Risky Loans and the Emergence of Rotating Savings and Credit Associations

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Abstract: This paper provides an explanation for the prevalence of rotating savings and credit associations (Roscas), a financial institution which is observed world-wide, vis-à-vis a credit market. I develop a model of lending to borrowers who are exposed to risk and whose liability is limited. Individual risks are distributed in a large population. I examine two alternative scenarios regarding information. When individual risks are publicly known, Roscas which allot funds using competitive bidding are as efficient as a centralized credit market and achieve the outcome in a decentralized fashion. When information on individual risk is privately held, Roscas with a bidding or a random allotment of funds may be more efficient than a credit market. These findings are related to the emergence of informal and formal Roscas in rural and urban settings.

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1 Introduction and Overview

The rotating savings and credit association (Rosca) is a group-based, revolving financial scheme which has been documented in developing countries around the world.[1] In a Rosca, a group of people get together regularly, each contributes a fixed amount, and at each meeting one of the members receives the collected pot. Once a member has received a pot she is ineligible to receive another one. The Rosca ends once each member has received exactly one pot. The institutional details of Roscas vary. In particular, the order of receipt of pots is typically determined by either a lottery or a sequence of auctions, which gives rise to the labels random Rosca and bidding Rosca.

Roscas are observed in fundamentally different environments. According to various accounts, informally organized Roscas form the backbone of village financial markets in several countries while registered, professionally managed Roscas are an important part of India's contemporary formal financial sector and flourished in Japan around 1900.[2]

Among economists, the existence of Roscas vis-à-vis banks is poorly understood. The only existing attempt to compare the efficiency of Roscas with a standard credit market is Besley et al. (1994), who find that bidding Roscas are always less efficient than a credit market. This is because, in their model, allocations generated by bidding Roscas are less flexible than those feasible in a credit market. Random Roscas, on the other hand, may be more or less efficient than a credit market, depending on parameters. These results are at odds with several stylized facts arising from empirical observation. First, bidding Roscas are extremely popular, in villages as informal institutions as well as in cities as part of the formal financial sector. Second, even in populations with access to bank credit, Roscas coexist alongside banks (e.g. Levenson and Besley, 1996).

In this paper, I resolve these puzzles and, moreover, explain several institutional features of actual Roscas. I do so by analyzing a model of lending to borrowers who are exposed to risk and whose liability is limited. That these two features are common characteristics of credit markets in low-income countries is amply documented (for example Banerjee, 2003; Udry, 1994). Moreover, I take seriously alternative contexts in which Roscas are observed. Specifically, I distinguish between alternative information regimes regarding the inherent riskiness of a potential borrower.

I consider an economy of agents each of which is endowed with one unit of a financial asset. Moreover, each agent has access to an indivisible investment project requiring an up-front investment of two units of the financial asset. For each agent, the investment yields an identical expected return. However, the probability of failure (or the riskiness)

[1] Countries and territories in which Roscas have been documented include Barbados, Benin, Bolivia, Cameroon, Chile, China, Congo, Cote d'Ivoire, Egypt, Ethiopia, Ghana, Ghana, Guyana, Hawaii, Hongkong, Mexico, India, Indonisia, Jamaica, Japan, Kenya, Korea, Liberia, Malaysia, Malawi, Mexico, Nepal, Niger, Nigeria, Pakistan, Papua-New Guinea, Peru, Philippines, Sambia, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Sudan, Taiwan, Tanzania, Thailand, The Gambia, Timor, Togo, Trinidad, Uganda, Vietnam, Zimbabwe, as well as the UK and the US, where Roscas have been observed among immigrants from Pakistan and Korea.

[2] According to Schrieder and Cuevas (1992), informal Roscas handle about one half of Cameroon's total national savings. Shah and Johnson (1996) estimate that in the south Indian state of Kerala, credit made available through formal Roscas alone is roughly twice the volume of bank credit.

of the project is distributed across agents. Borrowers cannot post collateral and liability for repayment is limited to the payoff of the investment project. Given that the expected net return on investment is positive, the efficient outcome is that half of the population lends its financial endowment while the other half borrows and undertakes the investment.

I model borrowing and lending in Roscas and a credit market in which a competitive bank intermediates between borrowers and lenders. I compare the efficiency of different types of Roscas with a credit market under alternative assumptions regarding an individual's option to quit a credit mechanism. Moreover, two scenarios regarding information on individual riskiness are considered. In the first, this information is publicly held, which I view as a stylized model of informal village financial markets where individuals are well-informed about each other (Udry, 1990). Roscas are modeled as a two-stage game. In the first stage, individuals match into groups. In the second stage, an auction or a lottery determines the identity of borrowers and the loan terms. I find that bidding Roscas are as efficient as a credit market and, moreover, achieve this outcome in a decentralized manner, i.e. without an intermediary or the assumption of price-taking agents. A random Rosca, on the other hand, is in general not efficient as it fails to discriminate by borrower risk. These findings provide a compelling rationale for the popularity of informal bidding Roscas.

In an alternative scenario, information on individual riskiness is privately held, which I view as a stylized model of formal, typically urban, financial markets. With this assumption, the model is similar to the model of adverse selection in a credit market by Stiglitz and Weiss (1981). As types are observationally identical, a centralized credit market cannot discriminate between borrowers of different risks. At a given interest rate, only sufficiently risky borrowers apply for a loan. In Roscas, on the other hand, matching into groups is random because types remain unobserved, and bidding is modeled as a private value auction. I show that, in general, neither a credit market nor a Rosca achieves an efficient allocation. This is because the bulk of total expected surplus is captured by high risk borrowers, leaving too little for safe lenders to make participation in such a scheme attractive. I show, however, that a bidding or a random Rosca can be more efficient than a credit market. These findings provide a rationale for the existence of formal Roscas in urban settings and the coexistence of bidding and random Roscas vis-à-vis bank credit. They, moreover, suggest that formal Roscas may be viewed as a market, rather than a non-market, institution when the market environment suffers from the friction of asymmetric information.

Another issue which is addressed for the first time in this paper is the endogenous formation of savings and credit groups. In particular, my results on matching into Roscas are in accordance with the empirical observation of homogenous membership in informal, and heterogenous membership in formal Roscas (Bouman, 1995; Eeckhout and Munshi, 2005).

The findings of this study add to a literature that has emerged in the aftermath of Stiglitz and Weiss (1981), which is concerned with how adverse selection problems can be overcome by additional features that allow screening or signalling. Bester (1985) for example shows that collateral can be used to separate between safe and risky borrowers. Another mechanism that can alleviate the adverse selection problem is reputation (Diamond, 1989). In this connection, the results of my model with private information show that when credit supply is endogenous, the outcome of a standard credit market may be improved upon by competitive bidding, which provides some degree of self selection, or lotteries, which decrease average borrower riskiness by pooling types.

The present analysis also provides an explanation for the disappearance of Roscas at more advanced stages of economic development. In developing countries, borrowers often lack collateral and, even if available, weak legal institutions make it difficult for the lender to seize collateral. Moreover, credit reporting agencies, which furnish reputation building in a formal financial sector, are largely absent. The analysis of this paper makes clear that the advantages of Roscas melt away once borrowers can post collateral and institutional lenders have access to additional information on potential borrowers, which is typically the case in high income countries. This is consistent with the empirical observation that Roscas are wide-spread in the former and rare in the latter group of countries.

This paper contributes to the understanding of financial institutions in development in three ways. First, none of the existing theoretical work on Roscas (Ambec and Treich, forthcoming; Besley et al., 1993, 1994; Anderson and Balland, 2002; Anderson et al., 2004; Basu, 2005; Klonner, 2003; Kovsted and Lyk-Jensen, 1999; Kuo, 1993) has explicitly addressed the problem of default while a large body of empirical literature on Roscas and lending in developing countries more generally is primarily concerned with this issue. Moreover, with the exception of Besley et al. (1994), none of this literature has addressed the efficiency of Roscas in comparison to bank lending. Finally, there is a large body of theoretical literature on how innovative elements of microfinance, most notably joint liability lending, can help overcome frictions which plague credit markets in low income countries (e.g. Armendariz de Aghion and Gollier, 2000; Ghatak, 2000; Rai and Sjöström, 2004; Stiglitz, 1990). In this paper, I am first to show that the Rosca as a long-standing indigenous institution which provides group based credit, can be viewed as an institutional response to precisely those problems.

The rest of this paper is organized as follows. The next section introduces the basic structure of the model and provides additional background on Roscas. Section 3 characterizes lending in Roscas and a credit market when information flows freely among individuals. An analogous analysis is carried out in section 4 under the assumption of private information on types. The final section concludes.

2 The Model

2.1 Basic Setup

There is a large population of agents, each of which is endowed with one unit of a financial asset, which will be denominated in dollars for convenience. There are two time periods. In the first, each agent has access to an investment project which costs 2 and yields an expected payoff of $\mu > 1$ per dollar invested one period later. With probability p the project yields $\frac{\mu}{p}$, and with probability $1-p$ the project payoff is zero. P is distributed over the population according to the continuously differentiable cdf $F(p)$ on support $[\underline{p}, \overline{p}]$, $0 \leq \underline{p} < \overline{p} \leq 1$. We denote by $P_{i:k}$ the i'th highest order statistic of a random sample of size k. p_m denotes the median of P's distribution. $E_P[P]$ and $E[P]$ both denote the expected value of P.

