that repayment improves as risk-sharing capabilities increase, then declines as free-riding in a large group becomes problematic. In the case of this variable, MEMBERS, the reason for the difference of results is easily found in a significant, positive correlation between group size and age of group in our data. Older groups tend to have more members and also have a greater chance of having defaulted in their history. When group age is controlled for, MEMBERS no longer appears negative.

As for the contract variables, the results on **q** are most robust, appearing in both types of tests in the whole sample and the central region subsample. These results strongly favor Stiglitz and Ghatak over BBG, especially in the central region. This is an interesting result, perhaps paradoxical, given the popularity of these types of contract. But recall, the main idea in the two models that predict this decline is that increasing q allows a decrease in r, while here we (and the BAAC) hold r fixed and vary q.

The results on **r** and **L** are not strong. One interesting point can be made, and that is the significant inverted-U shape of repayment with L in the central region logits. This is exactly what Ghatak would predict – more evidence for the adverse selection model in this region. Nonparametric estimates of the relationship, where the other covariates are controlled for linearly, are presented in Figure 6, both for the whole sample and the central region. Especially in the central region the inverted-U is pronounced in the function estimates. Though the estimate is not precise, it lends support to the logit result.

Productivity represented by our direct measure of education turns up evidence in favor of all four theories. This contrasts with previous empirical studies, in which the only measure of human capital used was a measure of literacy and the coefficient was not significantly different from zero. However, the logit produces a more significant positive relationship than the mean comparisons. Figure 7 presents a nonparametric estimate of the curve where the other covariates are controlled for linearly. The effect seems closer to the logit evidence: it is impossible to draw a curve through the error bands that does not slope up.

The dummies related to **screening**, SCREEN and KNOWTYPE, perform poorly in both types of tests.[65]

The direct measure of village **covariance of output**, COVARBTY, is a weakly significant predictor of good repayment. This is true in the whole-sample logit, the central nonparametric means tests, and in the nonparametric estimate, again where the other covariates are controlled for linearly, pictured in Figure 7. This result is in line with the predictions of Stiglitz and Ghatak. It is at odds with BC under certain assumptions as well as the empirical literature, which assumes high correlation should lead to lower repayment. The more indirect measure of covariance that measures homogeneity of occupations within the group, HOMOCCUP, is an insignificant predictor in each test.

The **cost of monitoring** proxies show mixed performance. LIVEHERE, the percentage of group members living in the village is insignificant in the logits, but shows some signs of a positive relationship with repayment in the nonparametric comparisons. This agrees with the BBG model that lower costs of monitoring should improve repayment performance. RELATPCT, the percent of members with a close relative in the group, which should also proxy the ease of monitoring,[66] is significantly and negatively associated with repayment in the mean tests, and always negative though not significant in the logits. This contradicts the cost of monitoring prediction of the BBG model. However, that model equates monitoring with the ability to impose penalties; it may be that imposing penalties is harder among relatives.

Penalties for default are crucial in the BC model, and their importance is upheld by these data, overwhelmingly so in the northeast region. We seem to be the first to document this, as the one paper in the literature to date that examined the issue found little effect (Wydick 1999). The unique measure for unofficial penalties – the exclusion of a delinquent borrower from future credit in his village – shows up very positively and significantly, again especially so in the poorer northeast region. See also Figure 8 for the nonparametric regression, with the other covariates controlled for linearly. We also find a more or less direct measure of institutional capacity in the village to be a positive predictor of repayment in the northeast logits. This can be taken as a proxy for official penalties (which depend on the legal system), and thus provides further confirmation of BC.

The **availability of outside credit sources** seems to hurt repayment. The prevalence of PCGs, which are basically village-run savings and loan institutions, is negatively and very significantly associated with repayment in both types of tests, especially the logits. The nonparametric regression (see Figure 8), again with the other covariates controlled for linearly, strongly supports this: any curve through the error bands must slope downward. This result has a substantial regional flavor as well, strongest in the northeast region.[67] The fact that the loan size of the average PCG is about 10-20% that of a typical BAAC loan (though contract terms can be better and delay less) puts this result in greater relief, implying that access to even small amounts of outside credit can hurt repayment. The evidence on commercial bank prevalence is weaker.[68] Overall, the evidence appears strong that the presence of other lenders decreases repayment to the BAAC.

Finally, we use rich data on sharing, relatedness, and decision-making in the group to clarify the puzzle surrounding the effect of **cooperation** on repayment. If anything, our results seem to tip the scale toward establishing cooperation's negative effect on repayment rates (though not necessarily borrower welfare).

If we take the extent of sharing among group members as the proxy for cooperation, it appears cooperation is negatively associated with repayment. This is most clear from SHAREUNR, which measures sharing among non-relatives in the group. All types of tests show significantly negative correlations. There is also some evidence from the univariate tests that SHAREREL, which measures sharing among relatives in the group, is a negative predictor of repayment, at least in the central region.[69] The third measure of cooperation, BCOOPPCT, results from a poll of villagers as to which villages exhibit the most cooperation. It is always negative in sign but only significant in the northeast sample logit and in a few nonparametric tests on the northeast and complete samples. This adds slightly more evidence that cooperation is associated with lower repayment.[70]

Thus far there is evidence that cooperation hurts repayment, favoring the BBG and BC models over the Stiglitz model. However, one strong exception to this conclusion arises in JOINTDCD, which is a positive predictor of repayment in both the logit and the nonparametric tests. Recall that JOINTDCD is the number of production decisions (regarding pesticides and fertilizers, for example, and which crops to grow) over which some or all group members have the final say. Thus JOINTDCD may not measure cooperation in the sense of being able costlessly to *enforce* agreements from which individuals have incentives to deviate, but rather may reflect a transfer of knowledge and expertise.[71] A second intriguing possibility is that the ability to cooperate is heterogeneous across different types of actions, and that JOINTDCD reflects cooperation on *project choice* as opposed to cooperation on *punishment behavior*. This is arguably the case since JOINTDCD reflects cooperation in explicit production decisions. In this case, it would best serve as a measure of cooperation in a model of moral hazard in project choice, such as Stiglitz. Stiglitz is exactly the model that predicts a positive effect of cooperation.[72] What is attractive here is that the three models with predictions on cooperation can be reconciled to this otherwise odd result.[73]

Table 4.3c is very useful in evaluating across the models. There are three kinds of variables. The first kind consists of variables that elicit predictions from multiple models, all of which agree. This includes r, outside credit options, and productivity. We find evidence, strong in two cases, to support the model's unanimous predictions.

The second type of variable is the focal variable in exactly one of the models. This includes screening in the Ghatak model, ease of monitoring in BBG, and penalties in BC. BC is powerfully confirmed along this dimension, with official and unofficial penalties being quite strong predictors of repayment, especially in the northeast sample. The evidence for BBG and Ghatak is not strong one way or the other along this dimension of our data.

A third kind of comparison involves variables about which the models disagree – L, q, covariance, and cooperation – and leads to the possibility of rejecting one model in favor of another. The evidence on q and L favors Ghatak, especially in the central region, at the expense of Stiglitz and BBG. The evidence on covariability, though weak, favors Stiglitz and Ghatak at the expense of BC. Finally, the evidence on cooperation turns in favor of BBG and BC at the expense of Stiglitz (except for cooperation in decision-making). Only the Ghatak model emerges unscathed.

Pooling all the evidence by region, it can be said that BC is quite strongly upheld in the northeast region, in particular its focus on unofficial penalties, and not contradicted in any. In the central region, however, Ghatak does quite well. It is quite possible, and not surprising, that different mechanisms are at work in the different regions, with joint liability potentially solving more of a selection problem in the central region and an enforcement problem in the northeast.

5 Conclusion

We have compiled and helped construct a theoretical framework through which to view repayment data of joint liability borrowing groups and to test between theories regarding them. Using this and rich data from Thailand on group characteristics and the villages where they are located, four models were compared.

We find that the Besley and Coate model of social sanctions that prevent strategic default performs remarkably well, especially in the more rural, poorer northeast region. The Ghatak model of peer screening by risk type to overcome adverse selection is well supported in the central region, closer to Bangkok.

No model, however, performs head and shoulders above the rest, nor are these data sufficient to firmly establish a set of universal stylized facts, if one indeed exists. The strongest facts that future modelling should take into account include the negative impact of the rate of joint liability (ceteris paribus), the negative effect of outside credit options, the strength of local sanctions in enforcing repayment, and the sometimes negative effect of more benign social ties such as relatedness and sharing.

One of the most striking aspects of the results for policy implications is the repeated confirmation of strong social ties – measured by sharing among non-relatives, cooperation, clustering of relatives, and village-run savings and loan institutions – having *adverse* effects on repayment performance. This result has not been seen in the previous empirical literature, nor focused on in the theoretical models. On the contrary, social ties are seen as positive for group lending.

Clearly this idea must be qualified: social structures that enable penalties can be helpful for repayment, while those which discourage them can lower repayment. However, a higher repayment rate is not always synonymous with higher welfare. It may merely reflect the use of cheap penalties to enforce repayment when it is not (ex ante) Pareto optimal for the group. Thus joint liability lending may flourish most in areas where social penalties are especially severe, even moreso than the borrowers would prefer.[74]

Notes

[1]Wydick (1999) provides a noteable exception to this.

[2]The groups in our data may be unrepresentative of all groups in this particular, in the sense that some groups with few landed households may have dispersed upon default and not appear in our data. Thus we may be losing part of the tail of the distribution, those with little land, which would reduce the variation of our measure of joint liability in the data. More generally, there can be some variation in default that our data do not capture, namely groups that have defaulted and gone out of existence. This arguably makes our job in this paper harder, as we estimate results from a subset of the range of outcomes.

[3]Stiglitz implicitly assumes the borrowers can enforce costlessly project choice agreements, while BBG and BC involve non-cooperative games.

[4]To be more precise, two of the models, Stiglitz and Ghatak, deliver the probability that one individual in the (homogeneous) group succeeds and repays, p say. The probability that both succeed and repay is then p^2. The probability that only one succeeds and repays his own obligation and some of his partner's is $2p(1-p)$. Finally, the probability that neither succeed or repay anything is $(1-p)^2$. However one classifies the middle outcome, where only one succeeds and the full group debt may not be repaid, the group repayment rate is monotonically increasing in p, being either p^2 or $p(2-p)$. Thus we focus in the theory just on p. Empirically, our measure of default would likely encompass the middle case, since it involves a penalty that is most often imposed on the defaulting individual, whether or not others in the group defaulted.

