To Get That Little: A Computational Model of Microfinance

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Money, says the proverb, makes money. When you have got a little it is often easy to get more. The great difficulty is to get that little.
Adam Smith, Wealth of Nations

1. Microfinance Background

1.1. The credit problem

There are many people in the world who have major difficulties obtaining credit. This can drastically constrain the economic opportunities available to them – they cannot start their own businesses, plant new high yielding varieties of crops, or survive through bad times caused by crop disasters or other factors. Without access to credit, they are stuck in a poverty trap, but with a small amount of credit, they might be able to dramatically improve their economic standing.

Lack of Physical Collateral

There are many reasons that traditional banks are unwilling to lend to people with very low incomes. Primarily, lending contracts are incomplete – a borrower can promise to pay back a loan, but if the borrower is bankrupt when the loan is due, there is little or nothing that the bank can do to enforce the contract. This makes lending very risky for banks. Among people with higher incomes, banks solve this difficulty by requiring physical collateral for loans. If the borrower defaults, the bank can legally seize the collateral, making it both more likely that the borrower will not default (as their collateral is at stake), and less costly for the bank if they do (they receive assets in cases of default).

In many situations in both the developing and developed world, however, potential borrowers do not possess any physical assets which can be put up as collateral. This severely constrains a bank's ability to lend to desperately poor people, even though they have a great need for credit.

Asymmetric Information

The other issue that banks have when facing the opportunities of lending to very poor people is that there is a problem of asymmetric information. Although individuals know how credit-worthy they are (how risky their uses of the credit are, whether they intend to pay it back at all, etc), it is very difficult for banks to know this information, and to set loan sizes and interest rates accordingly. Thus, banks risk getting entangled in moral hazard and adverse selection.

Moral hazard is simply that it might in many cases be the rational decision for someone facing a loan with a higher-than-appropriate interest rate or other aspects of a loan which are incompatible with their financial situation to default rather than repay. Due to lack of collateral and asymmetric information, it may be impossible for a bank to set up a situation in which the rational choice is for the borrower to repay.

Adverse selection occurs when the bank gets caught lending only to borrowers with low probabilities of repayment. This happens because the bank tries to set interest rates at a reasonable rate for borrowers with good track records, but also attracts people with little ability or inclination to repay. The bank then raises interest rates to avoid these "bad" borrowers, but ends up losing more of the "good" borrowers, because the "good" borrowers are more sensitive to interest rate variation. Thus, the bank is caught in a cycle where they can't get rid of the "bad" borrowers without losing "good" borrowers, and there is thus no way to lend only to people with relatively high abilities and inclinations to repay their loans.

Because credible banks will not lend to desperately poor people for the reasons above, people in need of credit are often forced to go to informal moneylenders to cover immediate needs for cash. These moneylenders charge usurious interest rates of hundreds of percent per month, thus enmeshing people in a spiral of debt, as they go to more moneylenders to pay back previous ones.

1.2. The microfinance solution

In 1976, Dr. Muhammed Yunus was visiting a village in Bangladesh, and met many women who were in the conditions described above – weaving bamboo stools, but only able to survive at a subsistence level because they were dependent on the men who were selling them materials. Dr. Yunus experimentally gave several women loans ranging from $27-$42 dollars, and all of them repaid. This success encouraged him to create the Grameen Bank, which is still one of the largest microlenders world-wide.

Microfinance has become a large movement, with over 7,000 microfinance institutions (MFIs) across the globe, lending to 25 million borrowers. Although different institutions have lending systems and policies that are adapted to the cultural and economic needs of their borrowers, most MFIs have the same basic structure as outlined below.

Small loan amounts over short time periods

Loans given by MFIs are in very small amounts, of ~$10-$500, with their quantity building up over time, and receiving new loans contingent on repayment of earlier loans. Thus, if borrowers want to continue receiving loans, they must continually repay. Future loans are a sort of collateral for the current loans. Also, borrowers who are not able or inclined to repay will generally stop repaying early in their relationship with the bank, when their loans are smaller, and never get to the larger loan sizes.

MFIs also generally have frequent repayment schedules, where installments on loan payments are due weekly or monthly. This keeps borrowers on track with repayment, and allows the bank to know nearly instantaneously when issues arise, rather than waiting until the end of a long loan period. Thus, it gives MFIs quick response times for working with borrowers to sort out issues that arise.