The basic setup is similar to Stiglitz and Weiss' (1981) model of adverse selection in credit markets with the exception that, in their model, there is an exogenous credit supply while, in my model, both demand and supply of funds are endogenous. Moreover, in their paper, information on types is privately held while I will consider, in addition, an alternative scenario in which each individual's type p is common knowledge.

Project outcomes are independently distributed. Each individual is a risk neutral expected utility maximizer who does not discount future consumption. There is limited liability. Specifically, if an individual obtains a loan and invests, her repayment is limited to the payoff of the project. There is no other form of collateral.

I consider four specific credit mechanisms, a centralized credit market, a random Rosca, and bidding Roscas with alternative auction protocols. A credit market is modeled by a bank that earns zero profits. Specifically, the bank posts interest rates for a unit loan and a unit deposit, where the interest rate may be contingent on the individual type. Subsequently, each individual chooses between remaining autarkic, demanding a unit loan and making a unit deposit.

In general, Roscas are savings and credit groups in which a group of individuals meet at a set of uniformly spaced dates. At each meeting, each member contributes a fixed amount to a so-called pot which is then allotted to a group member according to some pre-arranged principle. Each member obtains exactly one pot, which implies that there are exactly as many meetings as there are group members. Group membership ranges between ten (Geertz, 1962, for Shanghai) and one hundred (Radhakrishnan, 1975, for urban India) and the time between any two consecutive meetings may be as little as a day (Handa and Kirton, 1999, for Jamaica) and as much as six months (Geertz, 1962, for Shanghai).

To keep the analysis as simple as possible, all Roscas considered in this paper have exactly two members. With bidding Roscas, in the first period, individuals match into groups of two, each member contributes one dollar to the pot and an auction determines the identity of the borrower as well as the gross repayment amount R due in the second period. The borrower invests the funds obtained from the pot and pays R to the other Rosca member in the second time period - provided the project succeeds. This element of the model is analogous to Besley et al. (1993; 1994) in that the loan size in the first period is fixed and bidders bid for an additional future obligation. Such a payoff scheme for bidding Roscas is documented, for example, in Seibel and Shrestha (1988) for Nepal and Smith (1899) for rural China.[3]

I consider two auction protocols which are commonly observed in Roscas. Firstly,

[3] Another commonly observed form of bidding is for a contemporaneous discount from the loan (Radhakrishnan, 1975, on urban India; Smith, 1889, on rural China; Tankou and Adams, 1995, for Cameroon), which is paid as a dividend to the losing bidder of the auction.

Rosca members submit subsequent oral ascending (OA) bids for the gross repayment amount. The auction ends when the going bid fails to be raised further. The last bid is the gross repayment which the auction's winner owes a period later. According to the descriptive literature, the oral ascending auction appears to be the most common auction format in bidding Roscas. It is documented for Roscas in 14th century Japan (Izumida, 1992), 19th century China (Smith, 1899), contemporary Taiwan (Kuo, 1993), India (Eeckhout and Munshi, 2005), and Cameroon (Tchuindjo, 1998). In accordance with much of the economic literature on OA auctions, I model this auction as a button auction (see, e.g., Krishna, 2002).

Secondly, in a bidding Rosca with a first price sealed bid auction, each bidder submits a sealed envelope with her bid to an auctioneer. The high bidder obtains a unit loan from the other bidder and the gross repayment in the second period is given by the winner's bid. This auction protocol has been documented in rural areas of China (Smith, 1899) and Japan (Embree, 1946).

With random Roscas, individuals match into groups of two, both members contribute one dollar each to the pot, and a lottery with equal odds determines the borrower. Since repayment terms are not an element of this credit mechanism in practice, I assume a given gross repayment amount which is uniform across Rosca groups. In a classical random Rosca, as e.g. considered by Besley et al. (1993; 1994) and Anderson and Baland (2002), there is no interest rate component, which would amount to a repayment of $R = 1$ in the second period. As documented in Bouman (1995), however, random Roscas with an interest rate element are also observed in practice. In particular, he describes a random Rosca among Korean immigrants in Washington DC, in which "the first person to receive the pot makes a larger repayment than does the second person, who, in turn, pays more than the third person. A standard set of printed tables is used to determine how much each person repays to the Rosca. This way people know in advance how much interest they will pay or receive depending on their position." The model of a random Rosca developed in this paper captures precisely such a scheme. In particular, I allow for a repayment amount R which is uniform across Rosca groups but which may or may not equal unity.

For the models considered here, it is useful to specify a sequence of five stages which applies to all four credit mechanisms. In the first stage, each individual observes her type, and chooses to participate in the credit mechanism or remain autarkic. In case of participation in a Rosca, individuals match into Rosca groups of two. In a credit market, no matching takes place as this mechanism works in a centralized fashion, i.e. individuals trade with an intermediary. In the second stage, individuals bid in a bidding Rosca, and choose to apply for a loan or a deposit in a credit market. Since the repayment is fixed rather than endogenous in a random Rosca, in this mechanism, no actions occur at the second stage. In the third stage, the credit mechanism determines the identities of borrowers and lenders together with a repayment amount R for each borrower. In the fourth stage, a borrower chooses whether or not to invest her funds. For a borrower who does not invest, her wealth of two units is kept in an interest-free savings account until the next stage. In the fifth stage, project outcomes are realized and claims are settled. We assume that there are no enforcement problems, i.e. a borrower with a successful project outcome is liable up to the stipulated repayment amount. A borrower who chose not to invest at the fourth stage is liable up to an amount of 2.

2.2 Efficiency Conditions

Provided $\mu > 1$, total expected surplus is maximized if, and only if, half of the population lends one dollar each, and the other half borrows one dollar each and undertakes the investment. As the expected return is identical for all individuals, the identity of borrowers and lenders is irrelevant. Any efficient allocation involves an expected surplus of $\mu - 1$ per individual, while this figure is zero for an autarkic individual.

In this subsection, I define a participation constraint, which regards an individual's expected payoff at the first stage. I proceed to a continuation constraint, which regards the third stage. Finally, incentive compatibility of investing funds at the fourth stage is discussed. The conditions defined here will be used subsequently to assess and compare the potential of each of the four alternative credit mechanisms to generate an efficient allocation.

To start out, we introduce some notation. Denote by $\pi^k(p)$ the expected first stage utility of an individual of type p from participating in arrangement k, where $k \in \{CM, BRS, BRF, RR\}$. Denote by $\pi^A(p)$ type p's autarky payoff. Since, in this case, an individual merely consumes her endowment, $\pi^A(p) = 1$. For type p, participating in arrangement k is individually rational if, and only if, $\pi^k(p) \geq \pi^A(p)$. An efficient allocation with arrangement k requires that no individual chooses to stay autarkic. This is stated formally in the following participation condition,

$$\pi^k(p) \geq 1 \text{ for all } p. \tag{IR1}$$

Before the end of the third stage, a Rosca member is ignorant about whether she will be a borrower or a lender. We therefore consider the expected payoff to a lender and a borrower of type p at the end of the third stage separately and denote them by $\pi^{k,l}(p,R)$ and $\pi^{k,b}(p,R)$, respectively. We will consider three alternative scenarios. First, if all individuals can still choose autarky after the third stage, efficiency of credit mechanism k requires that no individual chooses to do so, which requires that

$$\pi^{k,m}(p,R) \geq 1 \text{ for all } R \in \mathcal{R}^{k,m}(p), \text{ all } p \in \mathcal{P}^{k,m},\ m = b, l. \tag{IR2}$$

$\mathcal{R}^{k,b}(p)$ ($\mathcal{R}^{k,l}(p)$) denotes the set repayment amounts which a borrower (lender) of type p faces in mechanism k at the end of the third stage with positive probability. To give an example, when each individual bids according to the same decreasing bidding function $R^F(p)$ in first price auction Roscas, $\mathcal{R}^{BRF,b}(p)$ is the singleton $R^F(p)$ while $\mathcal{R}^{BRF,l}(p)$ is the interval $(R^F(p), R^F(\underline{p})]$. $\mathcal{P}^{k,b}$ ($\mathcal{P}^{k,l}$) denotes the set of types who become borrowers (lenders) in mechanism k at the third stage with positive probability. In the example just given, each type p becomes a borrower or lender with positive probability and thus

$\mathcal{P}^{BRF,b} = \mathcal{P}^{BRF,l} = [\underline{p}, \overline{p}]$.

Second, only lenders may have the option to leave the credit mechanism after the third stage, for example if borrowers cannot enforce disbursement of the loan. In this case, continuation constraint IR2 is replaced by the weaker condition

$$\pi^{k,l}(p, R) \geq 1 \text{ for all } R \in \mathcal{R}^{k,l}(p) \text{ and all } p \in \mathcal{P}^{k,l}. \tag{IR2L}$$

If, third, only borrowers have the option to leave the credit mechanism after the third stage, because, say, a lender cannot enforce acceptance of the loan by a designated borrower, IR2 is replaced by

$$\pi^{k,b}(p, R) \geq 1 \text{ for all } R \in \mathcal{R}^{k,b}(p) \text{ and all } p \in \mathcal{P}^{k,b}. \tag{IR2B}$$

We now turn to the borrower's investment decision, which occurs at the fourth stage. We denote by $\pi^{k,b}_{inv}(p, R)$ and $\pi^{k,b}_{sav}(p, R)$ the expected fourth stage payoff to a borrower of type p in credit mechanism k given repayment R when she chooses to invest and save, respectively. We will require that the expected payoff from investing is strictly larger than from not-investing, which is justified if the investment requires, for example, some small extra effort. Efficiency of mechanism k then requires

$$\pi^{k,b}_{inv}(p, R) > \pi^{k,b}_{sav}(p, R) \text{ for all } R \in \mathcal{R}^{k,b}(p) \text{ and all } p \in \mathcal{P}^{k,b}. \tag{IC}$$

3 Public Information

3.1 Credit Market

With public information on types, loans can be priced according to a borrower's risk. It is therefore essentially a corollary of the first fundamental theorem of welfare economics that a centralized credit market in which agents act as price-takers, achieves an efficient outcome.

