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Peer Monitoring and Credit Markets

Joseph E. Stiglitz

A major problem for institutional lenders is ensuring that borrowers exercise prudence in the use of the funds so that the likelihood of repayment is enhanced. One partial solution is peer monitoring: having neighbors who are in a good position to monitor the borrower be required to pay a penalty if the borrower goes bankrupt. Peer monitoring is largely responsible for the successful financial performance of the Grameen Bank of Bangladesh and of similar group lending programs elsewhere. But peer monitoring has a cost. It transfers risk from the bank, which is in a better position to bear risk, to the cosigner. In a simple model of peer monitoring in a competitive credit market, this article demonstrates that the transfer of risk leads to an improvement in borrowers' welfare.

Difficulties in obtaining capital, and the high cost of capital when it can be obtained, may act as important impediments to improvements in productivity. Capital markets in the rural sector often appear to be underdeveloped. There are traditional moneylenders, but they are often reviled for charging usurious rates. The reason for these high rates remains a subject of controversy. There are widespread popular views that the rates are exploitative. These views implicitly assume that competition is limited. Local moneylenders make use of local knowledge, and this local knowledge may explain why competition is so limited. More recent views have questioned the extent of exploitation, suggesting that the high rates are a result of three factors: the high rates of default, the high correlations among defaults, and the high cost of screening loan applicants and pursuing delinquent borrowers.¹ Because of the importance of local information, moneylenders' loans are generally concentrated within a single geo-

1. See, for instance, Aleem, this issue.

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This article is based on earlier work on the general theory of moral hazard (Arnott and Stiglitz 1985, 1986, 1988) and on joint work with Richard Arnott on the general theory of peer monitoring (Arnott and Stiglitz 1990). It also draws heavily upon earlier joint work with A. Weiss on the theory of credit markets (Stiglitz and Weiss 1981, 1983, 1986, 1987a, 1987b). Financial support from the National Science Foundation, the Olin Foundation, and the Hoover Institution is gratefully acknowledged. I am greatly indebted to Richard Arnott and K. Hoff for helpful comments.

graphical area; the inability to diversify means that the risks they must bear are large.

Both in the rates charged and the institutional arrangements by which loans are extended, traditional moneylending appears markedly different from modern banking institutions of the form found in more developed economies. As a result, many governments have encouraged formal banking institutions to go into the rural sector (see Siamwalla and others, and Bell, this issue.) These institutions would serve to increase both economic efficiency—by making credit more widely available—and equality, by lowering the interest rates which poor farmers have to pay. This, it was believed, would be true whether the high interest rates reflected exploitation as a result of limited competition, or whether they reflected compensation for the undiversified risks which local moneylenders had to bear. Presumably, these more efficient modern institutions would drive out the less efficient local moneylenders.

As it has turned out—as shown in the articles by Bell, Siamwalla and others, and Aleem in this issue—the two groups have not only managed to coexist, but the local moneylenders seem able to continue to lend at high interest rates. Although the formal lending institutions often have suffered large losses, the local moneylenders have not only survived, in some cases they have actually thrived. Part of the reason for this is that the formal institutions have not made loans available to all farmers who would like them (or have not provided them with as much credit as they would like). But another part of the reason may be that the local moneylenders have one important advantage over the formal institutions: they have more detailed knowledge of the borrowers. They therefore can separate out high-risk and low-risk borrowers and charge them appropriate interest rates; and they can monitor the borrowers more effectively, making sure that the funds are used productively and thus lowering the default rate.² (See Aleem for the dramatic contrast in default rates.)

Of the banking institutions which have been set up to provide credit in the rural sector of developing countries, one institution, the Grameen Bank in Bangladesh, appears to be a model of success. It makes small loans—the average size is approximately seventy dollars. It makes about 475,000 loans a month. Its default rate is approximately 2 percent, in contrast to some other lenders, which have default rates of between 60 and 70 percent (Lurie 1988). There are a number of distinctive characteristics to the Grameen Bank, but the one I wish to focus on here is that the loans are made to self-formed groups of approximately five farmers, who are mutually responsible for repaying the loans. Moreover, other members of the group cannot obtain credit until existing loans are repaid.³

2. The incentive (moral hazard) and selection problems are two of the central problems facing any credit market.

3. Peer monitoring through group loans also appears to be used in some African loan markets and in Thailand. (See Migot-Adholla and others, forthcoming and Siamwalla and others, this issue.)

Thus, the Grameen Bank is able to exploit the local knowledge of the members of the group. It has devised an incentive structure whereby others within the village do the monitoring for it. I call this *peer monitoring*. Elsewhere, Arnott and I (1990) have argued that peer monitoring may be an effective way of designing an incentive-monitoring system in the presence of costly information.⁴

Peer monitoring is not without its cost. The members of the borrowing groups in the Grameen Bank bear risks that, in the absence of the monitoring problem, could much better be absorbed by the bank. Indeed, in the case of borrowing groups, the interdependence among the members of the group is artificially created. They have been induced to bear more risks than they otherwise would.