1.3. Group loans

The most innovative and important part of microfinance loans is that they are given to groups of people, rather than to individuals. Thus, a loan is given to 5-10 people together, and they all must repay, or risk termination of further loans for the entire group. This is a useful way of getting around nearly all of the issues mentioned above.

Lower transaction costs

For a bank, processing loans of tens to hundreds of dollars with frequent repayment of installments requires a large overhead, which makes loans to people with low incomes even more costly. With group loans, the bank deals only with groups, and not individuals, reducing the transaction costs greatly. For example, if there is a constant over head of $0.10 for each loan transaction, the costs of giving five loans of $1 each to five different individuals is $.50 per loan period, while the cost of giving a loan of $5 to a group consisting of those same individuals is $0.10. Thus, group loans dramatically reduce the high transaction costs faced by the bank.

Social collateral

The reason that the loan contract is generally incomplete when a low-income individual borrows from a traditional bank is that many individuals are too poor to have physical collateral. Group loans solve this problem in an ingenious way – rather than require physical collateral, MFIs dictate that people be in lending groups with other people in their communities. Thus, failing to repay a loan results not in the seizure of physical property by the bank, but rather in the social sanctioning of the defaulter by others in his or her group. People who thus have an incentive to not default, and their social standing in their village can be seen as a form of social collateral.

Altruistic punishment

Group loans also take advantage of people's demonstrated willingness to provide altruistic punishment. People are willing to punish others who do not repay their loans even though punishment is costly to the punisher. In a small village, shunning a friend can have high costs that are both social and economic (not being in a mutually beneficial relationship to help with each other's farms, etc). Yet, people are willing to incur costs to punish transgressors in both laboratory and field settings.

Mutual repayment

Group loans also reduce the risk for banks, because people often repay for others in their group. Many people receiving microfinance loans do not have any financial cushions, and if the project that they launched with the loan fails, they have no way of repaying, and default by necessity. With many people, however, there is a lower chance of default from necessity. If, for example, consider a situation where loans are of $1, and the chance of succeeding at a project is 0.7, returns if the project is successful are $2 and returns if the project fails are $0. If the bank gives a loan to an individual, the chance that they will default is the chance that the project will fail: 0.7. If the bank loans to a group of two, however, they will default only if both projects are unsuccessful (a single success will allow for repayment of the loan for both people). This probability is 0.09. Thus, by

simply loaning to a group of two people, the bank has decreased their risk of default by approximately 7.7 fold.

Centers

In many microfinance situations, 5-8 groups meet weekly in a "center" to discuss any issues that might arise, and see what is happening with other groups. This is meant to both form a community among people receiving microfinance loans, and also to provide a more convenient space for groups to air any issues that they have with the bank.

2. Project Goals

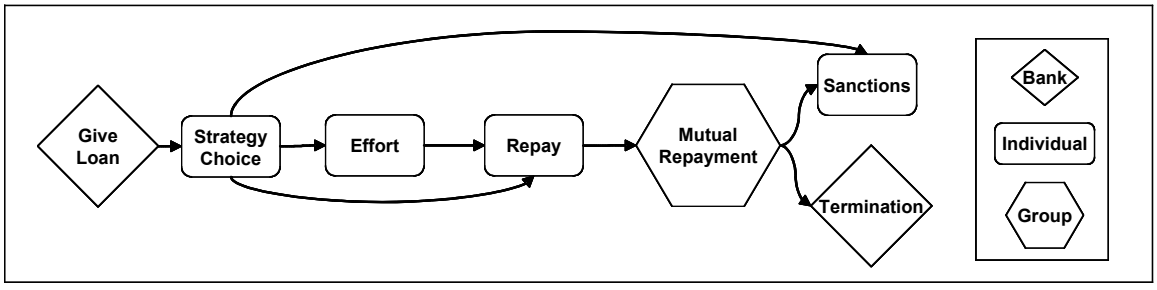
While microfinance is a large scale, world-wide operation, there are no good figures on how profitable it is as an industry, or on what makes a microfinance program succeed or fail financially. Most of the literature is in case studies, and it is difficult to find convincing models that unify the existing literature in a way that could be predictive of successes and failures of programs in many nations with many different policies. My goal in this project is to create a computational agent-based model of microfinance which could be instructive in qualitatively evaluating different programs of microfinance, as well as pointing out possible areas of concern or interest for policy makers.