One example of an efficient, budget balanced scheme for a bank is: offer a unit loan to all individuals with $p > p_m$ and $R(p) = \mu/p$, and offer a unit deposit with a certain repayment of μ to all remaining individuals. For a borrower, this involves a fourth stage expected payoff from investing of $2\mu - p\frac{\mu}{p} = \mu$ and from not-investing of $\max(2 - p\frac{\mu}{p}, 0) < \mu$, so IC clearly holds.

Turning to the conditions $IR1$ and $IR2$ impose in this particular case, at both the first and after the third stage, the expected payoff for each borrower is

$$2\mu - p\frac{\mu}{p} = \mu > 1,$$

and for each depositor

$$p\frac{\mu}{p} = \mu > 1,$$

which implies that $IR1$ and $IR2$ hold for all p. This is summarized in the following proposition.

Proposition 1 *With $\{IR1, IR2, IC\}$ a credit market always generates an efficient allocation.*

3.2 Bidding Roscas With Oral Ascending Auctions

In contrast to a credit market with price-taking agents, bidding Roscas involve strategic behavior. In the first stage individuals choose to join a Rosca and match into Rosca groups of two, in the second stage bidding occurs, and in the fourth stage borrowers choose whether or not to invest. We solve this game by backward induction. For a borrower of type p, at the fourth stage, IC requires

$$2\mu - pR > \max(2 - pR, 0). \tag{3}$$

Provided this holds, $IR2B$ moreover requires that

$$2\mu - pR \geq 1.$$

For a lender who is matched with a borrower of type p, $IR2L$ requires that

$$pR \geq 1.$$

We start the analysis at the second stage by considering a Rosca with types p_1 and p_2 and assuming that (3) holds. The objective is to calculate each type's stopout price in the button auction. Consider agent 1. Her expected payoff from winning the auction at price R is $2\mu - p_1 R$, and from losing the auction $p_2 R$. Agent 1's best response to a given stopout of the other bidder, R_2, is thus to bid

$$R_1 = \frac{2\mu}{p_1 + p_2} \tag{4}$$

if $R_2 \leq 2\mu/(p_1 + p_2)$ and R_2 minus a small increment otherwise. This implies that the unique pure strategy Nash equilibrium of this auction is $R_2 = R_1 = 2\mu/(p_1 + p_2)$. Thus, irregardless of the pair of types matched in a Rosca, both bidders have an identical stopout price. Since we are ultimately inerested in oral ascending bids, however, a tie will never occur in practice. Moreover, it is readily checked that IC as formalized in (3) holds for any pair (p_1, p_2).

We are now in a position to tackle the matching stage. In the terminology of matching theory, the present situation is a roommate problem (see Gale and Shapley, 1962). In a roommate problem, any two individuals of a population are a potential match. While, for such problems, the existence of a stable matching is not guaranteed in general, one can show that the unique stable matching in the present problem is assortative.

Lemma 2 *The unique subgame-perfect stable matching is assortative.*

Proof. Consider a finite population with n (n even) individuals randomly drawn from F. Denote by $p_{i:n}$ the i'th highest order statistic in this sample. It will be shown that the matching $M^*(n) = \{(p_{1:n}, p_{2:n}), ..., (p_{n-1:n}, p_{n:n})\}$ is the unique stable matching. It will be convenient to define the corresponding matching function

$$\sigma^*(i) = \begin{cases} i+1, \ i \text{ odd} \\ \\ i-1, \ i \text{ even,} \end{cases}$$

where i denotes the rank in the ordered (from safest to riskiest) population.

Stability of $M^*(n)$:

I show that no breaking pair to $M^*(n)$ exists. Conditional on the second stage bidding equilibrium, in a Rosca with types p_1 and p_2, the expected payoff of agent 1 is

$$\frac{2\mu p_2}{p_1 + p_2},$$

which is clearly increasing in p_2 for any p_1. Thus all types have identical preferences. In particular, individual utility is strictly decreasing in the Rosca partner's risk $(1-p)$. Now consider the potential breaking pair $s \equiv (j,k)$ with types $p_j > p_k$. Clearly, in s, j is matched with a riskier partner than according to $M^*(n)$. Since j strictly prefers a safer partner, however, j would not agree to join this breaking pair.

Uniqueness of $M^*(n)$:

Consider an arbitrary matching function $\sigma(i)$ (i.e. σ satisfies $\sigma(\sigma(i)) = i$) and the following induction:

1) Either $\sigma(1) = 2$ or $(1,2)$ is a breaking pair.

2) For i odd, if $\sigma(i-2) = i-1$ then either $\sigma(i) = i+1$ or $(i, i+1)$ is a breaking pair.

This establishes that no other stable matching function than $\sigma^*(\ )$ exists.

As n approaches infinity, $\max_{i \text{ odd}}(p_{i:n} - p_{i+1:n})$ approaches zero almost surely, which establishes that, in the limit, pairs consist of identical types. ■

The intuition for this result rests on the observation that each type in the population prefers a safer to a riskier partner. This feature and the assortative matching result are similar in spirit to Ghatak's (2000) model of the formation of joint liability credit groups.

Given assortative matching, the auction's bidding equilibrium involves bids of μ/p in each Rosca (see (4)). We are now in a position to assess the efficiency of bidding Roscas with oral ascending auctions. As will be shown, in equilibrium, the two members of each Rosca share the expected surplus from investment equally. This implies that OA bidding Roscas are efficient for any combination of efficiency conditions.

Proposition 3 *(i) With $\{IR1, IR2, IC\}$ bidding Roscas with oral ascending auctions always generate an efficient allocation;*

(ii) Matching into Rosca groups is assortative;

(iii) In the auction's pure strategy Nash equilibrium, each bidder bids μ/p.

Proof. (i) With the matching characterized in lemma 2 and the bidding equilibrium (4), we have the following:

IC : In a Rosca where both members are of type p, $R = \frac{\mu}{p}$. Hence (3) clearly holds.

$IR2$: The winner and the loser of an auction have an identical payoff of $\mu > 1$.
$IR1$: The first stage expected payoff to each individual is $\mu > 1$.
(ii) See lemma 2.
(iii) At the second stage, the expected payoff to an individual of type p_1 with a group partner of type p_2 when bids are R_1 and R_2, respectively, is $2\mu - p_1 R_2$ if $R_1 > R_2$, and $p_2 R_1$ otherwise. The best response to a given R_2 is to bid (4) if $R_2 \leq 2\mu/(p_1 + p_2)$ and R_2 minus a small increment otherwise. Hence the only pure strategy Nash equilibrium is $R_1 = R_2 = 2\mu/(p_1 + p_2)$. ■

3.3 Bidding Roscas with First Price Sealed Bid Auctions

The analysis of Roscas with first price sealed bid (FPSB) auctions is analogous to Roscas with OA auctions. Again, individual choices are made about matching, bidding and investing. The following proposition rests on the observation that the equilibrium outcome with FPSB auctions involves payoffs which are identical to oral ascending auctions. Hence the efficiency result of the previous subsection carries over to FPSB auctions.

Proposition 4 *(i) With $\{IR1, IR2, IC\}$ bidding Roscas with first price sealed bid auctions always generate an efficient allocation;*
(ii) Matching into Rosca groups is assortative;
(iii) In the auction's pure strategy Nash equilibrium each bidder bids μ/p.

Proof. (i) and (ii) See parts 1 and 2 of the proof of proposition 3.
(iii) At the second stage, the expected payoff to an individual of type p_1 with a group partner of type p_2 when bids are R_1 and R_2, respectively, is $2\mu - p_1 R$ if $R_1 > R_2$, and $p_2 R_2$ otherwise. The best response to a given R_2 is to bid R_2 plus a small increment if $R_2 < 2\mu/(p_1 + p_2)$ and any $R_1 < R_2$ otherwise. Hence the unique pure strategy Nash equilibrium is $R_1 = R_2 = 2\mu/(p_1 + p_2)$. ■

3.4 Random Roscas

As for bidding Roscas, there is a unique stable matching at the first stage which is assortative. As the repayment fails to be type-dependent, however, lenders to risky types find quitting after the third stage advantageous if R is not sufficiently large and so do safe borrowers if R is not sufficiently small. This is formalized in the following proposition.