This poses an analytical problem: are the gains from improved monitoring worth the costs of increased interdependence? This is the problem that this article sets out to model and answer. The article should be viewed as a first attempt at developing a general theory of peer monitoring. Thus the borrowing group consists of only two individuals. Moreover, the interdependence is limited—they have to pay only a limited amount in the event of default. But even this limited amount raises the risk that they must bear. I assume, moreover, that the information each member of the group has about each other is essentially costless; it is a by-product of living near each other. (In more general cases, the amount of monitoring will depend on the extent of interdependence, so that with only a little interdependence, one may obtain only limited monitoring.) Finally, I assume that the risks of default are independent. In practice, they are correlated. The existence of correlation would only strengthen the results of this analysis.

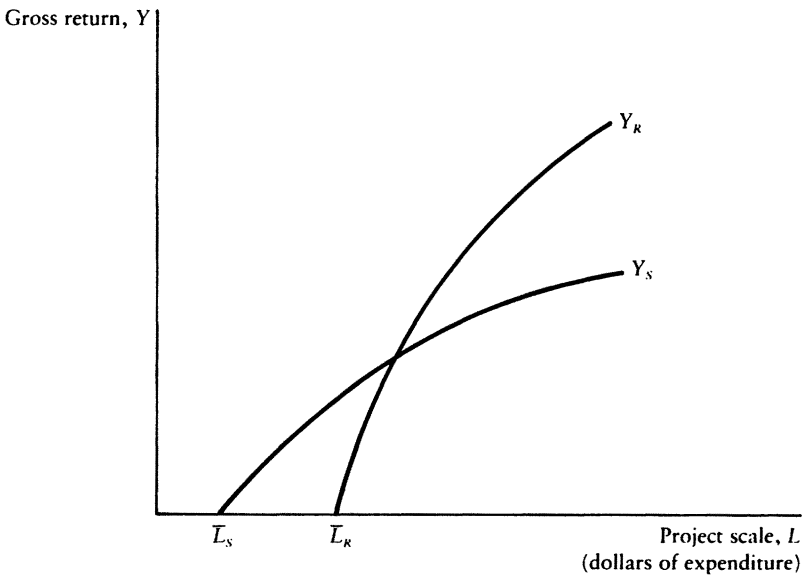
The article is divided into three sections. Section I presents the basic model, describing the equilibrium which would emerge in the absence of peer monitoring. Section II shows how peer monitoring works and explains why it will be adopted. Section III provides some concluding remarks.

I. THE BASIC MODEL

I assume all individuals have two projects which they can undertake, a relatively safe project yielding, if successful, a return of $Y_S(L)$ when undertaken at scale L (measured in dollars of expenditure), and a relatively risky project yielding, if successful, a return of $Y_R(L)$. If a project fails, returns are zero. The probability of success for each project is p_S and p_R , with $p_S > p_R$. I assume that the return is an increasing function of scale, but that the fixed costs, $\bar{L}$, associ-

4. In labor markets workers frequently have much better information about whether peers are shirking than do managers. In insurance markets, family members have a much better idea about what precautions each is taking against some insured event than does the insurance firm. The principles of peer monitoring that are developed here thus have important implications and applications in a variety of settings.

Figure 1. *Relationship between Gross Returns and Investment (Assuming Success) for Safe and Risky Projects*



Note: $\bar{L}$ = fixed costs; R = risky project; S = safe project.

ated with the risky project are larger: $\bar{L}_R > \bar{L}_S$. Accordingly, in the relevant region, $Y'_R > Y'_S$, as depicted in figure 1.

Assume that, taking into account the probability of success, the safe project always yields a higher return than the risky project:

$$Y_S(L)p_S - (1 + r)L > Y_R(L)p_R - (1 + r)L \quad \forall L$$

where r is the rate of interest. An individual who invests his own funds, therefore, will always choose the safe project. An individual who invests borrowed funds and declares bankruptcy if the project fails, however, will discount the cost of funds to reflect the probability of bankruptcy.