[5]Our data on R are binary-valued. Details are in sections 4.1 and 4.2.

[6]In practice, our data on R reflect whether, *in the history of the group*, any blemishes in the repayment record have occurred, as will be described in section 4.1 and 4.2. Thus we would have to control for group age in the likelihood 1. Since we have data on the age of the group, O^g say, we could do this by substituting each term $P(R^g = 1|X^g)$ in the likelihood 1 with the same term raised to the power O^g, $P(R^g = 1|X^g)^{O^g}$. Of course, this is equivalent to assuming the static models that deliver $P(R|X)$ are repeated every year with no feedback across years and no change in covariates. Ideally, the models and the data would be dynamic, but our more modest goal in this paper is to test the current state of the theory, which involves static models.

[7]In general, the theory we examine does not take into account intra-group heterogeneity, though this clearly exists in the data. The exception is Ghatak, who allows for intra-group heterogeneity in risk-type but shows that it does not exist in equilibrium.

[8]If the lender could observe output, this would be equivalent to observing project choice as long as $Y(p_S, L) \neq Y(p_R, L)$.

[9]This premise is shown in section 3.1.1, under assumption A4. The Switch Line is thus downward-sloping. A reduction in the interest rate increases the safe payoff more than the risky one. On a curve of indifference, it must then be accompanied by an increase in loan size, which differentially increases the risky payoff.

[10]For a proof, see Ahlin and Townsend (2002). There we show that $Y(p_R, L) \leq Y(p_S, L)$ guarantees the left-hand side of equation 4 is strictly greater than the right-hand side.

[11]Since $p(1-p)$ is a parabola maximized at $p = 1/2$, assumption A3 is equivalent to the condition that p_S be closer than p_R to 1/2.

[12]Stiglitz implicitly assumes that all groups are capital-constrained, that is, would like to borrow more at the terms under which they are currently borrowing. Other lenders offering similar contracts would simply

increase L for each borrower. The assumption we need in order to apply the same analysis as for L is that the outside lender offers the same contract parameters r and q. If, further, it is the *same joint liability group* under the outside lender, we can view outside credit as merely an increase in L on the Switch Line diagram. If, however, there is a different group under the outside lender, the analysis is more complicated and the Switch Line diagram no longer applies, but the result still goes through since it is only for q in a neighborhood of zero.

[13]It turns out there is a region of (r, L) space, just below the non-cooperative Switch Line, where the Nash equilibrium is not unique: both risky and safe project choices are non-cooperative equilibria. The non-cooperative repayment rate of equation 6 is thus an upper bound.

[14]A similar modification to a model of strategic default is analyzed by Armendariz de Aghion (1999).

[15]Here ϵ can be any number provided it is not so large or small that it causes any of the cells to exceed one or fall below zero.

[16]This follows from the fact that the entries in row one (column one) must add to p_i (p_j), and the entries in row two (column two) must add to $1 - p_i$ $(1 - p_j)$.

[17]One advantage of assumption A7 is that any $\rho \in [0, 1]$ is allowable. For assumption A6, $\epsilon \leq \min\{p_R(1 - p_R), p_S(1 - p_S)\}$ must hold for all cells in the distribution matrix to stay within $[0, 1]$.

[18]However, the departure from their paper is probably negligible, since one of their propositions shows that groups will not use internal funds if the outside lender has a lower opportunity cost of funds than do group members. This is quite possible in the rural data we examine: various distortions have likely prevented institutional lenders from taking full advantage of the investment opportunities there.

[19]The actual assumption made by BBG corresponding to A8 is that $0 < E'(p) < \rho$, where ρ is the lender's cost of funds and is connected to the interest rate through a zero-profit condition. For our derivations, however, we discard the zero-profit condition, as discussed in section 2.1. Therefore, we make the assumption directly on the interest rate r.

[20]The implicit assumption is that the monitor can make the liability payment in any state of the world.

[21]One can check that the second-order condition is (strictly) satisfied because M is strictly increasing and convex, and because $E''(p) \leq 0$, by assumption A8, which ensures that $c_{pp}(p, r) \geq 0$.

[22]In this section, we will assume an interior solution in all derivations.

[23]Note that this inequality is a condition on L and $F(L)$ as well as on $E(p)$ and r. For example, it will not hold for low L under Inada-like assumptions on $F(L)$. Thus the moral hazard problem would come into play only for high enough loan sizes.

[24]Clearly this inequality will not hold for high enough H as long as $G(H)$ is not bounded. Thus the moral hazard problem disappears for productive enough groups.

[25]This is due to utility being transferable. The maximized surplus can then be redistributed among the group members to achieve the desired distribution.

[26]A natural interpretation of the non-cooperative case with $M(c) = c$ is that the monitor can commit to paying a bonus to the borrower contingent on his project choice. This is a reward rather than the penalty discussed in the text, but the effect on the borrower's incentive constraint is the same, as is the cost to the monitor. In particular, the monitor's payoff is $(1 - p)(-q) - c$ and the borrower's incentive constraint is $E(p) - pr + c \geq E(\underline{p}) - \underline{p}r$.

There is reason to think that in general $M'(c) \leq 1$. This would effectively be true if the monitor had at his disposal not only penalties, but also the ability to commit to pay a bonus conditional on project choice. (This is not assumed in the model. Of course, if the borrower could commit to paying the monitor, we would be in the pure cooperative case.) Given these two options, he would use penalties up to the point where their marginal cost reached one. Beyond that, any further incentives would be through bonus payments, since this becomes the cheaper option. In this scenario, $M'(c)$ is bounded above at one.

[27]For the details of the game, see BC. In short, the borrowers decide simultaneously whether or not to repay r in a first stage. If the decision is not unanimous, the borrower who decided in the first stage to repay can revise his decision in a second stage, paying zero or $2r$.

[28]There can actually be multiple equilibria. We assume along with BC that the borrowers' preferred

equilibrium (repayment) is played when multiple equilibria exist.

[29]More precisely, the curve through the lower right AB box of Figure 3 represents $Y_j = \hat{\underline{Y}}(r, Y_i)$. It starts at (a, a) because $\hat{\underline{Y}}[r, \underline{Y}(r)] = \underline{Y}(r)$, since Λ_i is zero there. From (a, a), $Y_j = \hat{\underline{Y}}(r, Y_i)$ is strictly decreasing, because Λ_i strictly increases as Y_i increases for $Y_i \in (\underline{Y}(r), \underline{Y}(2r))$, raising unofficial penalties on borrower j and making him willing to repay with lower and lower output realizations. The curve ends at (b, z), where $z = \hat{\underline{Y}}(r, b)$. We know that $z > 0$ because at $Y_j = 0$ no penalties of either kind are imposed on borrower j; the point of indifference must therefore be at some positive output level. The line through the upper left AB box corresponds analogously to $Y_i = \hat{\underline{Y}}(Y_j)$, giving the symmetry about the 45-degree line.

[30]This may seem troubling if unofficial penalties are viewed as confiscation of output. This is not the interpretation, however; even under the original assumption A14, unofficial penalties can exceed any bound on a borrower who realizes near-zero output.

[31]We could obtain a similar result to the one we derive here without modifying assumption A14, but the conditions would be more complicated without adding anything substantive.

[32]The comparison is clear with the earlier, simpler example in section 3.1.4 and below in section 3.4.6.

[33]No perfectly general results are available. It is possible to introduce strong positive correlation in an irrelevant area of the distribution, that of high returns, and small negative correlation in the area of low returns, creating a situation of net positive correlation coupled with higher repayment rates. The reverse could be done just as easily.

[34]Note that though our base function g required only the distance $|Y_i - Y_j|$, we end up with a distorted function γ that requires the individual values Y_i and Y_j. This is because adding mass proportional only to the distance $|Y_i - Y_j|$ would alter the unconditional distributions. To see this, one can compare the vertical slices of the unit square when $Y_i = 0$ and $Y_i = 1/2$, respectively. The distance $|Y_i - Y_j|$ on the former slice varies from zero to one, and on the latter slice from zero to one half. Clearly, if the mass added strictly increases with distance $|Y_i - Y_j|$, it cannot sum to zero over both of these slices. In other words, $2\int_0^{1/2} \gamma(x)dx = \int_0^1 \gamma(x)dx$ is impossible if γ is strictly increasing. Thus corrections are made to γ through equation 28 to add more weight than the distance term alone would imply, near the boundaries of the square.

[35]Even under our assumption on covariance, no simple result appears to be available without restricting attention to box A of Figure 3. To see this, consider the case where $\underline{Y}(2r) \equiv b = 1$ and unofficial penalties are negligible, so that boxes A and AB lead to default. The area of repayment is then the box complementary to boxes A and AB, in the upper right corner of the support. The same reasoning underlying Proposition 14 would give that this box must increase in mass under an increase in correlation, since $|Y_i - Y_j|$ is on average smaller there than in the overall support. In this case, higher correlation would be associated with higher repayment. This case we do not explore because the required assumptions, that b is near 1 and that unofficial penalties are weak, must be made jointly on $F()$, r, c^o, and c^u, and are thus less general.

[36]If the lender observed risk-type, it would vary the interest rate by type, eliminating cross-subsidization of risky borrowers by safe ones and thus the adverse selection problem. Observing output would be equivalent to observing risk-type if E is known, since by assumption A17, $p = E/Y(p)$.

[37]That is, the cross partial with respect to p and p' is positive.

[38]For a direct test of this adverse selection result, see Ahlin and Townsend (2003).

[39]This is true unless the change is in $\underline{p}$ or $g(p)$, which influence $\tilde{p}$ directly and not through $\hat{p}$.

[40]This is actually the upper bound for $\hat{p}'$. If equation 34 has multiple solutions (which is possible for a density with sufficiently pronounced spikes) any of the solutions can be the equilibrium cutoff type, depending on borrower expectations. It is possible to show that if equation 33 has a solution, so does equation 34.

[41]We assume borrowers can see how many people are borrowing, B say, and can then infer the cutoff risk-type as $\hat{p}' = G^{-1}(B)$. Their expected partner risk-type is thus $\tilde{p}'$.