Proposition 5 *(i) With $\{IR1, IR2, IC\}$ random Roscas generate an efficient allocation if, and only, if*

$$\mu \geq \frac{1}{2}\left(1 + \frac{\overline{p}}{\underline{p}}\right); \tag{5}$$

(ii) Matching into Rosca groups is assortative;
(iii) Provided (5) holds, for an efficient allocation R has to satisfy

$$\frac{1}{\underline{p}} \leq R \leq \frac{2\mu - 1}{\overline{p}}. \tag{6}$$

Proof. (i) For an individual of the safest type who becomes a borrower, $IR2B$ requires that $2\mu - \overline{p}R \geq 1$, which may be rewritten as

$$R \leq (2\mu - 1)/\overline{p}. \tag{7}$$

For a Rosca member who lends to the riskiest type, $IR2L$ requires $\underline{p}R \geq 1$, which may be rewritten as

$$R \geq 1/\underline{p}. \tag{8}$$

Combining (7) and (8) gives (6). The requirement that the lower bound on R does not exceed the upper bound, is equivalent to (5).
(ii) At the first stage, the expected payoff from a random Rosca to an individual of type p_1 who is matched with type p_2 is

$$\frac{1}{2}\left(2\mu - p_1 R + p_2 R\right),$$

which is increasing in p_2. Thus, as with bidding Roscas, all types have identical preferences and strictly prefer a safer over a riskier partner. The rest of the proof is analogous to the proof of lemma 2.
(iii) See part 1 of this proof. ■

3.5 Discussion

This section has dealt with environments in which individuals are well informed about each other. This informational setup has been found to be a reasonable working assumption for credit transactions in villages (e.g. Udry, 1990) as well as for informal Roscas among residents of an urban slum (Anderson et al., 2006). It is needless to say that individuals in such environments are subject to various risks, which affect their ability to repay. It therefore comes as no surprise that almost any study of informal Roscas mentions default problems (e.g. Anderson et al., 2006; Graham, 1992; Handa and Kirton, 1999; Wu, 1974).

Although, according to our results, bidding Roscas are not more efficient than a credit market, they fair favorably when additional features are taken into account. First, a credit market considered here requires centralized intermediation while bidding Roscas generate an efficient allocation in an entirely decentralized fashion where lending occurs within pairs of agents. Second, a credit market requires price taking behavior by all agents while bidding Roscas make the price formation process explicit and allow for strategic behavior of individuals.

On the other hand, the random Rosca is clearly inferior to each of the other three mechanisms as it requires a sufficiently large expected return, which essentially has to compensate for the random Rosca's lack of ability to price-discriminate by borrower type. In particular, when extremely high risks ($\underline{p}$ close to zero) are in the population, an unrealistically high expected return is needed (see (5)) to achieve an efficient allocation.

Taken together, the findings of this section provide an important explanation for both the prevalence and the functioning of bidding Roscas in environments where information flows freely and borrowers are subject to risk to different extents. In particular, the feature of assortative matching in informal Roscas is extensively documented in extant empirical literature. In a survey of informal Roscas in Cameroon, Schrieder and Cuevas (1992) point out that "all groups are self-selecting regarding their membership" and Graham (1992) in a study of rural Niger reports that each of his sample Roscas "had a common occupational bond [...]. These occupational bonds were also highly correlated with similar income levels and, to a lesser extent, age groupings. Close proximity was also an important feature of their groupings." In the same vein, Bouman (1995) summarizes that, around the globe, membership in informal Roscas "tends to be homogenous" and that participants typically share the same occupation, income group and residential area.

It is interesting to compare our findings to Besley et al.'s (1994) comparative study of Roscas and a credit market. Their model shares the feature of an identical return to investment for all individuals in a population. Their model is more restrictive, however, in that investment projects involve no risk. It is more general, on the other hand, in that it considers an infinite, rather than a two period, time horizon. These authors find that bidding Roscas are never as efficient as a credit market. On the other hand, random Roscas may be preferred to a credit market, depending on parameters. Bidding Roscas fair poorly essentially because there are no distributed types in their model. This in turn implies that there is no scope for efficiency-enhancing price discrimination. I find, on the other hand, that bidding Roscas are efficient because they successfully price-discriminate by borrower risk, while random Roscas fail to do so.

Combining the two sets of results is useful to understand context-specific coexistence of both types of Roscas in village settings. Klonner (2001) for instance describes an agricultural village in south India where farmers engage in bidding Roscas with large, biyearly contributions while random Roscas with small, monthly contributions are popular among wage-earning women. Funds from the bidding Roscas are used for productive, but potentially risky, agricultural investments while the proceeds from random Roscas are spent on durable household goods, which involve no risk for the borrower's income stream. The situation of farmers closely matches the stylized facts captured by the model in this paper while the situation of wage-earning women in the study village resembles the scenario considered by Besley et al. (1994). The choice of the type of Rosca in these two sub-contexts is thus perfectly in accordance with the predictions of the two alternative modeling approaches.

4 Private Information

The basic setup is as in the preceding section, except that each individual observes only her own probability of success, p. Under this assumption, individuals are randomly matched into Rosca groups of two as there is no observable information according to which individuals could match. In a credit market, on the other hand, there can be only one "price" R, as discrimination according to risk is not feasible.

In the sequel, I analyze the four credit mechanisms in turn. It is shown that, unlike in the case of public information, neither of them achieves an efficient allocation for any $\mu > 1$ when $IR1$, $IR2$ and IC are required. Moreover, to facilitate a subsequent efficiency comparison with alternative specifications of the continuation constraint, each credit mechanism's properties regarding $IR2B$ and $IR2L$ are examined in some detail.

4.1 Credit Market

No price discrimination by risk is feasible. Instead a uniform repayment of, say, $\widetilde{R}$ is posted. I first consider the second stage and show that there is a unique $\widetilde{p}(\widetilde{R})$, such that only types with $p \leq \widetilde{p}$ apply for a loan and all types with $p > \widetilde{p}$ choose to lend. Individual expected utility from borrowing and investing is $\pi^{CM,b}(p, \widetilde{R}) = 2\mu - p\widetilde{R}$, and from lending $\pi^{CM,l}(p, \widetilde{R}) = \widetilde{R}E[P^B]$, where the random variable P^B is distributed according to the distribution of types among those who apply for a loan. With price taking behavior, we obtain the decision rule: apply for a unit loan if $\pi^{CM,b}(p, \widetilde{R}) \geq \pi^{CM,l}(p, \widetilde{R})$ or equivalently $2\mu - p\widetilde{R} \geq \widetilde{R}E[P^B]$, and lend one's endowment otherwise. This in turn implies that $E[P^B] = E[P|P \leq \widetilde{p}(\widetilde{R})]$. To ensure that exactly half of the population applies for a loan, which is needed for efficiency, it is required that $\widetilde{p}(\widetilde{R}) = p_m$, which in turn yields

$$R^* = \frac{2\mu}{p_m + E[P|P \leq p_m]}.$$

The following proposition characterizes when the various conditions set out in section 2.2 hold.

Proposition 6 *In a credit market with repayment* R^*
(i) IC *always holds,*
(ii) $IR1 \Leftrightarrow IR2 \Leftrightarrow IR2L \Leftrightarrow IR2B$.
(iii) There exists a unique value of μ *strictly greater than one,*

$$\mu^{CM} = \frac{1}{2}\left(1 + \frac{p_m}{E[P|P \leq p_m]}\right), \tag{9}$$

such that $IR1$ *holds if, and only if,* $\mu \geq \mu^{CM}$.

Proof.
(i) At the fourth stage, we have that, for all $p \leq p_m$,

$$\begin{aligned}\pi_{inv}^{CM,b}(p, R^*(\mu)) &= 2\mu - p\frac{2\mu}{p_m + E[P|P \leq p_m]} \\ &> 2 - \max\left[\frac{2\mu}{p_m + E[P|P \leq p_m]}, 2\right] = \pi_{sav}^{CM,b}(p, R^*(\mu)). \end{aligned} \tag{10}$$

The inequality is always strict as, for all $p \leq p_m$,

$$\pi_{inv}^{CM,b}(p, R^*) = \frac{p_m + E[P|P \leq p_m] - p}{p_m + E[P|P \leq p_m]}2\mu > 0.$$

(ii) In a credit market, each individual knows whether she will be a borrower or lender when deciding to join at the first stage. Therefore

$$\pi^{CM}(p) = \begin{cases} \pi^{CM,b}(p, R^*) \text{ for all } p \le p_m \\ \\ \pi^{CM,l}(p, R^*) \text{ for all } p > p_m. \end{cases}$$

Since, for all $p > p_m$, $\pi^{CM,l}(p, R^*) = \frac{2p_m\mu}{p_m+E[P|P\le p_m]} = \pi^{CM,b}(p_m, R^*) = \min_{p\le p_m} \pi^{CM,b}(p, R^*(\mu)) = \min_p \pi^{CM}(p)$, each of the four conditions holds if, and only if,

$$\frac{2p_m\mu}{p_m + E[P|P \le p_m]} \ge 1. \tag{11}$$

(iii) μ^{CM} in (9) is obtained from solving (11) for μ. ■

The intuition for parts 2 and 3 is as follows. In a credit market, all lenders achieve identical expected utility irregardless of the individual type, which, by the definition of the market clearing repayment amount, equals the expected utility of the safest borrower, who is of type p_m. Therefore, the participation and the three alternative continuation constraints are all equivalent to the condition that a lender's expected payoff be larger than under autarky. Part 3 states that the investment project's expected return has to be sufficiently large to make market participation beneficial for the safer half of the population. Otherwise the interest rate which equals supply and demand will not be high enough for safe types to make credit market participation superior to autarky. The result that efficient financing will not generally occur in a credit market with adverse selection is parallel to Stiglitz and Weiss' (1981) model with exogenous credit supply. Sufficiently high expected returns, on the other hand, help overcome this failure.