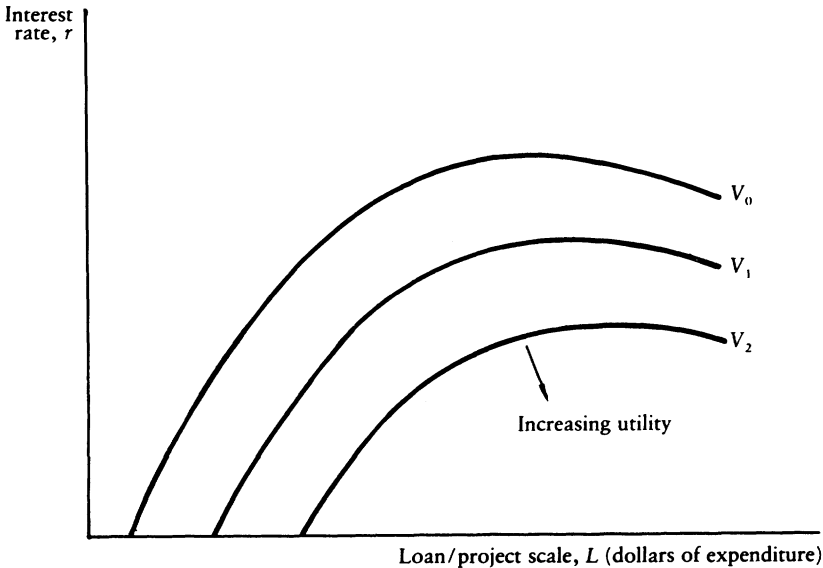
In order to focus on the incentive problem, I assume all individuals are identical⁵ and, for simplicity, that the level of effort required by the two projects at any given size is identical. Expected utility from undertaking project i is⁶

$$(1) \quad V_i(L, r) = U[Y_i(L) - (1 + r)L]p_i - v(e(L))$$

5. If villagers know each other's characteristics, then, in forming peer monitoring groups, there will be "assortative mating"; that is, the least likely to default will group together, the next most likely to default will group together, and so on, leaving the most likely to default to form a group. Thus the assumption that all members of the peer monitoring group are identical can really be viewed as one of the equilibrium conditions, which can be derived in a more general setting.

6. I assume that either the individual has no source of income other than that from the project, or that whatever the income is, it is constant and cannot be garnished by the bank if the project fails.

Figure 2. *Indifference Curves between Loan Size and Interest Rate Charged for a Single Project*



Note: V_i = expected utility from project i , where $V_0 < V_1 < V_2$.

where $U(Y)$ is the utility of income, $U' > 0$, $U'' < 0$, and the utility function is normalized so that $U(0) = 0$.^{7,8} The term $\nu(e(L))$ is the disutility of effort e ; $\nu' > 0$, $\nu'' > 0$. It is assumed that the level of effort required goes up as project size increases: $e'(L) > 0$. The individual's indifference curve for a given project (risky or safe) is given in figure 2. This curve gives all the contracts (L, r) that yield the borrower the same utility.⁹

7. This normalization is a convenient one for the exposition of this article but is in no way essential and encounters difficulties, for instance, with constant absolute risk aversion utility functions.

8. Implicit in this formulation is that the individual's investment in the project is equal to the amount that he can borrow, L . The results can be generalized to the case where the amount of his own funds that the individual is willing to invest depends on the amount that he can borrow.

9. I assume that the lender can monitor the borrowing activity of the borrower, ensuring that he does not obtain funds elsewhere, though the lender cannot monitor other actions of the borrower. This assumption is not entirely satisfactory. While the lender can limit the size of the loan he extends, formal lenders often have difficulty enforcing restrictions on loans taken out with other lenders. Thus several of the case studies in this issue suggest that while information and other transaction costs imply that the borrower has a credit relationship with only one (or at the most, very few) informal lenders, borrowers frequently borrow from both formal and informal credit institutions.

A full analysis of market equilibrium in which formal institutions could not restrict the amount of outside loans would take us beyond the scope of this paper. (See Arnott and Stiglitz 1990 for an analysis of the analogous problem in the context of insurance markets with moral hazard). Doing so, however, would strengthen the case for peer monitoring, because the inability to restrict outside loans will lower the level of expected utility attained by the borrower in formal credit markets without peer monitoring.

The slope of the indifference curve if the individual undertakes project i is¹⁰

$$(2) \quad \frac{dr}{dL} = \frac{Y'_i - (1 + r) - v'e'/U'p_i}{L}$$

The "switch line" can be defined as those combinations of (L, r) for which the individual is indifferent between the two projects; that is:

$$(3) \quad V_S(L, r) = V_R(L, r).$$

The switch line is negatively sloped under the plausible condition that, because returns to scale are more important for the risky project than for the safe, an increase in L , keeping r fixed, makes the risky project more attractive. In the relevant region ($L > \bar{L}_R$),

$$(4) \quad \frac{\partial V_S}{\partial L} < \frac{\partial V_R}{\partial L}.$$

Note that the indifference curve, letting the choice of project vary with the terms of the loan contract, is the scalloped shape shown in figure 3A. Above the switch line (at high levels of L) the individual undertakes the risky project.