[42]Specifically, we envision the lender offering a loan, and the borrower then making a binding counteroffer less than or equal to the lender's offer. In keeping with our past treatment of the lender, we assume it does not use the counteroffer to infer the borrower's risk-type and adjust contract terms toward some zero-profit condition.

[43]For $L > 0$, note that $0 < LF'(L) < F(L) - F(0)$, where the first inequality is because F is strictly in-

creasing and the second because F is strictly concave. Since $LF'(L)$ is sandwiched by two terms approaching zero as $L \to 0$, clearly it does also.

[44]In that case, the borrowing payoff at $L = 0$ would be at least as high as $\underline{u}$; and by Inada conditions on F, it can be increased by a small loan.

[45]When $\hat{p} < \check{p}$, that is when inequality 40 is satisfied, this issue does not arise and $E(p|p \le \hat{p})$ suffices. The reason is that for those loan sizes, all types in $[\underline{p}, \hat{p}]$ would prefer a loan greater than L, so we know none of them was offered more than L but accepted only L.

[46]In the same spirit as the analysis of previous models, in which we do not impose a zero-profit constraint, we assume the lender's offer of (maximum) loans varies exogenously across groups.

[47]Differentiability of G is not necessary, but used for convenience.

[48]Of course, if the productivity augmented the outside payoff more steeply than the borrowing payoff (violating assumption A19), the result of proposition 19 could easily be overturned.

[49]We do this because in order to continue to assign non-negative probability to the asymmetric events, ϵ must not exceed $p(1-p')$ and $p'(1-p)$ for every (p, p') combination. If p or p' can equal one, ϵ is then capped at zero, which is not interesting. Under assumption A21, one can verify that $\epsilon \le \underline{p}(1-\overline{p})$ is necessary (and sufficient if $\epsilon \ge 0$) to ensure non-negative probabilities for every event under assumption A20.

[50]For non-homogeneous groups, that is those for whom $p \ne p'$, ρ is not the correlation coefficient, but something closely related: it is the correlation, expressed as a fraction of the maximum correlation possible given individual probabilities of p and p'. In general, the *maximum* correlation coefficient across two projects (p, p'), call it $\overline{\rho}(p, p')$, is equal to

$$\overline{\rho}(p, p') = \min\{\sqrt{\frac{p(1-p')}{p'(1-p)}}, \sqrt{\frac{p'(1-p)}{p(1-p')}}\}.$$

Further, the correlation coefficient corresponding to the $\epsilon(p, p')$ of assumption A22 can be shown to equal $\rho * \overline{\rho}(p, p')$. Thus ρ has the interpretation described above, and it can vary freely from zero to one. Of course, it is clear from the formula that $\overline{\rho}(p, p) = 1$, so for homogeneous groups, ρ is just the correlation coefficient.

[51]For details, see Ahlin and Townsend (2002). This can be checked by showing that under either correlation assumption and homogeneous matching, a risky borrower would not be willing to pay enough to attract a safe borrower away from his safe partner. More precisely, if $\Pi(p, p')$ is the payoff for a borrower of type p matching with one of type p', one can show $\Pi(p, p') - \Pi(p, p) < \Pi(p', p') - \Pi(p', p)$ for $p' > p$. For the result to hold under assumption A22, we must restrict $\rho \ge 0$.

[52]Specifically, if $P(T)$ is the probability of not having defaulted in T years given an annual probability of not defaulting of p, then $P(T) = p^T$. Further, $P'(T) = \ln(p)p^T < 0$ and $P''(T) = [\ln(p)]^2 p^T > 0$. Thus the function is decreasing at a decreasing rate (in absolute value), as is the (negative) natural log.

[53] Let p be the probability of realizing output "Hi" and $1-p$ be the probability of realizing output "Lo". Given that the expected value must be "Ex", we know $pHi + (1-p)Lo = Ex$. This gives that $p = (Ex - Lo)/(Hi - Lo)$. The variance σ^2 is, using definitions, $p(Hi - Ex)^2 + (1-p)(Ex - Lo)^2$. Substituting in our expression for p in terms of Hi, Lo, and Ex, the variance simplifies to

$$\sigma^2 = (Hi - Ex)(Ex - Lo).$$

Dividing by $(Ex)^2$ and taking the square root, we calculate the household's coefficient of variation to be $\sqrt{Hi/Ex - 1}\sqrt{1 - Lo/Ex}$.

[54]One rai is approximately equal to 0.4 acres.

[55]It is calculated as follows. The number of different pairs of villagers in village v with N_v respondents is

$$\binom{N_v}{2} = N_v(N_v - 1)/2.$$

Similarly, if N_{vy} is the number of year-y respondents in village v, then the number of different pairs of v villagers in which both respondent indicated year y is N_{vy} choose 2, or $N_{vy}(N_{vy} - 1)/2$. Since the question is asked about the previous five years, the measure works out to be

$$\frac{\sum_{y=1}^{5} N_{vy}(N_{vy}-1)/2}{N_v(N_v-1)/2} = \frac{(\sum_{y=1}^{5} N_{vy}^2) - N_v}{N_v^2 - N_v} = \frac{(\sum_{y=1}^{5} s_{vy}^2) - 1/N_v}{1 - 1/N_v},$$

where $s_{vy} = N_{vy}/N_v$ is the share of villagers in village v who named year y as the worst.

[56]In measuring outside borrowing opportunities, we shy away from using *actual borrowing by the group* from other sources. This is not for lack of data, but because borrowing can be a sign of repayment problems. It is not uncommon to borrow in order to repay one BAAC debt and enable another. Instead we use measures of *loan availability in the village* from alternate sources in the village. This is presumably much less a function of a single group's repayment problems than is that group's current loans from other sources.

[57]PCGs also might be thought of as a measure of cooperation in the village, since they are essentially completely run by villagers, though formation is often spurred by local community development workers. They may measure to some degree the unity and civic pride of the community.

[58]Recall there are two regions represented in the sample. The more rural and poorer northeast region includes provinces Buriram and Srisaket, while the central region includes Chachoengsao and Lopburi, closer to Bangkok.

[59]Needless to say, partitioning into more than two subsamples and comparing across each combination of subsamples is also possible. However, for simplicity of reporting and interpreting the results, among other reasons, we focus our attention on partitions of the sample into two subsamples.

[60]Note that due to the requirement of strict inequality, there are fewer partitions that satisfy this condition the smaller the number of values the independent variable can take on. For example, SHAREREL, the measure of sharing among group members, is an index equalling the sum of five dummy variables. Thus there will be at most five partitions of the sample based on SHAREREL that satisfy strict inequality in SHAREREL across the subsamples. (These involve setting 0 as low and 1-5 as high, setting 0-1 as low and 2-5 as high, and so on.)

If we only required weak inequality, the number of partitions would in general increase the smaller the number of values the independent variable takes on. This is because ties are allowed across the high and low subsamples, and thus there is an indeterminacy that can be resolved in multiple ways.

[61]We recognize that this is an unusually low standard but report results so as to compare to the other methods. There are five entries in Table 4.3b significant at a 15% level but not higher.

[62]Future research could extend these models to incorporate what in this paper are control variables.

[63]If there are clusters of observations at the boundary of the bandwidth with the same value for the independent variable, all are included. Thus potentially more than 80% of the sample is used.

[64]Note that the Yatchew procedure identifies the function up to a constant. De-meaning the residuals is then essentially a normalization of each bootstrapped estimate with respect to the constants. Without this normalization, bootstrap error bands can get large merely because the constants are varying.

[65]KNOWTYPE does not appear in Table 4.3a because there were not fifteen groups responding negatively to the question, and thus two bins of sufficient size could not be constructed.

[66]RELATPCT can also be taken as a proxy for cooperation.

[67]One worry is that the prevalence of PCGs may indicate that an area has been abandoned by institutional lenders. This would lead to a potential endogeneity problem, if bad repayment is affected by some village-level variable we do not observe but these institutional lenders do. However, this does not appear to be the case, as there appears to be a positive, not negative, correlation between village borrowing from the BAAC and PCG prevalence. We calculate a correlation coefficient of 0.072 between percentage of villagers' loans that come from the BAAC with percentage of villagers who are PCG members.

[68]However, commercial banks typically serve a different segment of the capital market, borrowers with legal collateral. Thus it is not surprising the result is weak.

[69]Oddly, SHAREREL becomes a positive and significant predictor of repayment in the multivariate logit. It is clear that this result is only due to the controlling for sharing among non-relatives, SHAREUNR. If we exclude sharing among non-relatives from an otherwise unaltered logit regression, the sign on SHAREREL

becomes negative, though insignificant. Thus the result suggests that sharing per se within the group is bad for repayment; but holding fixed sharing among non-relatives, sharing among relatives is good for repayment. Explaining this result seems to require a theory far more precise than a casual invoking of "social capital".

[70]Two variables that are primarily classified in other categories, RELATPCT in cost of monitoring and PCGMEM in outside borrowing options, may also capture the degree of cooperation in the group. One might think it easier to make binding ex ante agreements among relatives, and the existence of PCGs is evidence of a certain level of self-enforcement in the village. These variables also show significant negative relationships with repayment, as mentioned above.

[71]Under this interpretation, JOINTDCD could fit under the heading of borrower productivity, and a positive sign would thus match our other results and all the models' predictions. Varian (1990) examines incentives for the transfer of human capital between jointly liable borrowers.

[72]However, BBG is also a moral hazard model, but can predict the opposite effect of cooperation. It is also a model of costly penalty imposition as is BC, and this drives the result on cooperation.

[73]One fact that supports both interpretations is that the correlation of JOINTDCD with each of the other measures of cooperation is statistically insignificant. Thus JOINTDCD appears to be measuring a different type of cooperation or a different phenomenon entirely.

[74]See the Rahman's (1999) study of Grameen borrowers. Of course, if they still borrow, they should be better off doing so than not.

References

[1] Christian R. Ahlin and Robert M. Townsend. Using repayment data to test across theories of joint liability lending. Working Paper, December 2002.

[2] Christian R. Ahlin and Robert M. Townsend. Selection into and across contracts: Theory and field research. Working Paper, September 2003.

[3] Beatriz Armendariz de Aghion. On the design of a credit agreement with peer monitoring. *Journal of Development Economics*, 60(1):79–104, October 1999.