4.2 Bidding Roscas with Oral Ascending Auctions

Matching into Rosca groups of two is random as types are unobserved. The Rosca auction thus has to be analyzed within the symmetric-independent-private-value (SIPV) framework of auctions (see Krishna, 2002).[4] I will show that for both auction formats considered here there exist equilibrium bidding functions which are decreasing in the individual's type. Equilibrium bidding functions are downward-sloping because, as in the preceding analysis, the valuation for a loan at a given repayment is increasing in individual riskiness. As a consequence, in each Rosca, the riskier participant is awarded the loan.

With an OA auction, the repayment amount is determined by the losing bidder. Consider a situation in which each bidder bids according to the function $R^S(p)$, where $dR^S(p)/dp < 0$. The expected payoff to an individual of type p at the second stage is

$$\pi^{BRS}(p) = (1 - F(p))(2\mu - pE[R(P)|P \ge p]) + F(p)R(p)E[P|P \le p].$$

[4] Previous analyses of Rosca auctions within the SIPV framework are Klonner (2003), Kovsted and Lyk-Jensen (1999) and Kuo (1993).

$2\mu - pE[R(P)|P \geq p]$ is the expected payoff if type p wins the auction. She will repay the expected repayment amount, which equals the expected bid of the other bidder, with probability p. For type p, the probability of winning the auction is $1 - F(p)$ because $\Pr(R^F(p) < R^F(P)) = \Pr(p > P) = 1 - F(p)$, where the first equality is due to $dR^F(p)/dp < 0$. $R(p)E[P|P \leq p]$ is the expected payoff to an auction's loser of type p. The repayment amount is determined by the loser's bid $R(p)$ while the probability of repayment is the expected value of the other, winning, bidder's type, $E[P|P \leq p]$. This is because this auction protocol does not elicit the winner's stopout price and hence her type throughout all stages of the game.

Proposition 7 *(i) In the symmetric Bayesian Nash equilibrium of an OA bidding Rosca, each bidder chooses her stopout price as*

$$R^S(p) = \frac{\mu}{E[P|P \leq p]} \left(2 - \frac{E[P_{1:2}|P_{1:2} \leq p]}{E[P|P \leq p]}\right),$$

which is strictly decreasing in p.
(ii) If $\underline{p} \geq \frac{1}{2}$, IC always holds; otherwise IC may or may not hold;
(iii) $IR2L$ implies $IR1$;
(iv) There exists a unique value of μ strictly greater than one,

$$\mu^{BRS} = \frac{\mu}{E[P]\, R^S(\overline{p})}, \tag{12}$$

such that $IR1$ holds if, and only if, $\mu \geq \mu^{BRS}$.

Proof. (i) It is readily verified through standard auction solving techniques (see, e.g., Krishna, 2002) that $R^S(\ )$ solves the necessary condition

$$\max_t (1 - F(t))(2\mu - pE[R(P)|P \geq t]) + F(t)R(t)E[P|P \leq t] \text{ for all } p, \tag{13}$$

bidder 1's stage 2 expected payoff if both bidders bid according to the decreasing function $R()$ but bidder 1 pretends to be of type t rather than p. To see that $R^{S\prime}(p) < 0$, consider the differential equation implied by (13),

$$R^{S\prime}(p) = \frac{2f(p)}{F(p)E[P|P \leq p]}(\mu - pR^S(p)). \tag{14}$$

Using L'Hopital's rule, one first shows that $R^{S\prime}(\underline{p}) = -\frac{2\mu}{3\underline{p}^2} < 0$ and $R^{S\prime}(\underline{p}) > -\mu/p^2 = \frac{d(\mu/p)}{dp}$, which, by a continuity argument, implies that there exists an $\varepsilon > 0$ such that, for all $\underline{p} < p < \underline{p} + \varepsilon$, $R^{S\prime}(p) < 0$ and $R^S(p) > \mu/p$. The second step is to show that $R^S(p) > \mu/p$ for all $p > \underline{p}$, which, by virtue of (14), establishes the claim. Toward this, assume that there exists a $p' > \underline{p}$ at which $R^S(p)$ and μ/p intersect. By virtue of (14), this implies $R^{S\prime}(p') = 0 > \frac{d(\mu/p)}{dp}$, which contradicts the previous finding that $R^S(p) > \mu/p$ for sufficiently small p.
(ii) First notice that $\mathcal{P}^{BRS,b} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{BRS,b}(p) = [R^S(\overline{p}), R^S(p))$. IC holds if, and only if, $\pi_{inv}^{BRS,b}(p, R^S(p')) > 0$ for all $p \in \mathcal{P}^{BRS,b}$ and all $R \in \mathcal{R}^{BRS,b}(p)$. This in turn is

equivalent to

$$\min_p \left(\min_{p'>p} \pi_{inv}^{BRS,b}(p, R^S(p')) \right) = \min_p \left[2\mu - pR^S(p) \right] > 0.$$

By l'Hopital's rule, $R^S(\underline{p}) = \mu/\underline{p}$. Since $R^{S\prime}(p) < 0$, we have that

$$R^S(p) \leq R^S(\underline{p}) = \mu/\underline{p}. \tag{15}$$

A sufficient condition for IC is thus $\mu/\underline{p} \leq 2\mu$, which is equivalent to $\underline{p} \geq \frac{1}{2}$.

We prove the second statement of part 2 through two examples. When P is distributed uniformly on the unit interval, $pR^S(p) = \frac{4}{3}\mu < 2\mu$ for all p. In this case IC holds. When the distribution of P has density $f(p) = 12(p - \frac{1}{2})^2$, $pR^S(p) > 2\mu$ for $p = 0.6$.

(iii) $\mathcal{P}^{BRS,l} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{BRS,l}(p) = \{R^S(p)\}$. I$R2L$ hence requires that $\min_p E[P|P \leq p]R^S(p) \geq 1$, which implies $\pi^{BRS,l}(\overline{p}, R^S(\overline{p})) = E[P]R^S(\overline{p}) \geq 1$. Turning to $\pi^{BRS}(p)$, notice that, by the envelope theorem, $\pi^{BRS\prime}(p) = -(1 - F(p))E[R(P)|P \geq p] < 0$, which implies that $IR1$ is equivalent to $\pi^{BRS}(\overline{p}) \geq 1$. The identity $\pi^{BRS}(\overline{p}) = \pi^{BRS,l}(\overline{p}, R^S(\overline{p}))$ establishes the claim.

(iv) As established in the proof of part 3, $IR1$ is equivalent to $\pi^{BRS}(\overline{p}) = E[P]R^S(\overline{p}) \geq 1$, from which (12) follows immediately. $\mu^{BRS} > 1$ as $E[P]R^S(\overline{p}) = \frac{E[P_{2:2}]}{E[P]}\mu < \mu$. ■

The first part of part 2 has a simple intuition. A borrower owes a principal of one dollar and has a payoff of $2\mu/p$ in the successful state. When the riskiest borrower still has a chance of success of at least one half, the expected repayment from her is at least μ when $R = 2\mu$. Thus, with $R = 2\mu$, the lender gets an equal share of the total profit if the borrower is the riskiest type ex post and even more than half of the surplus otherwise.

Part 3 states that the lender continuation constraint is in general more binding than the participation constraint. According to part 4, efficient financing in the presence of adverse selection problems will in general not occur if participation in OA bidding Roscas is subject to individual choice. Specifically, it is the safest type in the population who has the lowest first stage expected payoff and thus determines the profitability threshold below which an efficient allocation fails to be attained.

4.3 Bidding Roscas with First Price Auctions

As for OA bidding Roscas, matching into Rosca groups is now random. In contrast to an OA auction, however, the type of the auction's winner is revealed in the third stage as, in a first price sealed bid auction, the winning bid is announced by the auctioneer.

Consider a situation in which each bidder bids according to the function $R^F(p)$, where $dR^F(p)/dp < 0$. The expected payoff to an individual of type p at the second stage is

$$\pi^{BRF}(p) = (1 - F(p))(2\mu - pR^F(p)) + F(p)E[PR^F(P)|P \leq p].$$

$2\mu - pR^F(p)$ is the payoff to an auction's winner of type p provided she invests and $1 - F(p)$ is the probability of this event. $E[PR^F(P)|P \leq p]$ is the expected payoff to an auction's loser of type p, which is the expectation over the other bidder's type times that type's bid. $F(p)$ is type p's probability of losing the auction.

Proposition 8 *(i)The symmetric Bayesian Nash equilibrium bidding function in FPSB auction Roscas is*

$$R^F(p) = \mu E\left[\frac{1}{P_{2:2}}|P_{2:2} > p\right], \tag{16}$$

which is strictly decreasing in p.
(ii) IC always holds;
(iii) IR2B always holds;
(iv) if IR2L holds, then IR1 holds.
(v) There exists a unique value of μ strictly greater than one,

$$\mu^{BRF} = \frac{\mu}{E\left[R^F(P)P\right]}, \tag{17}$$

such that IR1 holds if, and only if, $\mu \geq \mu^{BRF}$.