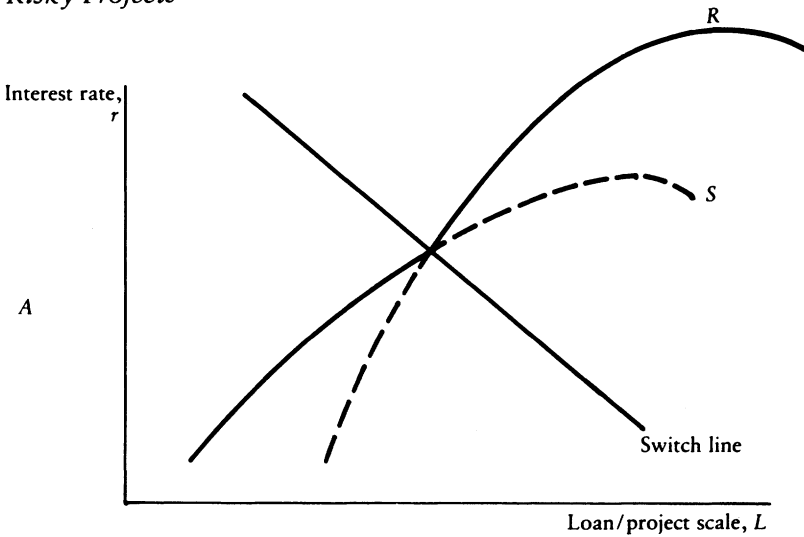
To see that the switch line is downward-sloping, fix the loan size and note that utility decreases with increases in r by the amount $LU'p_i$. Since for the risky project U' is lower and p_i is lower, the decrease in utility for each increase in r is smaller for the risky project. Hence, starting from a value of (L, r) at which the borrower is indifferent between undertaking the safe or risky project, such as point E in figure 4, an increase in r causes the risky project to dominate the safe project. But it was assumed in equation 4 that an increase in L at a fixed r increases the expected utility from the risky project more than that from the safe project. Therefore, an increase in L must be accompanied by a fall in r to leave the borrower indifferent between the two projects, which proves that the switch line is negatively sloped.

The borrower is compensated for the extra risk associated with the risky project by a higher return when the project is successful, but the bank is not. The risky project has a lower probability of success and, hence, the bank has a lower chance of being repaid. Clearly, if the bank could directly control the actions of the borrower, it would specify that the borrower undertake the safe project. It cannot, and this is the basic problem with incentives in credit markets. By controlling the terms of the loan contract, the bank can induce the borrower to undertake the safe project. That is, the bank must offer a contract which lies on or below the switch line.

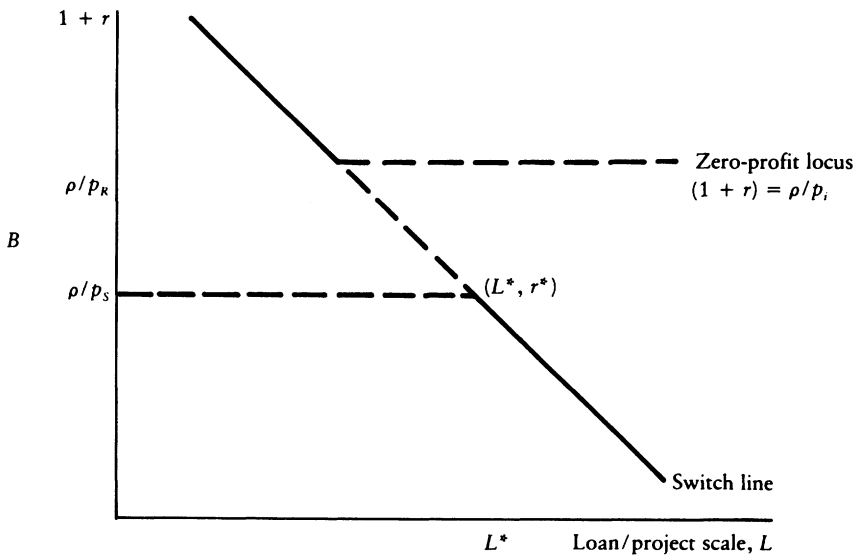
To analyze the market equilibrium one additional set of curves is needed—the zero-profit locus. The zero-profit locus can be constructed simply as follows. If the borrower undertakes the safe project, the expected return to the

10. The indifference curve for a given project is "well-behaved" in the relevant region where $Y'_i > (1 + r)$ provided $Y''_i < 0$ and $d^2(v'e')/dL^2 > 0$.