[4] Abhijit V. Banerjee, Timothy Besley, and Timothy W. Guinnane. Thy neighbor's keeper: The design of a credit cooperative with theory and a test. *Quarterly Journal of Economics*, 109(2):491–515, May 1994.

[5] Timothy Besley and Stephen Coate. Group lending, repayment incentives and social collateral. *Journal of Development Economics*, 46(1):1–18, February 1995.

[6] W. S. Cleveland. Robust locally weighted regression and smoothing scatterplots. *Journal of the American Statistical Association*, 74:829–836, 1979.

[7] Jianqing Fan. Design-adaptive nonparametric regression. *Journal of the American Statistical Association*, 87(420):998–1004, December 1992.

[8] Maitreesh Ghatak. Group lending, local information and peer selection. *Journal of Development Economics*, 60(1):27–50, October 1999.

[9] Bengt Holmstrom and Paul Milgrom. Regulating trade among agents. *Journal of Institutional and Theoretical Economics*, 146(1):85–105, March 1990.

[10] H. Ichimura. Semiparametric least squares (sls) and weighted sls estimation of single-index models. *Journal of Econometrics*, 58:71–120, 1993.

[11] Joseph Kaboski and Robert M. Townsend. Borrowing and lending in semi-urban and rural thailand. Mimeo, 1998.

[12] Edward Simpson Prescott and Robert M. Townsend. Collective organizations versus relative performance contracts: Inequality, risk sharing, and moral hazard. *Journal of Economic Theory*, 103(2):282–310, April 2002.

[13] Aminur Rahman. Micro-credit initiatives for equitable and sustainable development: Who pays? *World Development*, 27(1):67–82, January 1999.

[14] Manohar Sharma and Manfred Zeller. Repayment performance in group-based credit programs in bangladesh: An empirical analysis. *World Development*, 25(10):1731–1742, October 1997.

[15] Joseph E. Stiglitz. Peer monitoring and credit markets. *World Bank Economic Review*, 4(3):351–366, September 1990.

[16] Robert M. Townsend and Jacob Yaron. The credit risk-contingency system of an asian development bank. *Federal Reserve Bank of Chicago Economic Perspectives*, XXV:31–48, 2001.

[17] Hal R. Varian. Monitoring agents with other agents. *Journal of Institutional and Theoretical Economics*, 146(1):153–174, March 1990.

[18] Quang H. Vuong. Likelihood ratio tests for model selection and non-nested hypotheses. *Econometrica*, 57(2):307–333, March 1989.

[19] Mark D. Wenner. Group credit: A means to improve information transfer and loan repayment performance. *Journal of Development Studies*, 32(2):263–281, December 1995.

[20] Bruce Wydick. Can social cohesion be harnessed to repair market failures? evidence from group lending in guatemala. *Economic Journal*, 109(457):463–475, June 1999.

[21] Adonis Yatchew. Nonparametric regression techniques in economics. *Journal of Economic Literature*, 36:669–721, June 1998.

[22] Manfred Zeller. Determinants of repayment performance in credit groups: The role of program design, intragroup risk pooling, and social cohesion. *Economic Development and Cultural Change*, 46(3):599–620, April 1998.

A Proofs

Proof of Proposition 7. Totally differentiating Monitoring Equation 15 gives that

$$\frac{\partial p}{\partial L} = \frac{q - M''(c)c_p c_L - M'(c)c_{pL}}{M''(c)c_p^2 + M'(c)c_{pp}}. \tag{46}$$

An argument analogous to that of the proof of proposition 5 shows that the denominator is strictly positive. To sign the numerator, note from equation 15 that $q = M'(c)c_p/L$. Substituting this in and rearranging gives

$$M'(c)[c_p/L - c_{pL}] - M''(c)c_p c_L \tag{47}$$

as the expression that must be signed.

Since M is strictly increasing, $M'(c) > 0$. Differentiations of equation 14 give that

$$c_p/L - c_{pL} = E'(p)[F'(L) - F(L)/L].$$

Assumption A10 gives that $E'(p) \geq 0$. Since $F(0) = 0$ and F is strictly concave, it is clear that $F'(L) < F(L)/L$. Thus the first term in the sum of expression 47 is strictly negative.

Turning to the second term, strict convexity of M gives that $M''(c) > 0$. Differentiations of equation 14 give that $c_p = rL - E'(p)F(L)$, strictly positive by assumption A10, and

$$c_L = r(p - \underline{p}) - F'(L)[E(p) - E(\underline{p})]. \tag{48}$$

Clearly at $p = \underline{p}$, c_L is zero. For c_L to be positive when $p > \underline{p}$, the condition needed is

$$F'(L) \leq \frac{r(p - \underline{p})}{E(p) - E(\underline{p})}. \tag{49}$$

Now $[E(p) - E(\underline{p})]/(p - \underline{p})$ is the average product (in terms of per unit expected output) of an increase in p. Since $E(p)$ is concave, by assumption A10, this average product is decreasing in p. Condition 49 contains the inverse of this average product, and therefore the bound is tightest as $p \to \underline{p}$. Thus if c_L is ever strictly negative, it must be so on an interval $(\underline{p}, p)$. But we know that $c_L = 0$ at $p = \underline{p}$; and since c_L is continuous in p (see equation 48), it is impossible for it to go strictly negative on some interval $(\underline{p}, p)$. Therefore, c_L must be positive and the whole second term of expression 47 negative. This signs $\partial p/\partial L$ as negative.

Outside credit options can be interpreted as an increase in L identical to the above analysis, as long as the outside loan is at r and q, *and* the outside loan is monitored by the same monitor. If it is monitored by a different monitor, the result may not hold, since liability is linear in loan size but cost of monitoring is convex. This would lead to higher total monitoring if the liability is split between two monitors rather than confined to one. ■

Proof of Proposition 12. Equation 23 can be rewritten to express the probability of default, $1 - p$, as

$$1 - p = [F(a)]^2 + 2\int_a^b F[\hat{\underline{Y}}(Y)]dF(Y),$$

where $a \equiv \underline{Y}(r)$, $b \equiv \underline{Y}(2r)$, and the argument r is suppressed from $\hat{\underline{Y}}$. This can be further manipulated to get

$$(1-p)/2 = \int_0^a F(Y)dF(Y) + \int_a^b F[\hat{\underline{Y}}(Y)]dF(Y). \tag{50}$$

Next we transform equation 50 from an integral over output space to one over output-percentile space, since the measure over the latter space is the same for both groups. Specifically, let $z = F(Y)$, so that $dz = dF(Y)$ and $Y = F^{-1}(z)$. Making these substitutions in equation 50 allows us to write

$$(1-p)/2 = \int_0^{F(a)} zdz + \int_{F(a)}^{F(b)} F[\hat{\underline{Y}}(F^{-1}(z))]dz. \tag{51}$$

Define Δ as the difference in probabilities of default (scaled by two): $\Delta \equiv (1-p_1)/2 - (1-p_2)/2$. Showing that $\Delta > 0$ will establish that group 1 has a higher probability of default.

In the case where $F_1(a) \leq F_2(b)$,[1] Δ can be written, using equation 51, as

$$\begin{aligned}\Delta = &\int_0^{F_2(a)} (z-z)dz + \int_{F_2(a)}^{F_1(a)} \{z - F_2[\hat{\underline{Y}}(F_2^{-1}(z))]\}dz \\ &\int_{F_1(a)}^{F_2(b)} \{F_1[\hat{\underline{Y}}(F_1^{-1}(z))] - F_2[\hat{\underline{Y}}(F_2^{-1}(z))]\}dz + \int_{F_2(b)}^{F_1(b)} F_1[\hat{\underline{Y}}(F_1^{-1}(z))]dz.\end{aligned} \tag{52}$$

The first integral is clearly zero. The fourth integral is clearly non-negative. For the second integral, note that $F_2^{-1}(z) > a$ for $z > F_2(a)$. Next, recall that the cutoff $\hat{\underline{Y}}(r,Y) < \underline{Y}(r) \equiv a$ when $Y > a$, since both unofficial and official penalties will be imposed. Thus, $\hat{\underline{Y}}(F_2^{-1}(z)) < a$. Clearly then, $F_2[\hat{\underline{Y}}(F_2^{-1}(z))] < F_2(a)$. Since z is ranging from $F_2(a)$ upwards, the second integral must be positive, strictly so if $F_1(a) > F_2(a)$. Considering the third integral, note that $F_1^{-1}(z) \leq F_2^{-1}(z)$, that is a given percentile z means a lower output for a group 1 member than a group 2 member due to dominance. Since $\hat{\underline{Y}}$ is decreasing in Y, we know that $\hat{\underline{Y}}(F_1^{-1}(z)) \geq \hat{\underline{Y}}(F_2^{-1}(z))$. Hence, $F_1[\hat{\underline{Y}}(F_1^{-1}(z))] \geq F_2[\hat{\underline{Y}}(F_1^{-1}(z))] \geq F_2[\hat{\underline{Y}}(F_2^{-1}(z))]$, where the first inequality is from stochastic dominance, and the third integral is positive. Thus Δ must be positive.

The case where $F_1(a) > F_2(b)$ gives

$$\Delta = \int_{F_2(a)}^{F_2(b)} \{z - F_2[\hat{\underline{Y}}(F_2^{-1}(z))]\}dz + \int_{F_2(b)}^{F_1(a)} zdz + \int_{F_1(a)}^{F_1(b)} F_1[\hat{\underline{Y}}(F_1^{-1}(z))]dz. \tag{53}$$

Similar arguments establish Δ strictly positive in this case. Thus sufficient in both cases for Δ to be strictly positive is that $F_1(a) > F_2(a)$. ■

Proof of Lemma 2. Take first a continuous joint density $\phi(Y_i, Y_j)$ that preserves unconditional density f for Y_i and Y_j. If $\phi(Y_i, Y_j) = f(Y_i)f(Y_j)$, then setting $\kappa = 0$ and $g(Y_i, Y_j) = 0$

[1] We know that $0 < F_2(a) \leq F_1(a) < F_1(b)$ and that $0 < F_2(a) < F_2(b) \leq F_1(b)$. However, it is not clear whether $F_1(a)$ or $F_2(b)$ is greater.

works. Otherwise, take κ as strictly positive but arbitrarily close to zero. Then note that setting $g(Y_i, Y_j) = [\phi(Y_i, Y_j) - f(Y_i)f(Y_j)]/\kappa$ satisfies equation 27. This is because integrating out Y_i, Y_j, or both, produces zero. In the case of Y_i, we have

$$\int_0^1 g(Y_i, Y_j)dY_i = (1/\kappa)\int_0^1 [\phi(Y_i, Y_j) - f(Y_i)f(Y_j)]dY_i = (1/\kappa)[f(Y_j) - f(Y_j)] = 0,$$

where the middle equality is due to the fact that $\phi(Y_i, Y_j)$ preserves unconditional density f for Y_j. The same kind of equation holds for Y_j. Finally, g is continuous because ϕ and f are.