Proof. (i) It is readily verified that $R^F(\ )$ solves the necessary condition

$$\max_t (1 - F(t))(2\mu - pR(t)) + F(t)E[PR(P)|P \leq t] \text{ for all } p, \tag{18}$$

i.e. p maximizes bidder 1's stage two expected utility when both bidders bid according to $R^F(\ )$ but bidder 1 has the option to pretend to be of type t rather than her true type p. $R^{F\prime}(p) < 0$ follows from the fact that $\frac{d}{dp}\frac{1}{p} < 0$.
(ii) First notice that $\mathcal{P}^{BRF,b} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{BRF,b}(p) = \{R^F(p)\}$. At the fourth stage, we have that, for all p,

$$\pi_{inv}^{BRF,b}(p, R^F(p)) = 2\mu - pR^F(p) > 2 - \max\left[pR^F(p), 2\right] = \pi_{sav}^{BRF,b}(p, R^F(p)).$$

The inequality is always strict as, for all p, $2\mu - pR^F(p) > 0$. To see this, notice that, by (16), $R^F(p) \leq \frac{\mu}{p}$ for all p.
(iii) Recall that $pR^F(p) \leq \mu$. Thus

$$\pi^{BRF,b}(p, R^F(p)) = 2\mu - pR^F(p) \geq \mu > 1.$$

(iv) $\mathcal{P}^{BRF,l} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{BRF,l}(p) = (R^F(p), R^F(\underline{p})]$. $IR2L$ hence requires that

$$\min_p \left(\min_{p'<p} \pi^{BRF,l}(p, R^F(p'))\right) \geq 1,$$

which is equivalent to

$$\min_p \pi^{BRF,l}(\overline{p}, R^F(p)) = \min_p pR^F(p) \geq 1. \tag{19}$$

Turning to $IR1$, by the envelope theorem $\pi^{BRF\prime}(p) = -(1 - F(p))R(p) < 0$. Therefore

$IR1$ is equivalent to

$$\pi^{BRF}(\overline{p}) = E[PR^F(P)] \geq 1. \tag{20}$$

The claim follows from the fact that $E[PR^F(P)]$ in (20) is clearly larger than $\min_p pR^F(p)$ in (19).

(v) As established in the proof of part 4, $IR1$ is equivalent to $\pi^{BRF}(\overline{p}) = E[PR^F(P)] \geq 1$, from which (17) follows immediately. $\mu^{BRF} > 1$ as $E\left[\frac{1}{P_{2:2}}\right] > E[P_{2:2}]^{-1} > 1$. The first inequality holds by Jensen's inequality and the second because $E[P_{2:2}] < 1$. ■

By the nature of the first price auction, it is the borrower who determines the repayment amount in each Rosca. As the bidding equilibrium is such that a bidder always shades her bid sufficiently relative to her valuation for a loan, a borrower is always guaranteed a sufficiently large residual claim on her investment, which ensures both IC and $IR2B$. For an individual who becomes a lender, on the other hand, this bid shading generates allocations where the expected payoff to an auction's loser is smaller than under autarky. This underlies the result of part 4, which states that the lender's third stage continuation constraint is more restrictive than the first stage participation constraint. In particular, the proof of part 4 shows that, after the auction, the worst off lender has a lower expected utility than any individual at the time of joining a Rosca.

As for the credit market, part 5 states that efficient financing in the presence of adverse selection problems will in general not occur if participation in a Rosca is an individual's choice. More precisely, the expected return has to be sufficiently large to make participation advantageous for the safest type in the population, who knows with certainty that she will be lending to a riskier type than herself ex post.

4.4 Random Roscas

As in bidding Roscas, individuals are randomly matched into Rosca groups of two. As in section 3.4, it is assumed that the repayment amount R is fixed upfront and uniform across all Roscas. Under these assumptions, the expected payoff to an individual of type p at the second stage is

$$\pi^{RR}(p) = \frac{1}{2}(2\mu - pR) + \frac{1}{2}E[P]R. \tag{21}$$

$2\mu - pR$ is the payoff of the lottery's winner of type p provided she invests and $1/2$ is the probability of this event. R is the payoff of the lottery's loser when the winner is successful, which occurs with probability $E[P]$ in expectation.

Proposition 9 *(i) IC holds if, and only if,* $R < \frac{2\mu}{\overline{p}}$*;*
(ii) IR2B holds if, and only if, $R \leq \frac{2\mu-1}{\overline{p}}$*;*
(iii) IR2L holds if, and only if, $R \geq \frac{1}{E[P]}$*;*
(iv) There exists a unique value of μ *strictly greater than one,*

$$\mu^{RR} = \frac{E[P] + \overline{p}}{2E[P]}, \tag{22}$$

such that $IR2$ holds if, and only if, $\mu \geq \mu^{RR}$.
(v) $IR1$ holds if, and only if, $\mu \geq 1 + R(\overline{p} - E[P])/2$.

Proof. (i) First notice that $\mathcal{P}^{RR,b} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{RR,b}(p) = R$. Analogous to the proof of proposition 8, IC holds if, and only if, $\pi_{inv}^{RR,b}(p, R) > 0$ for all p. This in turn is equivalent to

$$\min_p \pi_{inv}^{RR,b}(p, R) = \min_p [2\mu - pR] = 2\mu - \overline{p}R > 0.$$

The last inequality is equivalent to the condition stated in the proposition.
(ii) $IR2B$ requires that

$$\min_p \pi^{RR,b}(p) = \min_p [2\mu - pR] = 2\mu - \overline{p}R \geq 1.$$

The last inequality is equivalent to the condition stated in the proposition.
(iii) $IR2L$ requires that

$$\min_p \pi^{RR,l}(p) = \min_p E[P]R = E[P]R \geq 1.$$

The last inequality is equivalent to the condition stated in the proposition.
(iv) $IR2$ requires that the conditions for $IR2B$ and $IR2L$ stated in parts ii and iii hold simultaneously. This in turn requires that $1/E[P] \leq (2\mu - 1)/\overline{p}$, which gives μ^{RR} when solved for μ.
(v) Substituting $\overline{p}$ for p in (21) and solving $\pi^{RR}(\overline{p}) = 1$ for μ gives the condition stated in the proposition. ■

For parts 1 and 2, incentive compatibility of investing, as well as the continuation constraint for borrowers, requires a sufficiently large residual claim from investing for the borrower, which is ensured only if the repayment amount does not exceed a specific threshold. On the other hand, part 3 states that a lender will only be willing to continue if repayment in the successful state of the borrower exceeds a certain threshold.

Finally, part 4 states that efficient financing in the presence of adverse selection problems will in general not occur if continuation in a Rosca is subject to individual choice. According to part 5, the participation constraint is not binding for random Roscas when R is zero. This is precisely because of the lottery element, which makes an extremely unequal ex post distribution of surplus - the borrower takes all - individually rational ex ante. This is in stark contrast to the other three credit mechanisms where the safest type knows already at the first stage that she will become a lender subsequently. Such a type would never join a mechanism which, at the third stage, distributes surplus the way a random Rosca does.

4.5 Efficiency

In this section, I consider the efficiency of each of the four credit mechanisms under alternative combinations of participation, continuation and incentive compatibility constraints.

In particular, it will always be required that a credit mechanism satisfies the participation ($IR1$) and investment incentive compatibility constraint (IC). Moreover, alternative forms of the continuation constraint will be added ($IR2$, $IR2B$, $IR2L$). To be precise, I will consider four sets of constraints, $\{IR1, IC\}$, $\{IR1, IR2B, IC\}$, $\{IR1, IR2L, IC\}$, and $\{IR1, IR2, IC\}$. For each set of conditions and each mechanism, I focus on the smallest expected project return which ensures an efficient allocation, or return threshold for short. In the sequel, for a given set of conditions, the credit mechanism with a return threshold strictly smaller than the return threshold of any other credit mechanism will be called most efficient. This property implies that there exists a range of expected returns for which only the most efficient credit mechanism implements an efficient allocation. Moreover, for a given set of conditions, credit mechanism A will be called more efficient than B if A has a strictly smaller expected return threshold than B.

The objective of this exercise is twofold. First, I will show that, depending on the set of conditions and the distribution of risks in the population, a random or a bidding Rosca, or a credit market may be most efficient. This justifies the existence of each of these mechanisms, which are all observed in practice, in private information environments. Second, I will identify under what conditions which mechanisms are most efficient. This will allow indirect inference about structural features of an economic context in which a particular credit mechanism prevails.

We start with a partial ranking among Roscas. In particular, the following proposition gives conditions under which Roscas with first price auctions are less efficient than other forms of Roscas.

Proposition 10 *(i) With $\{IR1, IC\}$ or $\{IR1, IR2B, IC\}$, a random Rosca with $R = 0$ is more efficient than a bidding Rosca with first price auctions.*
(ii) If $\underline{p} = 0$, then, with $\{IR1, IR2L, IC\}$ or $\{IR1, IR2, IC\}$, a bidding Rosca with OA auctions is more efficient than a bidding Rosca with first price auctions.