Figure 3. Influence of Loan Size and Interest Rate in Selection of Safe and Risky Projects

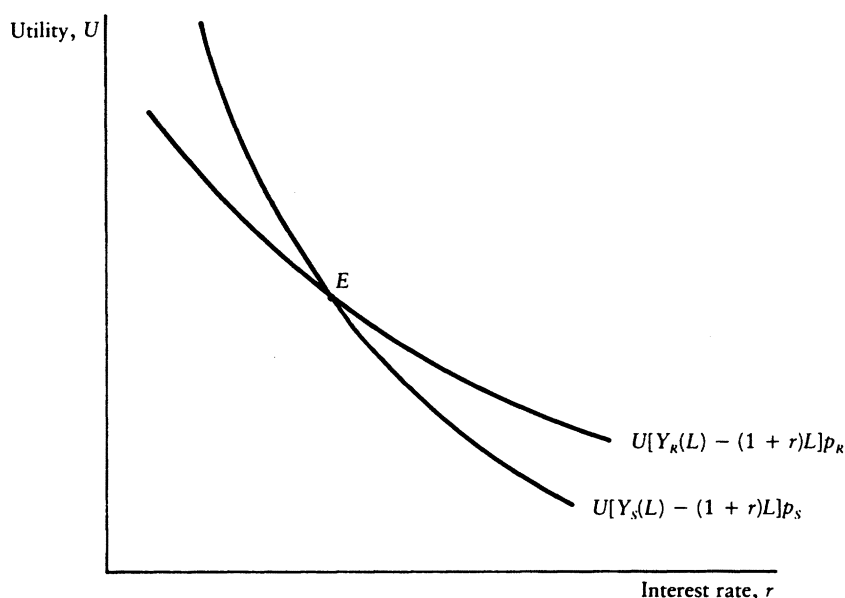


Note: Because at larger loan sizes individuals undertake the risky project, the indifference curve—letting the technique employed vary with the contract—has an escalated shape. R = risky project; S = safe project.



Note: Market equilibrium occurs at the contract (L^*, r^*) , where profits are zero. It is the largest loan size along the zero-profit locus for which individuals are willing to undertake the safe project. The variable ρ = cost of capital; p_i = probability of success of project i ($i = R, S$).

Figure 4. *Effect of Interest Rates on Utility in Selection of Risky or Safe Projects at a Given Loan Size*



Note: L = loan/project size; p_i = probability of project success; R = risky project; S = safe project; Y = gross return.

bank is $p_S(1 + r)$. If the cost of capital is ρ , then profits are zero provided $1 + r = \rho/p_S$. Similarly, if the borrower undertakes the risky project, expected profits are zero provided $1 + r = \rho/p_R$. The zero-profit locus is thus the peculiarly shaped dashed line in figure 3B.

The market equilibrium is that point on the zero-profit locus which maximizes the borrower's expected utility. (It is assumed that the borrower does not have alternative sources of credit or, equivalently, that the lender can monitor the total amount borrowed by any single individual.) In figure 3B, the equilibrium loan contract is (L^*, r^*) . Clearly, the borrower would like to borrow more at the market rate of interest; and if the borrower could credibly commit himself to not undertaking the risky project, the lender would be willing to lend him a larger amount at that rate. But given that the borrower cannot commit himself, and that the lender cannot enforce such a promise, even were it made (and the borrower and lender both know that), the lender must limit his loan size to L^* .

This is only one of the two forms that credit rationing may take. It also may take the form that of a group of identical borrowers, some get loans and some don't. The usual argument for why this kind of credit rationing cannot occur is that those who have been rationed out of the market offer to pay higher interest rates. As they do so, the interest rate gets bid up, until demand for funds equals supply. But this argument does not work here, because lenders

know that at any interest rate above the switch line, borrowers will undertake the risky project. Though the amount borrowers promise to pay is higher, the amount they actually pay (on average) is lower.¹¹

II. PEER MONITORING

Now assume that every borrower has one (and only one) neighbor who is also a borrower. The success of their projects is independent. The two borrowers can monitor each other. The lender would like each to report if his neighbor is using the risky technique. He wants to create an environment in which it is in the interests of each to monitor the other and to report any cheating.

The following is a simple way of doing so. The lender offers a contract in which if his neighbor agrees to cosign—in a specific sense to be described below—the borrower can obtain a lower interest rate and additional funds. The cosigner agrees to pay qL dollars to the lender in the event that the loan he has cosigned goes into default—provided, of course, that he himself does not go into default.

Now, the cosigner's expected utility depends on whether his neighbor undertakes the risky or the safe project. Given their interdependence and the symmetry we have imposed on the problem, it is reasonable to assume that they cooperate; that is, they decide jointly on whether to undertake the safe or the risky project, and if they undertake the risky project, they agree not to report it.¹²

11. This argument is set forth in greater detail in Stiglitz and Weiss (1981). In the simple model presented here, lenders are indifferent to lending any size loan below the switch line, at a given interest rate. But if the model is modified slightly to allow p_i to increase slightly with loan size, then below the switch line the zero-profit locus is negatively sloped, and lowering the loan size below L^* actually lowers the expected return to the lender.