Next take any continuous function $g(Y_i, Y_j)$. The function $\phi(Y_i, Y_j)$ defined using $g(Y_i, Y_j)$ in equation 27 is continuous because f and g are. Further, it is a joint density function as long it stays non-negative and integrates to one over Y_i and Y_j together. Finally, it preserves unconditional density f as long as it integrates over Y_i to $f(Y_j)$ and over Y_j to $f(Y_i)$.

Note that non-negativity is satisfied as long as κ is close enough to zero. This because $f(Y)$ is strictly positive and continuous, and thus $f(Y_i)f(Y_j)$ is bounded below by a strictly positive number on the (compact) unit square; and the bracketed term of equation 27 is bounded below on the unit square because $g(Y_i, Y_j)$ is continuous. Thus however negative the bracketed term is, κ can be set low enough to make the subtracted amount small compared to $f(Y_i)f(Y_j)$. Note also from integrating equation 27 with respect to Y_i that

$$\int_0^1 \phi(Y_i, Y_j)dY_i = \int_0^1 f(Y_i)f(Y_j)dY_i + \kappa[\int_0^1 g(Y_i, Y_j)dY_i - \int_0^1 g(Y_i, Y_j)dY_i$$
$$- \int_0^1\int_0^1 g(Y_i, Y_j)dY_i dY_j + \int_0^1\int_0^1 g(Y_i, Y_j)dY_i dY_j] = f(Y_j).$$

Similarly, $\int_0^1 \phi(Y_i, Y_j)dY_j = f(Y_i)$. Thus the unconditional densities are preserved. Finally, this fact implies that $\phi(Y_i, Y_j)$ must integrate to one over Y_i and Y_j together. ■

Proof of Proposition 14. For convenience, define $a \equiv \underline{Y}(r)$ and $b \equiv \underline{Y}(2r)$. Modifying equation 23 to get the repayment rate in the case of generalized joint density function $\phi(Y_i, Y_j; \kappa)$ gives

$$p(\kappa) = 1 - \int_0^a\int_0^a \phi(Y_i, Y_j; \kappa)dY_i dY_j - 2\int_a^b\int_0^{\hat{\underline{Y}}(Y_i)} \phi(Y_i, Y_j; \kappa)dY_j dY_i, \quad (54)$$

where the dependence of $\hat{\underline{Y}}$ on r is suppressed. From equations 27 and 28, which write $\phi(Y_i, Y_j; \kappa) = f(Y_i)f(Y_j) + \kappa\gamma(Y_i, Y_j)$, we get that $d\phi/d\kappa = \gamma(Y_i, Y_j)$. Using this in equation 54 gives

$$dp/d\kappa = -[\int_0^a\int_0^a \gamma(Y_i, Y_j)dY_i dY_j + 2\int_a^b\int_0^{\hat{\underline{Y}}(Y_i)} \gamma(Y_i, Y_j)dY_j dY_i\ ]. \quad (55)$$

This equation merely says that the effect of higher correlation on p is inversely related to the amount of mass that the introduced correlation adds to the Default Region. Our strategy is to show that the first double integral (corresponding to box A in Figure 3) is strictly positive and that the second double integral is close enough to zero as unofficial penalties get sufficiently severe.

Carrying out the first integration in equation 55 using the expression for $\gamma(Y_i, Y_j)$ of equation 29 gives

$$\int_0^a \int_0^a \gamma(Y_i, Y_j) dY_i dY_j = 2a(1-a) \sum_{k=1}^{N} \beta_k \frac{1 - a^{\alpha_k+1} - (1-a)^{\alpha_k+1}}{(\alpha_k+1)(\alpha_k+2)} \equiv \mathcal{A},$$

say. Clearly $\mathcal{A}$ is strictly positive as long as $1 - a^{\alpha_k+1} - (1-a)^{\alpha_k+1}$ is, since $\alpha_k, \beta_k > 0$ and $a \in (0,1)$. Considering $1 - a^{\alpha_k+1} - (1-a)^{\alpha_k+1}$, note that it equals zero at $\alpha_k = 0$ and is continuous and strictly increasing in α_k.[2] Since $\alpha_k > 0$, this term, and hence $\mathcal{A}$, is strictly positive.

Call the second double integral in equation 55 $\mathcal{AB}$. Let $\underline{\gamma}$ be the minimum value $\gamma(Y_i, Y_j)$ (a continuous function) can take over its (compact) domain $[0,1]^2$. Inspection of equation 55 reveals that

$$\mathcal{AB} \geq 2\underline{\gamma} \int_a^b \int_0^{\underline{\hat{Y}}(Y_i)} dY_j dY_i. \tag{56}$$

Note that if $\underline{\gamma}$ were not negative, $\mathcal{AB}$ would be positive and the proof would be complete ($dp/d\kappa$ signed as negative). We thus consider only the case where $\underline{\gamma} < 0$.

Next define

$$\epsilon \equiv \min\{\frac{\mathcal{A}}{2|\underline{\gamma}|b}, \frac{b-a}{2}\} \tag{57}$$

and assume unofficial penalties are strong enough to satisfy[3]

$$c^o(\epsilon) + c^u(\epsilon, c^o(a+\epsilon) - r) \geq r. \tag{58}$$

Condition 58 implies that $\underline{\hat{Y}}(a+\epsilon) \leq \epsilon$, ensuring that a borrower, i say, who realizes output ϵ and whose partner j realizes $a+\epsilon$[4] will face total penalties of at least r. The point of indifference for borrower i, $\underline{\hat{Y}}(a+\epsilon)$, is thus no higher than ϵ, since total penalties on him would only be higher with higher output.

As argued in section 3.3, $\underline{\hat{Y}}(Y)$ is strictly decreasing from a to some $z > 0$ as Y increases from a to b. Using this and the fact that $\underline{\hat{Y}}(a+\epsilon) \leq \epsilon$, we know that $\underline{\hat{Y}}(Y) \leq a$ for $Y \in [a, a+\epsilon]$ and $\underline{\hat{Y}}(Y) \leq \epsilon$ for $Y \in [a+\epsilon, b]$.[5] It follows that

$$\int_a^b \int_0^{\underline{\hat{Y}}(Y_i)} dY_j dY_i \leq \int_a^{a+\epsilon} \int_0^a dY_j dY_i + \int_{a+\epsilon}^b \int_0^\epsilon dY_j dY_i = \epsilon(b-\epsilon) < b\epsilon.$$

Recalling that $\underline{\gamma} < 0$, this inequality can be rewritten as

---

[2] Its derivative with respect to α_k is $-[\ln(a)]a^{\alpha_k+1} - [\ln(1-a)](1-a)^{\alpha_k+1}$. This is strictly positive because $a \in (0,1)$.

[3] Unofficial penalties this strong need not violate assumption A14 because $\epsilon > 0$ and $c^o(a+\epsilon) - r > 0$, since $c^o(a) = r$ by construction and c^o is strictly increasing. Thus such a severe unofficial penalty function is possible, requiring only that $c^u(Y, \Lambda)$ increase fast enough in either argument.

[4] Note that since $a < a+\epsilon < b$, the loss to borrower j equals $\Lambda(a+\epsilon) = c^o(a+\epsilon) - r$.

[5] Graphically, we have merely pinned the Default Curve running through the lower right AB box in Figure 3 below the point $(a+\epsilon, \epsilon)$, and symmetrically for the upper right AB box.

$$2\underline{\gamma}\int_a^b \int_0^{\hat{\underline{Y}}(Y_i)} dY_j dY_i > 2\underline{\gamma} b\epsilon.$$

Combining this with inequality 56 gives that $\mathcal{AB} > 2\underline{\gamma} b\epsilon$. Finally, equation 57 defining ϵ gives that $\epsilon \leq \mathcal{A}/[2|\underline{\gamma}|b]$. Combining these last two inequalities, given that $\underline{\gamma} < 0$, gives

$$\mathcal{AB} > 2\underline{\gamma} b\epsilon \geq 2\underline{\gamma} b\mathcal{A}/[2|\underline{\gamma}|b] = -\mathcal{A}. \tag{59}$$

Thus $\mathcal{A} + \mathcal{AB} > 0$ and $dp/d\kappa$, expressed in equation 55, is negative. ■

B Figures and Tables

Table 4.2a - Independent Variables

Variables marked with an asterisk are taken or constructed from the household-level survey, HH. All others are from the group-level survey, BAAC.

Variable	Description	Mean	(σ)
Control:			
LNYRSOLD	Number of years group has existed (Log)	11.4[a]	(8.5)
VARIBLTY*	Village average coefficient of variation for next year's expected income	0.30	(0.09)
WEALTH*	Village average wealth (million 97 Thai baht)	1.1	(2.1)
MEMBERS	Number of members in the group	12.3	(5.1)
Fundamentals:			
r	Average interest rate faced by the group	10.9	(2.0)
L	Average loan size borrowed by the group (thousand 97 Thai baht)	18.7	(18.3)
q	Percent landless in the group	0.06	(0.15)

[a]Here the mean and standard deviation are for age, not log of age.

Table 4.2b - Independent Variables

Variables marked with an asterisk are taken or constructed from the household-level survey, HH. All others are from the group-level survey, BAAC.

Variables marked with a † might also be included under the next set of variables; variables marked with a ‡ might also be included under the previous set.