It must be taken into account that different MFIs have varying goals – some are for-profit banks, while others approach microfinance as a method of charity that is less costly (some of the loans get repaid), and encourages entrepreneurship. Thus, when we say that one microfinance program is "better" than another, the goals of the program must be considered.

3. Model

3.1. Overview

This model is that of a center – there are eight groups, with each group comprised of individuals, and a bank. Groups, individuals, and banks each have different actions that they perform each time period, as shown in the diagram below.



The bank has two roles in this model. Firstly, it determines when a group that defaults gets terminated with the bank (in this model, a temporary termination of several loan periods). Additionally, it provides credit to groups in good standing.

Individuals choose a strategy, which consists of decisions of whether to put in effort on the loan they receive, whether to repay the loan, and whether to sanction non-

repaying individuals, and then does each of these actions. All possible strategies are shown in the table below. An individual choosing strategy 4, for example, puts in effort when given the loan, repays if his project succeeds, and does not sanction borrowers who do not repay.

Strategy	Effort	Repay	Sanction
0	Yes	Yes	No
1	Yes	No	No
2	No	Yes	No
3	No	No	No
4	Yes	If Lucky	No
5	Yes	Yes	Yes
6	No	Yes	Yes
7	Yes	If Lucky	Yes

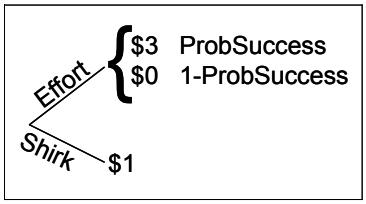
Groups of individuals are mutually liable, and have the option to have other individuals repay for those who cannot or will not to avoid this liability. Sanctioning individuals only sanction others in their group. Further description of each of these stages will be provided below.

3.2. Details

Below is a more detailed description of the workings of the model, moving through a time step as shown in the flowchart above. The description starts in the middle of a time step with the decision on whether to put in effort or not, because the giving of the loan and the strategy choice are strongly related to other group member's actions, and are best described last. It is thus assumed throughout (until the bank makes a new loan decision and the individual makes a new strategy decision) that the individual has been given a loan of $1, and has chosen a strategy detailing their decisions on effort, repayment, and sanctioning.

Effort

The first decision made by individuals is whether or not to put in effort on their loan. When the bank gives a loan, it is $1 per individual, and each individual then decides whether or not to put in effort. If shirks, he retains the $1, but if he does put in effort, with a given probability (ProbSuccess) his project succeeds and he receives $3, and with probability (1-ProbSuccess) his project fails and he ends the loan period with $0, as is graphically depicted below.



Repayment

A person who repays gives the bank 1*(1+interest rate). A person who does not repay does not face any immediate change in her financial situation, but faces potential sanctions in later periods, as will be more fully specified below.

Mutual repayment

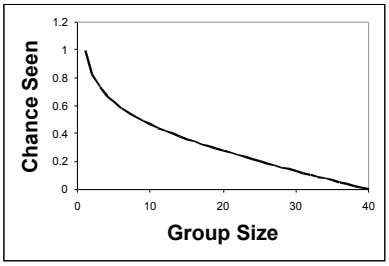
If there are enough people in a group who have put in effort and have been successful, they will split the costs of repaying the loans of all the people who did not repay. They do this to avoid termination from the bank (see below), which will occur if the bank does not receive repayment from all group members. The successful people repay for all other people if they are able, regardless of whether those who did not repay worked or shirked.

Individual sanctions

While the bank terminates a group indiscriminately if all loans are not repaid, individuals have information about others in their groups, and are able to use it to target sanctions towards members of their group that do not repay. In microfinance situations, these sanctions can be social (e.g., not involving non-repaying members in social activities, or not helping harvest their crops), or economic (not patronizing their businesses).

Individuals who sanction are those who have sanctioning as part of their strategy. Individuals who are sanctioned are those who either did not put in effort and then didn't repay, or those who put in effort, got results, and still did not repay. People who put in effort, but who's projects fail, and then don't repay, are not sanctioned.