Proof. (i) By proposition 9, part 1, IC always holds for random Roscas when $R = 0$. For $R = 0$, $\pi^{RR}(p) = \mu > 1$ and $\pi^{RR,b}(p, 0) = 2\mu > 1$ for all $\mu > 1$. By proposition 8, part 4, there exist $\mu > 1$ for which $\min_p \pi^{BRF}(p) < 1$. Therefore there exist $\mu > 1$ for which $\min_p \pi^{RR}(p) > 1 > \min_p \pi^{BRF}(p)$, which is the claim.
(ii) It follows from (19) that, for bidding Roscas with first price auctions, $IR2L$ implies $\underline{p}R^F(\underline{p}) = \mu E[\underline{p}/P_{2:2}] \geq 1$. $E[\underline{p}/P_{2:2}]$ is clearly equal to zero for $\underline{p} = 0$, and so is $\underline{p}R^F(\underline{p})$ for any finite μ. Therefore, for $\underline{p} = 0$, $IR2L$ never holds for Roscas with first price auctions. For Roscas with OA auctions, $IR2L$ is equivalent to $\min_p E[P|P < p]R^S(p) \geq 1$. This minimand is clearly greater than zero for any $\mu > 1$ and $p > 0$. Moreover, for $p = 0$, the minimand equals 1 for any $\mu > 1$ (see the definition of $R^S(p)$ in proposition 7). Therefore there exist $\mu > 1$ for which bidding Roscas with OA auctions satisfy $IR2L$, which establishes the claim. ■

The first part of proposition 10 establishes that when neither Rosca participant's, or only the borrower's continuation is of concern, random Roscas are more efficient than bidding Roscas with first price auctions. This is essentially because the random element together with no obligation to repay makes each type's first stage expected utility equal to μ, which implies that, with $IR1$ and IC, participation is advantageous for all types whenever the investment project is profitable in expectation.

When $IR2L$ is required, a random Rosca with zero repayment is not any longer feasible because it leaves the lender with a zero expected payoff. Part 2 of proposition 10, however, establishes that in this case Roscas with first price auctions are less efficient than Roscas with OA auctions if sufficiently high credit risks are in the market. In particular, whenever a designated lender in a first price auction Rosca is confronted with such a borrower, she will not continue while she would in a Rosca with an OA auction.

The following proposition gives possible efficiency rankings for Roscas vis-à-vis a credit market.

Proposition 11 *Among the three credit mechanisms, credit market, bidding Rosca with OA auction and random Rosca,*
(i) with $\{IR1, IC\}$ *or* $\{IR1, IR2B, IC\}$*, a random Rosca with* $R = 0$ *is most efficient;*
(ii) with $\{IR1, IR2L, IC\}$*, a credit market, a bidding Rosca with OA auction or a random Rosca with* $R = 1/E[P]$ *is most efficient;*
(iii) with $\{IR1, IR2, IC\}$*, a credit market or a random Rosca with* $R = 1/E[P]$ *is most efficient.*

Proof. (i) It has been shown in part 1 of proposition 10 that a random Rosca with $R = 0$ satisfies $IR1$, $IR2B$ and IC for any $\mu > 1$. Further, part 3 of proposition 6 and part 4 of proposition 7 establish that $IR1$ does not hold for μ sufficiently close to one for a credit market and OA auction Roscas. Taken together, these two observations establish the claim.
(ii) First notice that, by part 3 of proposition 9, a random Rosca with $R = 1/E[P]$ satisfies $IR2L$. Moreover, $\mu \geq \mu^{RR}$ and $R = 1/E[P]$ imply that IC as stated in part 1 of proposition 9 holds:

$$R = \frac{1}{E[P]} < \frac{1}{E[P]} + \frac{1}{\overline{p}} = \frac{2\mu^{RR}}{\overline{p}}.$$

For a credit market, IC always holds according to part 1 of proposition 6, and, according to parts 2 and 3 of proposition 6, $IR1$ and $IR2L$ hold simultaneously if, and only if, $\mu \geq \mu^{CM}$. The efficiency properties of a random Rosca and a credit market can thus be summarized by μ^{RR} and μ^{CM}, respectively. For OA bidding Roscas, IC holds by part 2 of proposition 7 if $\underline{p} \geq 1/2$. By part 4 of proposition 7, $IR1$ holds for all $\mu \geq \mu^{BRS}$. The minimum value of μ satisfying $IR2L$, on the other hand, needs to be calculated as

$$\mu^{BRS,l} \equiv \frac{\mu}{\min_{p} E[P|P \leq p]R^S(p)}$$

(see the proof of part 3 of proposition 7).
A credit market is most efficient if $\mu^{CM} < \min[\max(\mu^{BRS}, \mu^{BRS,l}), \mu^{RR}]$, a bidding Rosca with OA auction is most efficient if $\max(\mu^{BRS}, \mu^{BRS,l}) < \min[\mu^{CM}, \mu^{RR}]$, and a random Rosca with $R = 1/E[P]$ is most efficient if $\mu^{RR} < \min[\mu^{CM}, \max(\mu^{BRS}, \mu^{BRS,l})]$. We

provide three examples of distributions of P with support $[0.5, 1]$ to prove the claim.

	CM	BRS		RR
$f(p)$	μ^{CM}	μ^{BRS}	$\mu^{BRS,l}$	μ^{RR}
2	1.100	1.125	1.125	1.167
$3657.15(p-0.725)^2(p-0.5)(1-p)$	1.142	1.119	1.122	1.127
$93.2039(p-0.725)^2$	1.195	1.145	1.153	1.126

In the first example, a credit market is most efficient, in the second an OA bidding Rosca is most efficient, and in the third a random Rosca is most efficient.

(iii) For a random Rosca with $R = 1/E[P]$, it has been shown in the proof of part 2 of proposition 11 that $IR2L$ holds, and that $\mu \geq \mu^{RR}$ and $R = 1/E[P]$ imply that IC as stated in part 1 of proposition 9 holds. We now show that $\mu \geq \mu^{RR}$ and $R = 1/E[P]$ imply that $IR2B$ as stated in part 2 of proposition 9 holds:

$$R = \frac{1}{E[P]} = \frac{\overline{p} + E[P]}{\overline{p}E[P]} - \frac{1}{\overline{p}} \leq \frac{2\mu^{RR}}{\overline{p}} - \frac{1}{\overline{p}}.$$

The efficiency properties of a random Rosca with $R = 1/E[P]$ thus solely depend on μ^{RR} when $\{IR1, IR2, IC\}$ are required.

To state $IR2B$ for an OA bidding Rosca, notice that $\mathcal{P}^{BRS,b} = [\underline{p}, \overline{p}]$ and $\mathcal{R}^{BRS,b}(p) = [R^S(\underline{p}), R^S(p))$, which implies that $IR2B$ is given by

$$\min_p \left(\min_{p'<p} \pi^{BRS,b}(p, R^S(p')) \right) = \min_p \left[2\mu - pR^S(p)\right] \geq 1,$$

from which we define the minimum value of μ for which $IR2B$ is satisfied as

$$\mu^{BRS,b} \equiv \frac{1}{\min\limits_p \left[2 - \frac{p}{\mu} R^S(p)\right]}.$$

For an OA auction bidding Rosca to be more efficient than a random Rosca with $R = 1/E[P]$ it is necessary that

$$\mu^{BRS} < \mu^{RR} \tag{23}$$

and

$$\mu^{BRS,b} < \mu^{RR}. \tag{24}$$

We now prove that an OA auction bidding Rosca cannot be more efficient than a random Rosca with $R = 1/E[P]$ by showing that (23) and (24) contradict each other. First notice that $\mu^{BRS} = E[P]/E[P_{2:2}]$. (23) is thus equivalent to

$$\frac{E[P]}{E[P_{2:2}]} < \frac{E[P] + \overline{p}}{2E[P]},$$

which can be rearranged as

$$2E[P]^2 - E[P_{2:2}]E[P] - \overline{p}E[P_{2:2}] < 0. \tag{25}$$

Further, $\mu^{BRS,b} > 1/\left(2 - \frac{\overline{p}}{\mu} R^S(\overline{p})\right) = 1/\left(2 - \overline{p}E[P_{2:2}]/E[P]^2\right)$. Thus a necessary condition for (24) to hold is

$$1/\left(2 - \overline{p}E[P_{2:2}]/E[P]^2\right) < \frac{E[P] + \overline{p}}{2E[P]},$$

which can be rearranged as

$$2E[P]^2 - E[P_{2:2}]E[P] - \overline{p}E[P_{2:2}] > 0,$$

which contradicts (25). This establishes that an OA auction bidding Rosca is never more efficient than a random Rosca with $R = 1/E[P]$ and thus never the most efficient credit mechanism.

For a credit market, according to parts 2 and 3 of proposition 6, $IR1$ and $IR2$ hold simultaneously if, and only if, $\mu \geq \mu^{CM}$. An efficiency comparison between a credit market and a random Rosca thus solely depends on μ^{CM} and μ^{RR}. Hence the first and third example provided in the proof of part 2 of this proposition complete establishing the claim. ■

The first part of proposition 11 complements part 1 of proposition 10. In particular, a random Rosca with zero repayment is most efficient when lenders' continuation is of no concern because it is the only mechanism equalizing first stage expected utility across all types. The second part, in contrast, states that any of the three mechanisms considered may be most efficient when the lender continuation constraint is imposed in addition to the participation and incentive compatibility constraint. In this case, a random Rosca must have a repayment that is sufficient to ensure a lender's continuation, which turns out to equal the inverse of P's expectation (see also part 3 of proposition 9). Most notably, a bidding Rosca with an OA auction may be more efficient than both a credit market and a random Rosca, a result which contrasts Besley et al. (1994), who find that bidding Roscas are always inferior to a credit market among ex ante identical individuals.