Variable	Description	Mean	(σ)
Productivity:			
AVGLAND	Average landholdings of group members (rai)	23.6	(15.7)
EDCATION	Index of group average education levels	3.1[a]	(0.32)
Screening:			
SCREEN	Do some want to join this group but cannot?	0.39	
KNOWTYPE	Do group members know the quality of each other's work?	0.94	
Covariance:			
COVARBTY*	Measure of coincidence of economically 'bad' years across villagers	0.28	(0.16)
HOMOCCUP†	Measure of occupational homogeneity within the group	0.87	(0.24)
Cost of Monitoring:			
LIVEHERE	Percent of group living in the same village	0.88	(0.22)
RELATPCT†	Percent of group members having a close relative in the group	0.58	(0.36)
Cooperation:			
SHAREREL	Measure of sharing among closely related group members	2.1	(1.6)
SHAREUNR	Measure of sharing among unrelated group members	1.5	(1.4)
BCOOPPCT*	Percent in tambon naming this village best in the tambon for "cooperation among villagers"	0.25	(0.11)
JOINTDCD	Number of decisions made collectively	0.37	(0.91)
Outside Credit Options:			
PCGMEM*‡	Percent in village claiming Production Cooperative Group membership	0.08	(0.16)
CBANKMEM*	Percent in village claiming to be clients of a commercial bank	0.28	(0.18)
Penalties for default:			
BINSTPCT*‡	Percent in tambon naming this village best in the tambon for "availability and quality of institutions"	0.27	(0.19)
SNCTIONS*	Percent of village loans where default is punishable by informal sanctions	0.10	(0.11)

[a] See text for the interpretation of this education index.

Table 4.3a - Univariate Mean Comparisons

For each independent variable, the sample was partitioned into two subsamples as many ways as possible satisfying 1) no subsample had less than fifteen groups and 2) each group in one subsample had strictly higher values for the independent variable than each group in the other subsample. For each partition, a significant difference in the mean of the dependent variable across subsamples was tested for, at the 90% level. (Recall that the dependent variable equals one if the group has never had its interest raised as a penalty for late payment.) The table lists the percentage of partitions for a given independent variable producing significant mean differences, with the sign indicating a positive or negative relationship.

Variables that could be included in the next group are denoted by a †; in the previous group by a ‡.

	Percent of tests significant at 90%, with sign						Total Tests		
	Northeast groups		Central groups		All groups		NE	CE	All
Control:	(+)	(−)	(+)	(−)	(+)	(−)			
LNYRSOLD	0%	83%	0%	90%	0%	85%	18	20	26
VARIBLTY	3%	3%	8%	0%	0%	0%	73	50	140
WEALTH	5%	0%	0%	49%	0%	12%	73	51	139
MEMBERS	0%	0%	0%	50%	0%	53%	9	14	17
Fundamentals:									
r	0%	5%	0%	0%	0%	28%	20	16	29
L	0%	3%	0%	0%	0%	9%	37	24	55
q	0%	0%	0%	95%	0%	96%	5	20	27
Productivity:									
AVGLAND	0%	0%	68%	0%	11%	0%	29	34	46
EDCATION	30%	0%	7%	0%	18%	0%	23	14	44
Screening:									
SCREEN	0%	0%	0%	0%	0%	0%	1	1	1
KNOWTYPE	—	—	—	—	0%	0%	0	0	1
Covariance:									
COVARBTY	0%	8%	38%	0%	10%	0%	49	32	71
HOMOCCUP†	0%	0%	0%	0%	0%	0%	11	28	46
Cost of Monitoring:									
LIVEHERE	0%	0%	20%	0%	38%	0%	13	30	42
RELATPCT†	0%	2%	0%	18%	0%	35%	44	39	57
Cooperation:									
SHAREREL	0%	0%	0%	25%	0%	0%	5	4	5
SHAREUNR	0%	0%	0%	67%	0%	50%	4	3	4
BCOOPPCT	0%	3%	0%	0%	0%	2%	60	38	108
JOINTDCD	33%	0%	—	—	100%	0%	3	0	3
Outside Credit Options:									
PCGMEM‡	0%	100%	0%	0%	0%	55%	9	6	11
CBANKMEM	0%	0%	0%	0%	0%	20%	13	9	20
Penalties for Default:									
BINSTPCT‡	0%	0%	8%	0%	0%	0%	63	37	108
SNCTIONS	55%	0%	0%	0%	0%	0%	33	25	51

Table 4.3b - Logit Results

Dependent Variable = 1 if BAAC has never raised the interest rate as a penalty, 0 if it has.

Standard errors in parentheses; significance at 5, 10 and 15% denoted by ***, **, and *, respectively.

Variables that could be included in the next group are denoted by a †; in the previous group by a ‡.

	Northeast groups	Central groups	All groups
	N=130	N=89	N = 219
Control:			
LNYRSOLD	-1.54 (.488)***	-1.61 (.701)***	-0.958 (.282)***
VARIBLTY	1.41 (4.40)	-10.1 (5.82)**	-3.47 (2.66)
WEALTH	1.00 (1.29)	0.125 (.117)	0.026 (.083)
MEMBERS	-0.014 (.089)	0.113 (.079)	0.034 (.047)
Fundamentals:			
r	-0.056 (.142)	-0.385 (.299)	-0.119 (.101)
L	20.4 (48.3)	187.4 (99.8)**	32.9 (30.8)
L^2	-0.319 (.409)	-2.39 (1.42)**	-0.463 (.335)
q	-4.69 (6.76)	-7.69 (3.31)***	-3.65 (1.51)***
Productivity:			
AVGLAND	-0.013 (.026)	-0.007 (.023)	-0.006 (.013)
EDCATION	1.88 (.935)***	0.949 (1.25)	1.28 (.698)**
Screening:			
SCREEN	-0.950 (.624)*	1.17 (.876)	-0.364 (.402)
KNOWTYPE	-1.38 (1.23)	2.24 (2.12)	-0.139 (.773)
Covariance:			
COVARBTY	1.66 (2.13)	1.82 (4.03)	2.05 (1.39)*
HOMOCCUP†	1.39 (1.45)	0.061 (1.69)	0.220 (.858)
Cost of Monitoring:			
LIVEHERE	-0.694 (1.84)	1.01 (1.26)	0.879 (.831)
RELATPCT†	-1.29 (.925)	-0.574 (1.21)	-0.590 (.573)
Cooperation:			
SHAREREL	0.491 (.417)	0.375 (.487)	0.382 (.250)*
SHAREUNR	-0.497 (.410)	-0.586 (.558)	-0.553 (.266)***
BCOOPPCT	-6.65 (3.53)**	-5.12 (5.97)	-2.30 (2.40)
JOINTDCD	0.317 (.358)	1.58 (.765)***	0.499 (.265)**
Outside Credit Options:			
PCGMEM‡	-6.56 (1.98)***	-2.98 (3.42)	-3.81 (1.18)***
CBANKMEM	-2.07 (2.39)	0.206 (2.34)	0.288 (1.21)
Penalties for Default:			
BINSTPCT‡	3.42 (1.91)**	5.24 (3.81)	2.10 (1.36)*
SNCTIONS	12.1 (4.34)***	-1.04 (3.55)	3.18 (1.95)*

Table 4.3c - Summary of Results

Dependent Variable = 1 if BAAC has never raised the interest rate as a penalty, 0 if it has.

Significance in the logit regression at 15, 10, and 5% denoted by one, two, and three arrows, respectively; similarly, significant mean differences at the 10% level in 20, 50, and 80% of the nonparametric, univariate tests denoted by one, two, and three arrows, respectively.

Variables that could be included in the next group are denoted by a †; in the previous group by a ‡.

Predictions that require us to make non-trivial assumptions are marked with a §.

Variable	NE	CE	All	Others'	S	BBG	BC	G
	(Nonparametric,Logit)			Results				
Control:								
LNYRSOLD	↓↓↓,↓↓↓	↓↓↓,↓↓↓	↓↓↓,↓↓↓		np	np	np	np
VARIBLTY	∅,∅	∅,↓↓	∅,∅	↓↑	np	np	np	np
WEALTH	∅,∅	↓,∅	∅,∅	missing	np	np	np	np
MEMBERS	∅,∅	↓↓,∅	↓↓,∅	↑	np	np	np	np
Fundamentals:								
r	∅,∅	∅,∅	↓,∅	missing	↓	↓	↓	↓
L	∅,∅	∅,↑↑↓↓	∅,∅	↓	↓	↓	np	↗↘
q	∅,∅	↓↓↓,↓↓↓	↓↓↓,↓↓↓	missing	↓§	↑	np	↓
Productivity:				↑↓	↑	↑	↑	↑
AVGLAND	∅,∅	↑↑,∅	∅,∅	↑				
EDCATION	↑,↑↑↑	∅,∅	∅,↑↑	∅				
Screening:				↑	np	np	np	↑
SCREEN	∅,↓	∅,∅	∅,∅					
KNOWTYPE	∅,∅	∅,∅	∅,∅					
Covariance:					↑	np	↓§	↑
COVARBTY	∅,∅	↑,∅	∅,↑	missing				
HOMOCCUP†	∅,∅	∅,∅	∅,∅	↓				
Ease of Monitoring:				↑	np	↑	np	np
LIVEHERE	∅,∅	↑,∅	↑,∅	↑				
RELATPCT†	∅,∅	∅,∅	↓,∅	↓↑				
Cooperation:				↑↓	↑	↓§	↓§	—
SHAREREL	∅,∅	↓,∅	∅,↑					
SHAREUNR	∅,∅	↓↓,∅	↓↓,↓↓↓					
BCOOPPCT	∅,↓↓	∅,∅	∅,∅					
JOINTDCD	↑,∅	∅,↑↑↑	↑↑↑,↑↑					
Outside Credit Options:				↓↑	↓	↓	np	np
PCGMEM‡	↓↓↓,↓↓↓	∅,∅	↓↓,↓↓↓					
CBANKMEM	∅,∅	∅,∅	↓,∅					
Penalties for Default:								
BINSTPCT‡	∅,↑↑	∅,∅	∅,↑	missing	np	np	↑	np
SNCTIONS	↑↑,↑↑↑	∅,∅	∅,↑	↑	np	np	↑	np

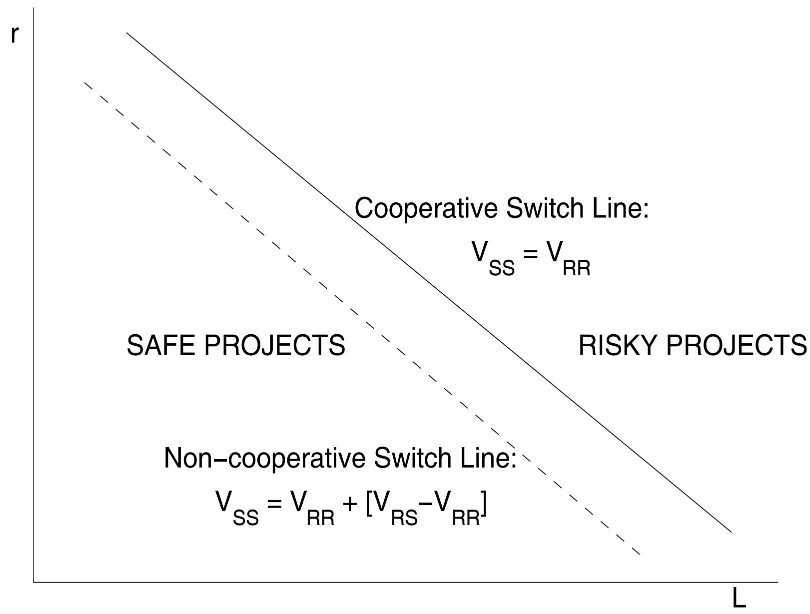

Figure 1: **The Switch Line**. To the left of the solid line, safe projects are chosen, to the right risky ones. The dashed line is the Switch Line for groups acting non-cooperatively, discussed in section 3.1.2.