As the size of a group increases, the amount of information that individuals have about one another decreases (in a group of 5, all people can be friends with and keep tabs on each other person, but in a group of 40, people are more distant from each other). In the model, this is represented by the chance that any one sanctioning individual "sees" the non-repayment any one sanctioned individual. This probability declines in group size, as shown below.



Additionally, the effect that the sanctions will have on the sanctionee and the cost to the sanctioner depend on the ratio of sanctionees to sanctioners in a group. If there are many sanctioners relative to sanctionees, each sanction will not be very costly to the sanctioners, but will harm the sanctionee fairly greatly. Inversely, a large ratio of sanctionees to sanctioners will mean that sanctions are costly to sanctioners, but not very costly to sanctionees. In short, the cost to sanctioners and sanctionees are given by the equations below:

Sanction Magnitude

const*(p(Seen)*NumSanctioning)*(NumSanctioning/NumSanctioned)

number of sanctions *effectiveness of sanctions*

Sanction Cost

const*(p(Seen)*NumSanctioned)*(NumSanctioned/NumSanctioning)

number of sanctionees *cost of sanctions*

Bank termination

If the bank does not receive back all that it is owed from a group (NumberOfMembers*LoanSize*(1+interestRate)), it will, with high probability, terminate the group from receiving loans for a given number of periods. The bank does not care whether the money that it receives comes from each member paying back his or her own part of the loan, or from mutual repayment as detailed above.

Occasionally, the bank will not terminate a group that does not repay. This can be interpreted as the bank deciding that there was, for example, a natural disaster that prevented the group from being able to pay.

Strategy choice

At the end of each period, 20% of members of groups that are not currently terminated by the bank are given the chance to change their strategies. They compare their own cumulative record over the last 10 time periods with that of two other members of their group, and adopt the strategy with the highest cumulative record.

Additionally, with a probability of 0.5%, each individual adopts a strategy randomly chosen among all eight possible strategies.

Summary of Parameters

The table below summarizes the values of all key parameters mentioned above in the description of the model, as they were set for Experiment 1, the results of which are described below.

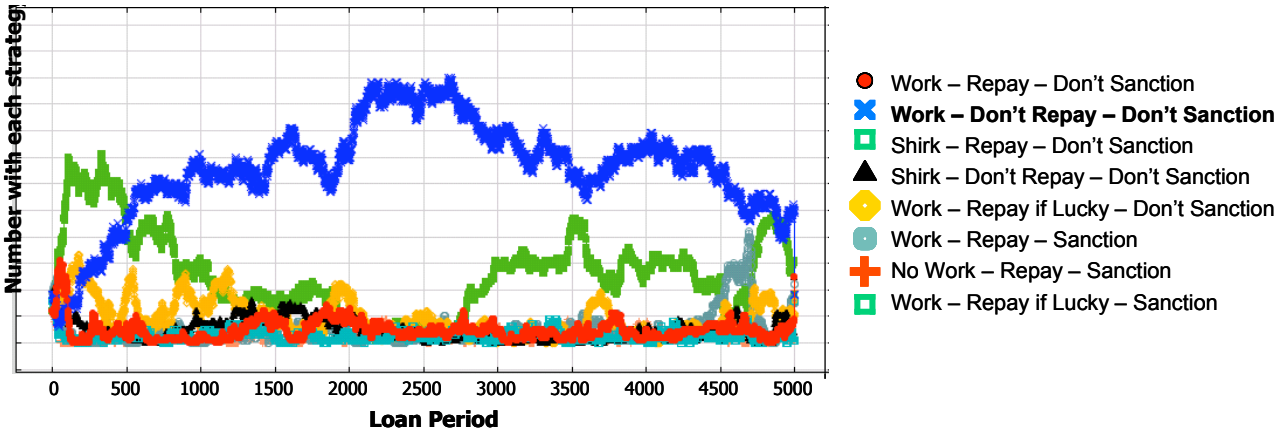
Individual
- Probability of success of project with effort……...**0.8**
- Number of peers compared for strategy change..**2**
- Window for cumulative record to evaluate peers..**10**
- Probability of comparative strategy change……..**0.2**
- Probability of random strategy change……**0.005**
- Constant for sanction size……...**1.3**
- Constant for sanction cost……...**0.2**

Group
- Number of groups……....**8**
- Probability of mutual repayment if possible……**0.8**
- Group Size……**10**

Bank
- Probability that bank will terminate if not repaid....**0.9**
- Termination period……**10**
- Interest Rate……**0.1**

4. Experiment 1

A typical result from the running of Experiment 1 (the simulation with the parameters specified above), is below. The Work-Don't Repay-Don't Sanction strategy appears to dominate the groups fairly quickly, and be fairly difficult to dislodge.