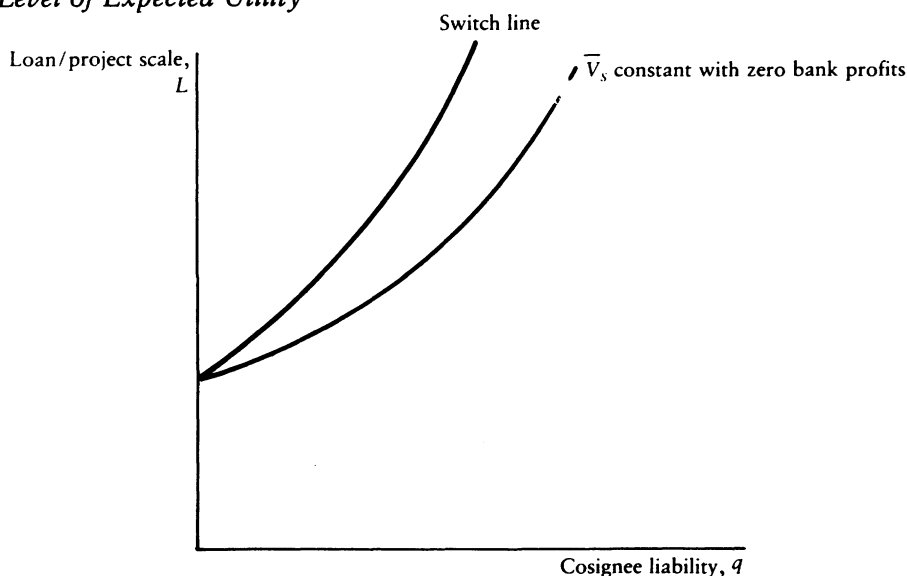
Other modifications to the model, to make it more realistic, provide further reasons why lenders will not wish to make small loans, to "underfund" projects. For instance, borrowers often have the discretion to take actions which put the lender in a position of choosing to ante up more money or risk the loss of everything previously lent. Borrowers thus can "force" lenders to lend them more. See Stiglitz and Weiss (1981) and Hellwig (1977).

12. The interactions among the individuals which result in this being an equilibrium are not modeled in detail. It is easy to construct a game for which this is an equilibrium. For instance, assume that at any date at which one side reports that his neighbor has undertaken the risky project, the other side has time to report the same information. Then it would not pay either party to renege on the agreement not to report.

More generally, it is reasonable to assume that social sanctions would ensure that they behave cooperatively, when each's income depends not only on his own actions but also on those of his neighbor. There are natural information assumptions which assure that they cannot cheat on each other.

Throughout, it is assumed that if the borrower cheats on the contract by undertaking the risky project, the cosigner can "force" the reversal of the action; for example, the loan contract provides that in the event of such cheating, the loan is in default and the lender assumes control and gets all the returns.

Figure 5. *Relationship between Loan Size and Cosignee's Liability at a Fixed Level of Expected Utility*



Note: $\bar{V}_s$ = fixed level of utility from safe project (S). The switch line is the maximum loan size, for each q , which induces individuals to undertake the safe project.

Making the individual cosign his neighbor's loan imposes on him an additional risk. Since the zero profit condition ensures that the interest rate will adjust to leave the expected return to the bank unchanged—taking into account the payment from the cosignee, the effect of the cosignatory provision is to induce a mean-preserving spread on the borrower's income at any given level of his loan L : if both borrowers are successful, utility is higher; but if one is successful and the other is not, the first borrower's utility is lower. To compensate him for undertaking this additional risk, the lender must provide a larger loan. The relationship between the minimum-size loan required to attain a given level of expected utility and the magnitude of the cosignee's payment rate, q , is depicted in figure 5. Equation A-5 in the appendix shows that at $q = 0$, and given the bank's zero-profit condition

$$(5) \quad \left. \frac{dL}{dq} \right|_{\bar{V}_s} = 0$$

This means that (at low levels of q) the risk burden imposed on the borrower by cosigning is exactly compensated by the reduction in the competitive interest rate charged.

The only remaining question is to ascertain what happens to the switch line.

If the two parties act cooperatively, the switch line is now given by the equation

$$(6) \quad U[Y_S(L) - (1 + r)L]p_S^2 + U[Y_S(L) - (1 + r - q)L]p_S(1 - p_S) \\ = U[Y_R(L) - (1 + r)L]p_R^2 + U[Y_R(L) - (1 + r - q)L]p_R(1 - p_R)$$

Equation A-7 in the appendix shows that so long as the condition of equation 4 is satisfied and the interest rate adjusts as q increases to maintain zero profits for the lender, the maximum L at which the individual undertakes the safe project increases with q . That is,

$$(7) \quad \left. \frac{dL}{dq} \right|_{\text{switch line at } q=0} > 0.$$

As shown in figure 5, peer monitoring will be welfare-enhancing: for low levels of q , the increase in L which it allows (with borrowers undertaking the safe project) is greater than that required to compensate the individual for the increase in risk-bearing.