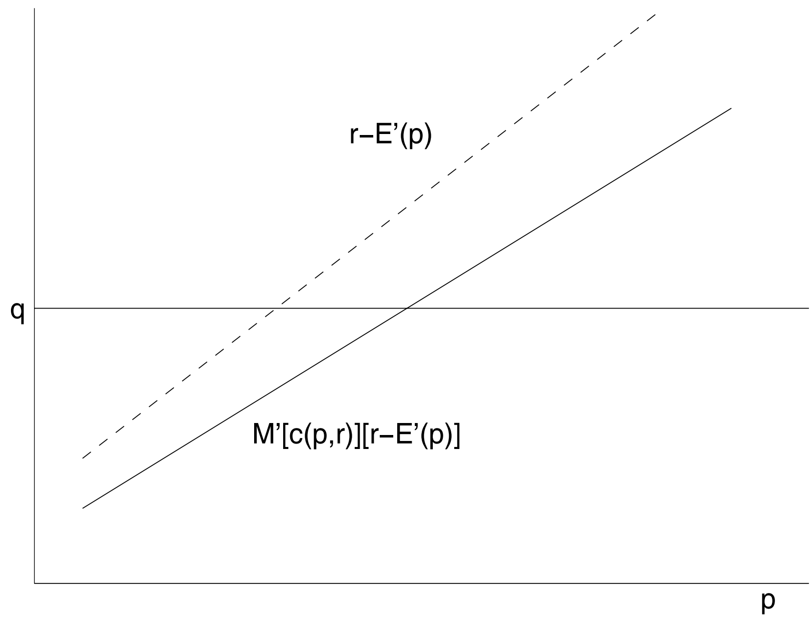

Figure 2: Determination of p under costly monitoring (solid line) and costless cooperation (dashed line).

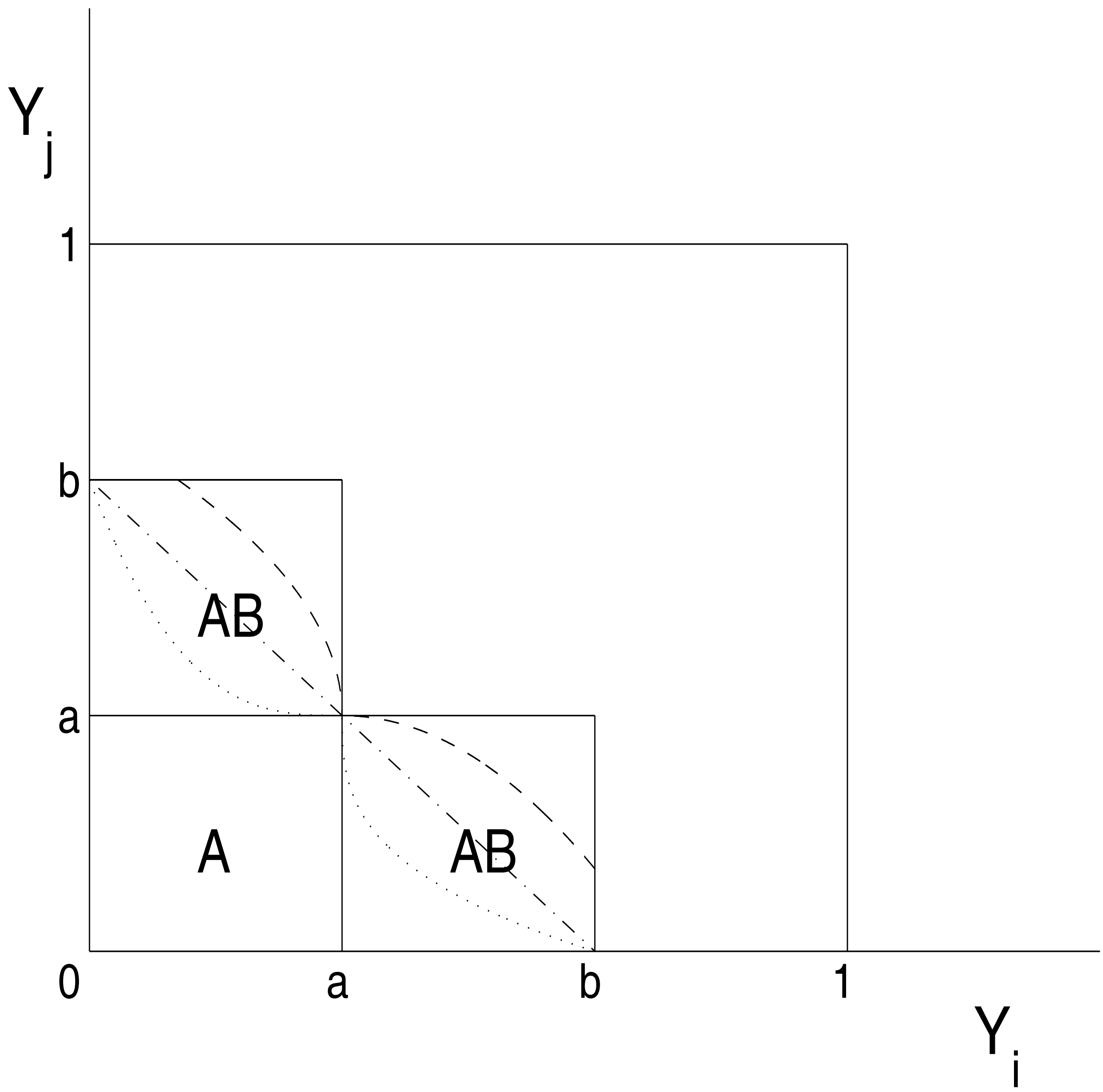

Figure 3: **Default Region**. (Note that $a \equiv \underline{Y}(r)$, $b \equiv \underline{Y}(2r)$, and Y_{max} is normalized to one.) Default in the non-cooperative game occurs if joint output realizations fall in box A, or in boxes AB below the $\underline{\hat{Y}}$ curve (the dashed curve, for example). More generally, the only restriction on the curve through the lower AB box is that it start at (a, a) and strictly decrease to (b, z), for some $z > 0$. The curve through the upper AB box must be its reflection about the 45-degree line, due to borrower symmetry. Default under cooperation (see section 3.3.4) occurs below the dash-dotted line, for example, and under the non-cooperative game, severe unofficial penalties, and assumption A15 instead of A14, below the dotted curve.

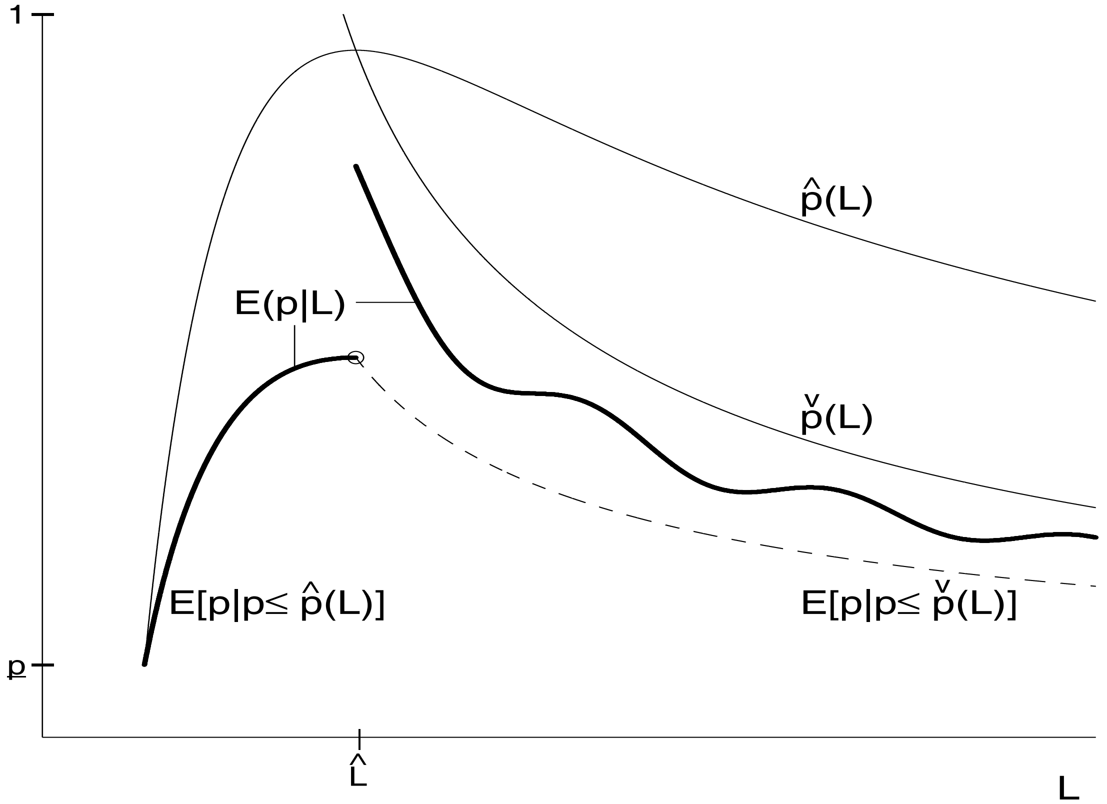

Figure 4: When L is small enough – specifically, below $\hat{L} \equiv \Gamma^{-1}([\underline{u} - EF(0)]/E)$ – then $\hat{p}(L) < \check{p}(L)$ and $E(p|L)$ follows $E[p|p \leq \hat{p}(L)]$. For $L \geq \hat{L}$, $\check{p}(L) \leq \hat{p}(L)$ and $E(p|L)$ is a convex combination of $\check{p}(L)$ and $E[p|p \leq \check{p}(L)]$.