This is because it takes there being several people repaying in a group before the group is actually able to repay the group loan. Thus, in groups with only a small number

of people repaying, those people lose the money that they repay to the bank, and their group is still terminated by the bank, giving them a worse yield than others in the group who didn't repay at all. It then becomes very difficult for groups to develop a steady state of repayment.

Similarly, it is difficult for people to adopt sanctioning, because sanctioning is costly, and is only worthwhile if it causes sanctionees to switch to strategies involving repayment, and thus brings the group above the threshold needed to achieve repayment. With low initial levels of sanctioning or repayment, however, it becomes very difficult for sanctioning to become a common part of strategies.

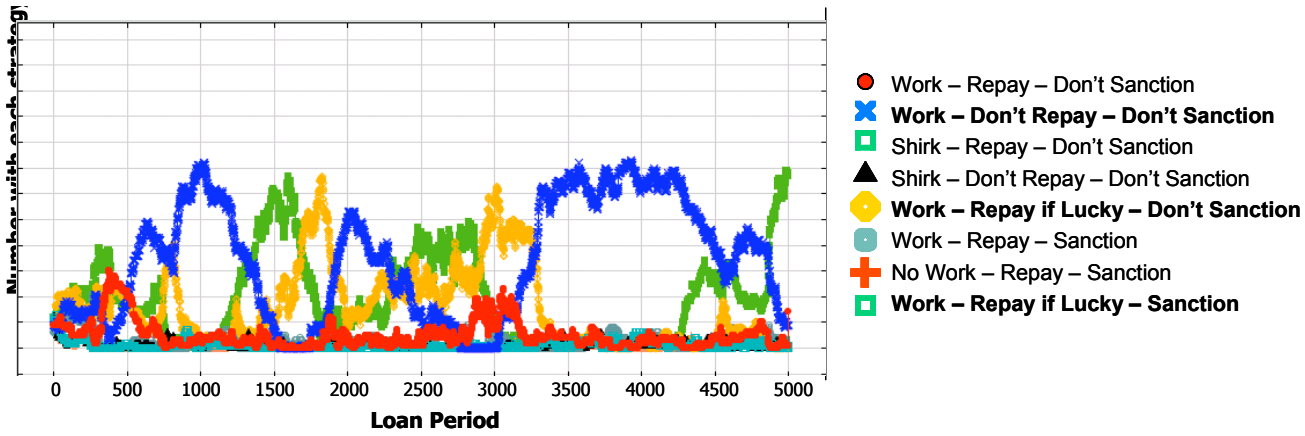
5. Experiment 2

The most important reason, however, why sanctioning and repayment did not become part of strategies in Experiment 1, however, is that, due to the method of strategy choice, individuals don't "see" the bank's punishment. Individuals only compare their cumulative records with those of other people within their group, and the bank sanctions the group all together. Thus, a person who doesn't repay always appears to be doing better than someone who does repay, because individuals do not have the ability to compare themselves with groups that aren't sanctioned.

For example, assume that John is in a group in which everyone is repaying. If he, too, repays, he will get a high yield, because the group won't be sanctioned, and he can continue to make returns for the next 10 loan periods. If he does not repay, he might (if mutual repayment does not occur) cause the group to be terminated. For that one period, however, John's yield is higher than that of the others in the group, because they repaid and he did not. When the other people choose strategies the next period, they will choose John's non-repaying strategy, because they are only comparing his yield with their own, and have no idea that they could have all done much better had they all repaid. Thus, repayment will disintegrate quickly.

It is possible to get around this issue, however, by having people sometimes compare their records with people outside their group. In example above, if a repaying member of John's group compares her strategy with both John and a member of a group in which everyone repays, the group in which everyone repays will have not been terminated, and thus have the best record, even though John got the one-time boost from not having repaid.