III. CONCLUSIONS

This analysis of the value of peer monitoring suggests some of the ingredients in the design of successful peer monitoring systems. First, the members of the peer group must be provided with incentives to monitor the actions of their peers. In the Grameen Bank this is provided by the fact that members of the peer group are jointly liable for repayment of loans, and by the fact that they cannot gain access to credit until the debts of the group are discharged. The denial of access to further credit can be an effective incentive device, as the earlier study of Stiglitz and Weiss (1983) emphasized.

The Grameen Bank employed small groups. The small size increased the risk from a single member's default but increased the incentives for peer monitoring. The gains from the latter exceeded the losses from the former. With large groups there is a free rider problem—each would prefer that others expend the energy required to monitor and incur the ill will that would result from reporting offenders who have misused the funds lent to them. Moreover, the costs to each as a result of a default by any member are sufficiently small that incentives to monitor—even apart from the free rider problem—would be minimal.

There are strong incentives for groups with similar risk characteristics to form. Because the group acts as a cooperative, if some individual is more prone to default than others, he is being subsidized. When groups are identical, there is no subsidy (at least in an *ex ante* sense). Of course, those with high risks of default would like to join groups with a low risk of default. The assortative grouping comes about as those with the lowest risk of default recognize their mutual interest in grouping together; then those with the lowest risk among the ones remaining group together; and the process continues until the individuals with the highest risk are forced to group together. Villagers have an informa-

tional advantage over formal credit institutions not only in monitoring but also in selection. By eliminating some of the cross-subsidization that occurs in credit markets with imperfect screening, peer selection with substantial cross-guarantees may enhance the effectiveness of rural credit markets, although, like peer monitoring, it increases the risks that borrowers have to bear. Having groups which are self-formed may thus be an important ingredient in the success of the Grameen Bank.¹³

Provisions for cosigning have traditionally been viewed as a way of increasing the effective collateral behind a loan. This article has provided an alternative interpretation. Cosigning provides an incentive for the cosignee to monitor the actions of the person for whom he has cosigned the loan. Cosigning also increases risk. But in the kind of symmetric competitive equilibrium analyzed here, interest rates adjust to reflect the improved monitoring. It has been proven that at low levels of q , the gains from peer monitoring more than offset the loss in expected utility from the increased risk-bearing.

In developing countries the inability of those outside a village to monitor loans has posed a major impediment to the development of effective capital markets. Within the village, risks are sufficiently highly correlated and there are sufficiently few individuals with wealth that the lending market is both imperfectly competitive and carries with it high risk premia.

Although governments have recognized the existence of a problem, they have paid insufficient attention to its root causes. If informational problems are the barrier to the development of an effective capital market, then there is no reason to presume that governmental lending agencies will be in a superior position to address these problems. Indeed, the lack of incentives for government bureaucrats to monitor loans may exacerbate the problem. The experience of government losses in such programs (see, for instance, Sanderatne 1978, and Bell, this issue) suggests that it may be foolish for government to go where the market has feared to tread.

But government may be able to use peer monitoring to offset its informational disadvantage. This article has illustrated a simple way by which such peer monitoring can be implemented, but there are alternative institutional arrangements that could work as well or better. For instance, government could lend to small lending cooperatives within a village, making each member of the cooperative collectively liable for the whole.

A question naturally arises at this juncture: if peer monitoring is so effective, why isn't it employed by private markets? In capital markets in developed countries, it may be extensively employed. As noted above, provisions for cosigning may be important not only for the increased effective collateral but also for the induced peer monitoring.

13. There still may be some cross-subsidization across groups if interest rates charged to different groups do not correspond to differences in group default rates. Successful peer monitoring, however, lowers group default rates to the point where this cross-subsidization may be relatively unimportant.

In developing countries a major impediment to the development of peer monitoring—as well as to the development of other institutions—comes from inadequate legal systems to enforce contracts. Government has one advantage over private lenders, a difference which is particularly important in developing countries, where the judicial system is at best slow, at worst ineffective. Government may have powers of enforcing contracts that private lenders might not have.

This suggests an alternative policy reform to more extensive government provision of credit: legal reforms giving lenders more security for the recovery of their loans. It may, however, be difficult to isolate legal reforms directed at making the credit markets more effective from a broader range of legal reforms. And there may be serious impediments to undertaking this broader range of legal reforms. Although legal reforms can facilitate the use of peer monitoring in private markets, even short of such fundamental reforms, well-designed government lending programs, taking advantage of the opportunities provided by peer monitoring, may, in these circumstances, be an effective second-best policy.