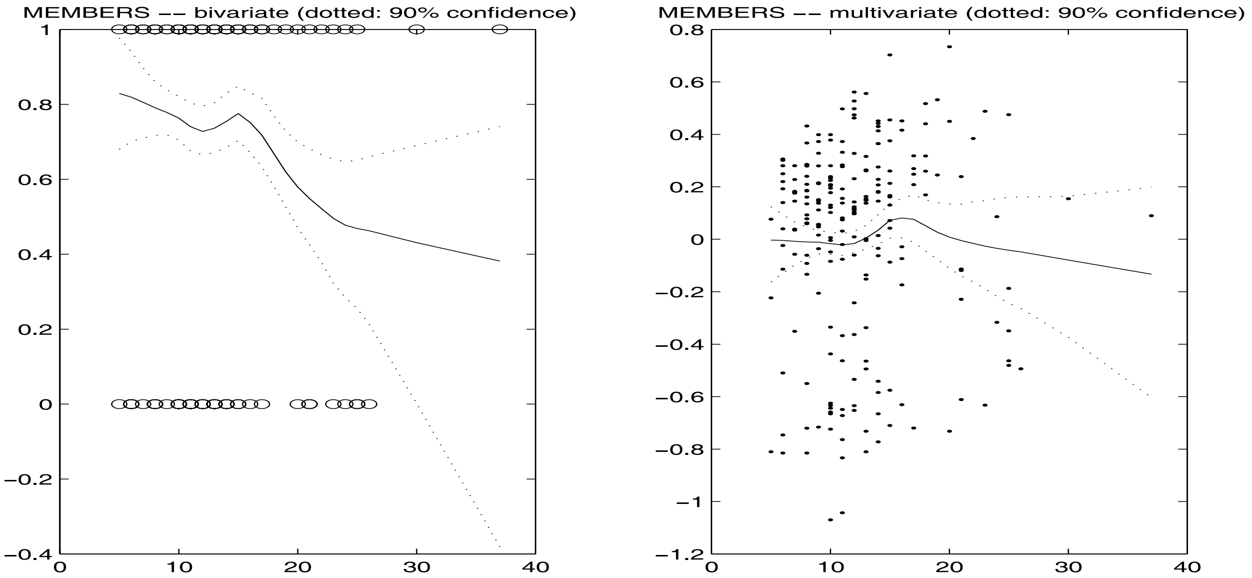

Figure 5: Number of Members against Repayment in a bivariate locally linear regression and in a partially linear regression.

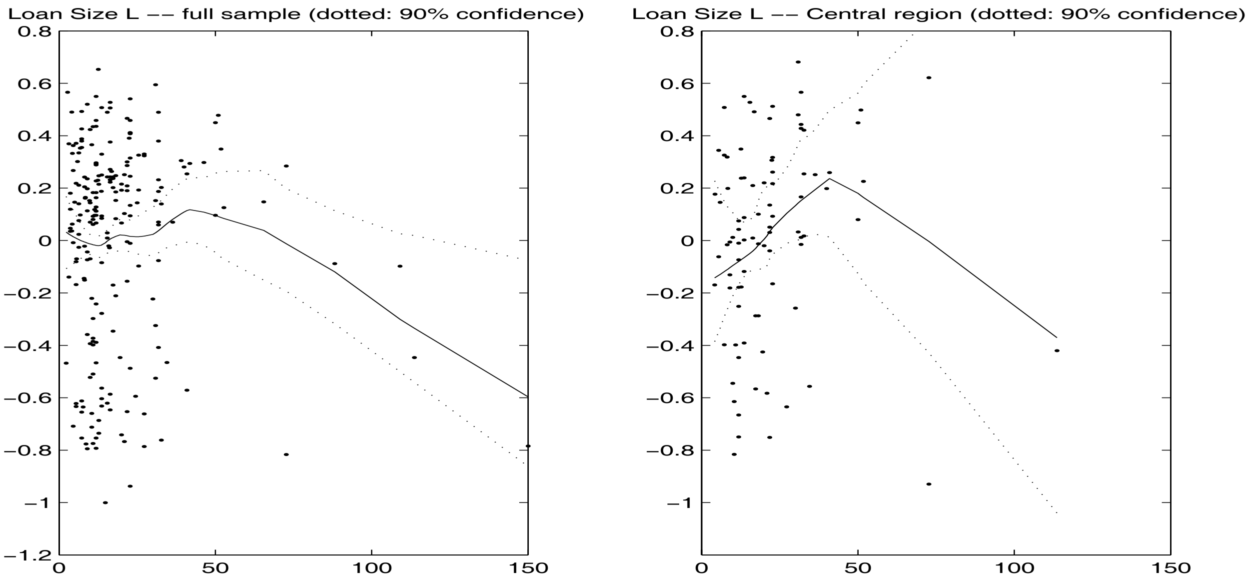

Figure 6: Partially linear regressions – Loan size against Repayment for the whole sample and the central region only.

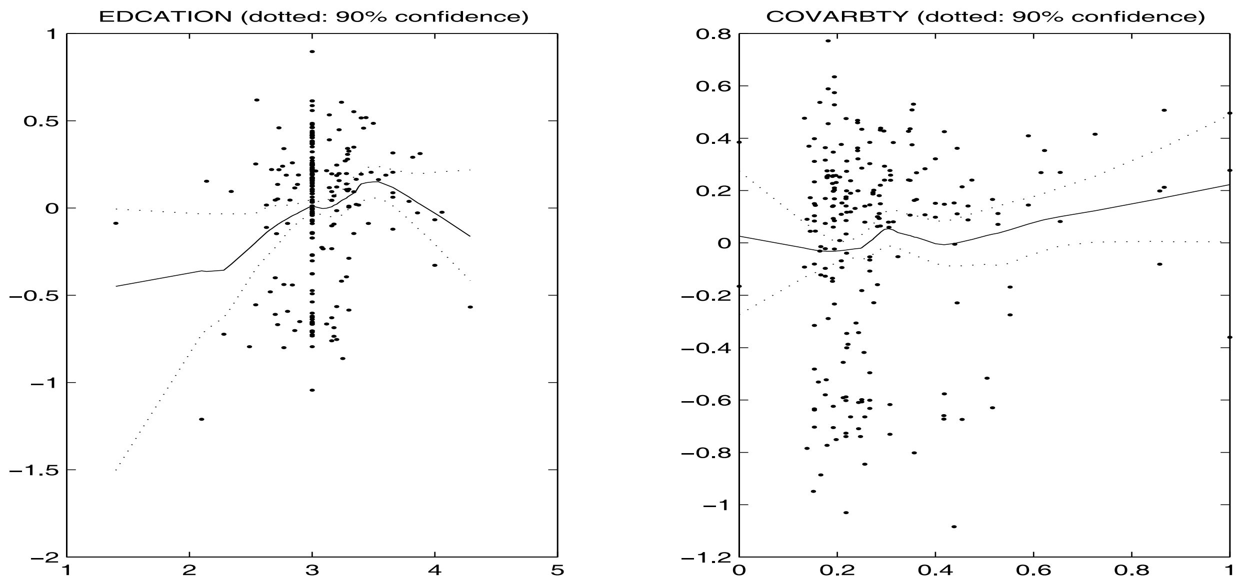

Figure 7: Partially linear regressions – Group Average Education, Village Covariability against Repayment.

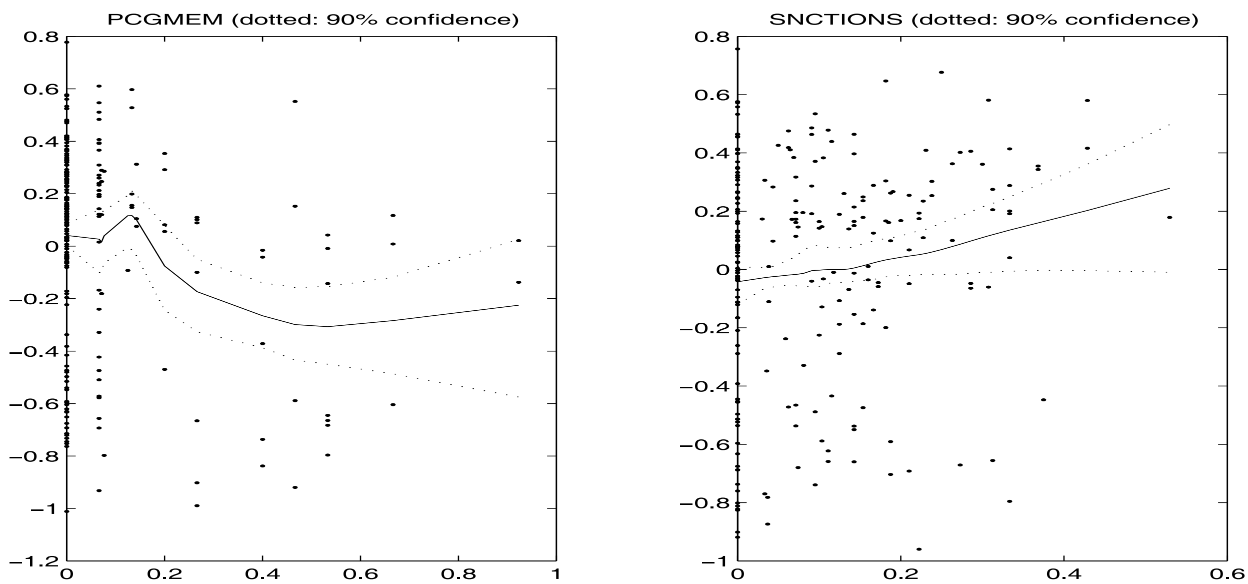

Figure 8: Partially linear regressions – PCG Prevalence, Village Sanctions against Repayment.