To this end, a new parameter is introduced – the probability that the peers selected for comparison during strategy choice are in one's own group. It seems reasonable to assume that people in microfinance situations actually do compare their repayment strategies with people in other groups – it should be remembered that microfinance institutions explicitly encourage this by having multiple groups meet together weekly at "center" meetings. For the simulations below, the chance that a person chosen for comparison is in one's own group is set to 0.8. A typical result is shown below:



As can be seen above, with this new parameter, the strategy choice becomes cyclic. At around period 1000, most people are not repaying and not sanctioning (blue line). Then, through random mutations, a group happens to have many people who are sanctioning, which means that the other people in that group switch away from not repaying and instead begin to repay if they are lucky. People in other groups then see that this group is doing well and not being terminated, and adopt this strategy. By period 1500, nearly all the people in all the groups are repaying if lucky, and sanctioning (green line). At this point, some individuals begin to repay if lucky, but not sanction, because when almost everyone is already repaying, sanctioning is costly to the individual, with not a very large benefit. Thus, repaying if lucky, but not sanctioning becomes the most prevalent strategy by around 1800 (gold line). This, however, opens up the door for people to stop repaying, because there are no longer many sanctioners in the population, and the cycle starts again (blue peak at 2000).

This appears to be a more realistic model than that of Experiment 1 – repayment can be achieved, but is difficult to sustain. In fact, it might accord with the what is actually happening in the real world, and show the progression over a longer time scale than we can see at this time – the Grameen bank started with high repayment rates (equivalent to a green or orange peak in the figure above), which are now falling (a blue peak). It is not unreasonable to think that at some point in the future, people might begin to realize that it is preferable to repay again, and repayment rates might begin to rise.

6. Policy Perspective

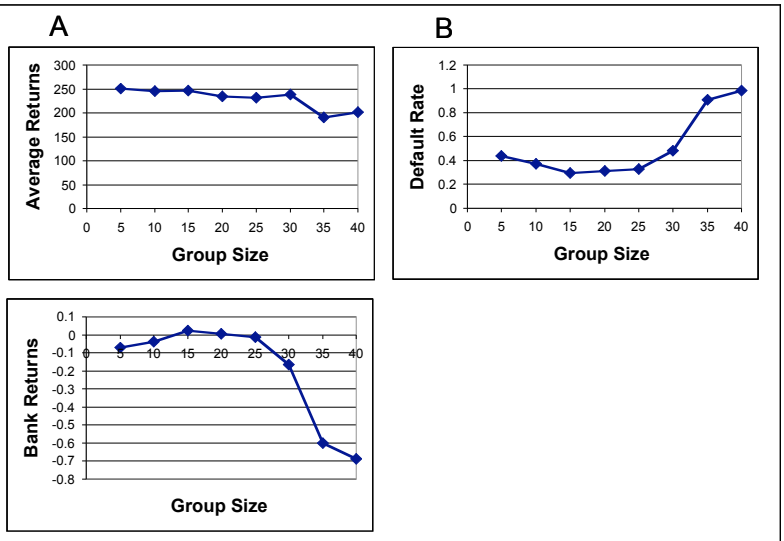
If the model is to be of use from a policy perspective, it is important to consider which parameters are able to be changed by MFI policy. It is generally difficult to change individual behavior, such as the way that people compare themselves with peers, or how much it costs to sanction. Equally, some group level parameters, such as the probability of mutual repayment if possible, are set by individuals and probably not very amenable to being changed by policy makers. There are, however, some aspects of microfinance that are easily manipulable people involved in MFIs. The two that are focused on below are group size and interest rate, both of which are set by the MFI, and so results from the model might be able to have some effect on policy.

6.1. Group Size

There are 2 main effects that group size could have on repayment rates and default rates for the bank. At low sizes, the group could be small enough that even when all members of the group put in effort, enough of them fail that they are unable to repay their debt to the bank. With large groups, on the other hand, people are less likely to accurately punish those who do not repay, and thus sanctions are less effective. There should, then, be a group size that maximizes repayment rates and minimizes default rates when there two effects balance each other out – that is, the group size is large enough that default because of bad luck is rare, but small enough that people know each other well enough that they are able to use sanctions effectively.