APPENDIX

No Peer Monitoring

To simplify the notation, let $\bar{r} \equiv 1 + r$, the principal and interest charged by the bank; $U_i \equiv U[Y_i(L) - \bar{r}L]$, the utility of a borrower who succeeds at project i ; and $i = R, S$.¹⁴

Recall that $V_i(r, L) = U_i p_i$, the expected utility of a borrower who undertakes project i , and the switch line is the set of contractual terms (L, r) for a rationed borrower where

$$(A-1) \quad V_R = V_S$$

We assume in equation 4 in the text that in the relevant region ($L > \bar{L}_R$), the benefit of an extra dollar of credit is greater for the risky than for the safe project:

$$(A-2) \quad U'_R(Y'_R - \bar{r})p_R = \frac{\partial V_R}{\partial L} > \frac{\partial V_S}{\partial L} = U'_S(Y'_S - \bar{r})p_S$$

Differentiating the switch line (A-1) completely yields

$$\left. \frac{dr}{dL} \right|_{\text{switch line}} = \frac{\left(\frac{\partial V_R}{\partial L} - \frac{\partial V_S}{\partial L} \right)}{L(U'_R p_R - U'_S p_S)} < 0$$

where the sign condition follows from equation A-2 and the fact that $p_R < p_S$

14. Throughout the appendix, the effort required to manage the project is ignored. Incorporating the effects of changes in effort induced by changes in loan size is straightforward.

and $U'_R < U'_S$. Thus the switch line is downward-sloping, as illustrated in figure 3.

Peer Monitoring

With peer monitoring, the borrower faces in effect three states of the world: (1) both his own and his neighbor's projects succeed; (2) his own succeeds but his neighbor's fails; and (3) his own fails. Utility in the three states is

$$U_i \equiv U[Y_i(L) - \bar{r}L]$$

$$U_{iq} \equiv U[Y_i(L) - \bar{r}L - qL]$$

$$U(0) = 0$$

Expected utility in a symmetric equilibrium—where both the borrower and his neighbor choose the same project, R or S—is

$$(A-3) \quad \bar{V} = U_i p_i^2 + U_{iq} p_i (1 - p_i) = V_i(r, L, q)$$

Assuming that equilibrium is characterized by credit rationing, the bank chooses a contract (r, L, q) that ensures the individual will choose the safe project. The bank's zero-profit condition is

$$p_s(1 + r) + p_s(1 - p_s)q = \rho$$

so

$$(A-4) \quad \frac{dr}{dq} = -(1 - p_s).$$

For any r equations A-3 and A-4 define a relationship between the borrower's loan limit and the copayment which keeps the borrower's expected utility unchanged and is consistent with the bank's zero-profit conditions. That relationship is characterized by

$$\left. \frac{1}{L} \frac{dL}{dq} \right|_{\bar{v}} \text{ and the bank's zero-profit condition}$$

$$\frac{-U'_i p_i^2 (1 - p_s) + U'_{iq} p_i p_s (1 - p_i)}{U'_i (R'_i - \bar{r}) p_i^2 + U'_{iq} (Y'_i - \bar{r} - q) p_i (1 - p_i)}$$

$$(A-5) \quad = \frac{-M_i}{\partial V_i / \partial L}$$

$$(A-5') \quad = 0 \text{ if } q = 0 \text{ and } p_i = p_s$$

$$(A-5'') \quad > 0 \text{ if } q = 0 \text{ and } p_i = p_R$$

where

$$M_i \equiv \frac{\partial V_i}{\partial q} + \frac{\partial V_i}{\partial r} \frac{dr}{dq}.$$

Equation A-5' yields the result that in an equilibrium in which the borrower undertakes the safe project and banks earn zero profits, imposition of a low cosigner liability rate q at a fixed loan limit L leaves borrower utility unchanged. See the lower curve in figure 5.

It is useful to write the switch line (equation A-1 or equation 6 above) explicitly:

$$(A-6) \quad p_R^2 U_R + p_R(1 - p_R)U_{Rq} = p_S^2 U_S + p_S(1 - p_S)U_{Sq}.$$

Differentiating A-6 totally yields

$$\left. \frac{dL}{dq} \right|_{\text{switch line}} = - \frac{M_R - M_S}{\partial V_R / \partial L - \partial V_S / \partial L}.$$

From the assumption stated as equation A-2, the denominator is positive. Using A-5' and A-5'', respectively, we have that at $q = 0$,

$$M_S = 0$$

$$M_R < 0$$

so

$$(A-7) \quad \left. \frac{dL}{dq} \right|_{\text{switch line at } q=0} = \frac{-M_R}{\partial V_R / \partial L - \partial V_S / \partial L} > 0.$$

Equation A-7 shows that peer monitoring shifts up the switch line. It relaxes the constraint on (L, r) required to ensure that the borrower undertakes the safe project. Comparing A-5' and A-7 indicates that at low levels of q , the shift up in the switch line *exceeds* the shift needed to maintain the borrower at constant expected utility, as illustrated in figure 5. Peer monitoring will thus increase the borrower's welfare.

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