As can be seen in the figures below, the effects that were predicted were indeed seen. Group size has a purely negative effect on average returns to individuals (See graph A), because even in groups that were not able to pay back their entire loan and were terminated, those who were lucky paid back what they could. At large group sizes, the sanctions became ineffective, the group defaulted frequently, was terminated frequently, and thus had low returns.

For the bank, the group size also showed the expected patterns (graphs B and C). At small group sizes, the default rates were high because of chance, and at large group sizes, they were also high because of ineffective sanctions. In the middle (at approximately 15-20 people), the group sizes were optimal, with a low default rate (~0.3), and positive returns to the bank (~0.02).



In the figure above, each point represents the average value of 50 runs of the simulation at that group size. In figure A, the Y axis represents the averaged value of total returns over the last 1000 loan periods. Figure B represents the percentage of group loans on which there was default, and Figure C is the returns the bank realizes on loans offered.

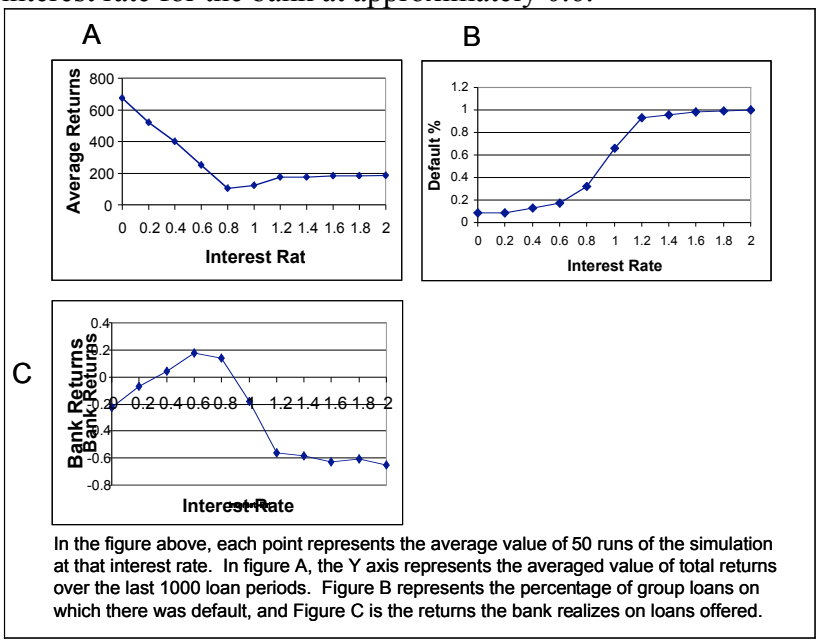
6.2. Interest Rate

Another parameter that can be set by MFIs is the interest rate on loans. As with the group size discussed above, there are competing effects on interest rate for the bank. With very low interest rates, repayment rates should be high, but each time that a group repays, the yield will be small. With higher interest rates, there should be a higher rate of

default, but each time with returns should provide a high yield. These effects should again yield an optimal interest rate for the bank.

For individuals, there should be no benefit to a higher interest rate. Returns should strictly drop with interest rate.

As seen below, this is indeed the pattern that was seen. For individuals, returns strictly dropped with interest rate, default rates strictly rose, but there was an optimal interest rate for the bank at approximately 0.6.



In the figure above, each point represents the average value of 50 runs of the simulation at that interest rate. In figure A, the Y axis represents the averaged value of total returns over the last 1000 loan periods. Figure B represents the percentage of group loans on which there was default, and Figure C is the returns the bank realizes on loans offered.

6.3. Discussion

It is interesting to note that in both the case of group size and interest rates, the optimal values were different for individuals receiving microloans and for the microfinance institution (for interest rates, the optimal for individuals was 0, while it was 0.6 for banks; for group sizes, the optimal for individuals was 5, while it was 15 for banks). This raises a question for microfinance institutions – is the goal to maximally assist people in developing countries, or to be a profit making operation? Traditionally, MFIs have claimed that they can do both, but these initial result suggest that there are tradeoffs between the two, and that choices might need to be made. Which way MFIs lean, however, is outside the scope if this study.

7. Why do we care?

This model is not meant to exactly represent real-world situations. The statements above are not meant to suggest that MFIs should set group sizes to 15, and interest rates to 0.6 to maximize profits. The model leaves out many key aspects of real microfinance situations, vastly simplifying the roles of both individuals and banks. Why, then, should anyone care about its results?

While the model is vastly imperfect, the goals are to give qualitative results, not quantitative ones, and hopefully to point out different effects (for example, the competing effects on group size), to help guide policy. While quantitative results are extremely

difficult if not impossible, hopefully these qualitative results can assist program managers in choosing how to structure loan policies, etc.

Additionally, at this time, the parameter values that are being used are highly imperfect, and have been chosen fairly arbitrarily. Over time, however, we hope to be able to set the parameters to more realistic values using a combination of two methods.

Firstly, we will do a sensitivity analysis on all the parameters to determine which ones the results of the model depend on sensitively. These are then more important to set correctly, as small changes in these key parameters might have large effects on the results. Those on which the model is not sensitive can be set more arbitrarily, as errors in their values will have small to negligible effects on the results.

Once we have identified those parameters on which the model depends sensitively, we will attempt to determine their correct values through the use of case studies. There are many case studies written of both successful and unsuccessful microfinance programs, and we will attempt to finesse the model so that in situations with the extracted parameter values the model behaves as it did in those situations. Once the model is replicating these past histories correctly, it becomes more likely that new results are closer to the truth.

8. Further Directions and Conclusions

There are many possible directions in which to proceed. While it would be possible to carry out the sensitivity analysis and the parameter setting as shown above, it seems more useful at this time to add in other aspects of the behavior individuals and institutions involved in microfinance to make a potentially more realistic model before doing so. At the moment, it might be impossible to match the real-world data to the model, but with a more complicated model, it will hopefully become easier.

The current extensions that are being considered are many. Firstly, in the current version, groups are formed at the very beginning of a run, and stay the same throughout all the time periods, with the bank terminating groups for several loan periods. In real microfinance situations, however, banks terminate groups forever, but allow individuals to re-form groups and reapply for new loans. This leads to assortive matching, with repaying individuals being matched with other repaying individuals into new groups. This will have an effect on the repayment rates and composition of the groups.

Additionally, in the model people currently do not have a choice to not participate in the microfinance program. Every time step they are in their group, and if the group receives a loan, they receive their part. However, it is not clear that everyone who is eligible for participation in MFIs does so.

Many microfinance programs prefer to give loans to women rather than men. One potential reason for this is that women engage in different professions than men, tending to be involved with crafts or other non-agricultural pursuits, while men are more involved in agriculture. Agriculture carries highly correlated risks – if your crop is ruined by drought, it is highly likely that your neighbors' (and other group members') crops have also been ruined by the same drought. This makes default more likely, as people will tend to fail all at the same time, and thus be unable to cover for one another. Thus, the presence of correlated risks and whether or not they vary with gender needs to be investigated.

Another avenue for exploration is to make the ways in which your chances of being sanctioned vary with group size. This is currently a fairly arbitrary function, but the introduction of some type of network (possibly a small-world network) relating people in the community would allow for a more natural determination of effectiveness of seeing others and effectiveness and cost of sanctions. People who were direct acquaintances would be very accurate in seeing the non-repayment of others, and sanctions would be very effective and very costly. As distance increased (in number of steps in the network necessary to get from one to the other), the chances of seeing would decrease, as would the effectiveness and cost of sanctions. It might be particularly interesting to see how this view would interact with the re-forming of groups after termination, as groups would initially be made of very close friends, but, as time went on, and close friends turned out to be bad borrowers, groups would start to be made of people who were more and more tenuously related, but who were also better borrowers (higher repayment rates). This could potentially account for what microfinance institutions have seen already, where repayment rates begin high but gradually fall.

A final option to explore would be multiple MFIs. Bangladesh, for example, has been seeing lower repayment rates, which is sometimes attributed to the multitude of MFIs that operate there. People feel like the pressure to repay is low, because even if they are cut off from their current MFI, they can always transfer to another. Competition between MFIs is thus another potentially interesting path.

The results presented herein are very preliminary. As the model grows to incorporate some or all of the suggestions above, hopefully it will become a better match to real world data, and thus a potential predictor of the success or failure of real world programs, and perhaps be able to assist program planners.