When, in addition to $IR2L$, the borrower continuation constraint is imposed, a bidding Rosca with OA auctions can no longer be the most efficient mechanism according to part 3 of proposition 11. The proof establishes that, with $IR2$, an OA auction bidding Rosca is never more efficient than a random Rosca with $R = 1/E[P]$. One can construct examples, however, for which a bidding Rosca with OA auctions is exactly as efficient as a random Rosca with $R = 1/E[P]$.[5]

I did not succeed in including Roscas with first price auctions in the efficiency comparisons covered in the second and third part of proposition 11. More precisely, I could neither prove that a FPSB Rosca is never most efficient, nor find a distribution of types for which a FPSB Rosca is most efficient. Therefore proposition 11 includes only the three remaining credit mechanisms. When propositions 10 and 11 are combined, however, a comprehensive efficiency comparison obtains in which a FPSB Rosca is never most efficient.

[5] For instance, this is the case when P is uniformly distributed on $[0, a]$ for any $0 < a \leq 1$.

Corollary 12 *(i) With* $\{IR1, IC\}$ *or* $\{IR1, IR2B, IC\}$*, a random Rosca with zero repayment is most efficient.*
When sufficiently high risks are in the population,
(ii) with $\{IR1, IR2L, IC\}$*, a credit market, a bidding Rosca with OA auctions or a random Rosca with* $R = 1/E[P]$ *is most efficient;*
(iii) with $\{IR1, IR2, IC\}$*, a credit market or a random Rosca with* $R = 1/E[P]$ *is most efficient.*

4.6 Discussion

This section has dealt with environments in which individuals are poorly informed about each other. The analysis of Roscas under this assumption is largely inspired by the observation that Roscas have seen a vast expansion from informal financial institutions into the formal financial sector. There, specialized financial businesses administer Roscas whose members typically do not know each other at the time of joining the Rosca. Such a development is recorded as early as for Japan's Edo Period (1603-1867). Izumida (1992) cites sources on Japanese Roscas, *kous*, which mention "one man who managed 220 kous. Obviously, this tended to occur mostly in urban areas where it was possible to organize a number of kous in a relatively small area." In 1915, the government instituted legislation which ruled business practices and introduced a registration requirement. Izumida goes on to describe precisely what unobserved individual riskiness in our model captures: "In the process of transforming these informal organizations into formal ones, the main problem was how to determine creditworthiness of members and to establish some measure of mutual trust in the groups." On the other hand, Izumida points out that the organizing companies screened applicants, enforced claims, and provided insurance against the default of individual members. "Their business was not based on mutual trust of participants, but on reputation of the company."

In India the transition of Roscas from informal to formal institutions occurred more recently and still is in full swing. As previously in Japan, specific federal as well as state-level legislation, known as Chit Funds Acts, governs the operations of Rosca companies (Radhakrishnan, 1975). Typically, a Rosca company invites the public to join a Rosca with specific terms (number of members and contribution per month) through newspaper advertisements and rallies. In response, interested individuals register in the company's branch and a Rosca starts once the specified number of members is reached (Eeckhout and Munshi, 2005). At the point of joining, an individual is thus not aware of the identity of the other group members, which is captured by our assumption of random matching into groups. In return, the company takes over the responsibility to enforce payments and to insure recipients of later pots against the default of early borrowers. Rosca companies screen potential customers by requiring a reliable wage income and even cosigners as additional security once a pot is received (Klonner and Rai, 2005). This way, a formal Rosca closely resembles the lending operations of a bank. Given the Rosca companies' policies, moreover, customers of Rosca companies usually also qualify for bank loans.[6]

[6] That the sets of bank clients and Rosca members are not disjunct is most neatly illustrated by Bouman

The relevance of the modeling approach of this section is highlighted by recent empirical work which shows that lending in urban areas of of low-income countries, be it through a standard credit contract or Roscas, indeed faces adverse selection problems (Karlan and Zinman, 2005; Klonner and Rai, 2005). For such a context, we have found that a random Rosca with zero R, which amounts to a winner-takes-all lottery, is most efficient when lender continuation is of no concern. Arrangements which resemble such a Rosca are reported by Izumida (1992) for Japan's Edo Period. In a *torinoki-mujin* "members did not pay further into the mujin after winning the fund." While this author does not provide precise details on the informational environment in which these Roscas operated, he points out that "these appeared in many urban areas, especially in conjunction with temples." This may indicate that these groups were in fact operating in a private, rather than a public, information environment, which would be in accordance with the prediction of our model that such Roscas are especially suited for such environments. The fact that such arrangements are not reported in any other study of Roscas, however, suggests that the popularity of mechanisms in which all surplus accrues to only the borrower is rather limited.[7]

For the case where continuation is a lender's choice, it has been shown in proposition 11 that any of the three mechanisms, credit market, random and OA bidding Rosca, may be most efficient, depending on the parameters of the environment. This result provides a rationale for the current prominence of formal bidding Roscas in India and the popularity of formal bidding and random Roscas in 19th century Japan. It is, moreover, the first successful attempt to rationalize the coexistence of all three credit mechanisms in a formal financial sector.

The results also offer a tentative explanation for the popularity of oral ascending versus tender auctions in formal Roscas. Specifically, proposition 10 demonstrates that when sufficiently high risks are in the population, Roscas with first price sealed bid auctions are never as efficient as random and OA bidding Roscas. In accordance with this prediction, tender auctions seem to be absent and oral ascending auctions the dominant mode in contemporary India's formal Roscas (Radhakrishnan, 1975). Moreover, the only mentions of tender auctions which I could locate are for informal village Roscas in China and Japan (Smith, 1899; Embree, 1946), which is once again perfectly in accordance with the predictions of section 3 of this paper.

5 Concluding Remarks

In an influential paper, Geertz (1962) labeled Roscas a "middle rung" in development, i.e. an "intermediate institution growing up within peasant social structure, to harmonize agrarian economic patterns with commercial ones, to act as a bridge between peasant and trader attitudes toward money and its issues." Our findings confirm and differentiate this

(1995), who reports that three quarters of the employees of the Agricultural Bank in Egypt are members of Roscas.

[7] In this connection, Izumida (1992) notes that torinoki-mujins were banned by the government at some point with the reason that they gambled with people's funds.

view based on a thorough theoretical analysis.

At early stages of economic development, the traditional village economy in which production is organized at the household level, mobility is low, and risk experienced by individuals is substantial, is confronted with monetization and expanding economic opportunities. As Geertz's middle rung argument has it, in such a setting informal Roscas satisfy a credit need which emerges from increasing commercialization, by traditional means of reciprocal exchange. The findings of the present paper highlight the role of especially bidding Roscas in such an environment when risk faced by borrowers is explicitly taken into account. Specifically, I have shown that bidding Roscas provide efficient, decentralized financial intermediation among individuals who are well informed about each other because the auction allows to charge each borrower a risk-commensurate interest rate.

While Geertz's rationale for Roscas ends at this stage, in the present paper, I have also provided a rationale for formal urban Roscas. To continue the above line of argument, as economic development proceeds, larger scale production arrives, individual mobility, in particular rural-urban migration, increases, and market institutions begin to emerge. Risk faced by individuals is, nevertheless, still high, as urban employment prospects are uncertain, access to medical facilities is limited and the prospects for new small-scale businesses are variable. Moreover, in the credit market, borrowers typically lack collateral and formal lenders tend to be poorly informed about potential borrowers, e.g. because of the absence of credit reporting agencies. These developments are reflected by the Rosca's transition from an informal, peer-selected, and village-based scheme to a formal, urban-based institution in which individuals who are not informed about each other are matched by regulated financial businesses. Within such a context, I have provided a compelling rationale for the existence of Roscas vis-à-vis banks. Specifically, it has been shown that bidding Roscas may outperform a centralized credit market plagued by information asymmetries because the auctions introduce price discrimination by borrower risk, which a credit market with a single interest rate fails to achieve. Random Roscas may also be superior to a credit market because the lotteries generate a pool of borrowers which is less risky than the borrowers who apply for a bank loan at the market clearing interest rate. These findings help explain the current state of India's urban financial sector, where formal Roscas intermediate a major fraction of savings and loans.

At a more advanced stage of economic development, information problems in the credit market are mitigated by credit reporting agencies. Accordingly, formal lenders tend to be better informed about a potential borrower than her peers. Moreover, as household wealth grows, collateral is more readily available. While such a situation has not been explicitly analyzed in this paper, it is obvious that within the framework considered here, Roscas' advantages melt away in such an environment. That Roscas tend to disappear at this stage of development has in fact been observed in Japan, where formal Roscas became extremely popular in cities in the 19th and early 20th century, but disappeared about 50 years ago when Rosca businesses transformed into cooperative banks (Izumida, 1992).

Existing studies of financial markets and institutions in low income countries tend to focus on either a particular institution at a time or individual financial activity portfolios. The present analysis suggests that future empirical work should pay closer attention to interactions between the economic environment, individual financial needs, and characteristics of observed financial arrangements. In conjunction with careful theoretical analyses, this will not only deliver a deeper understanding of institutional responses to particular market frictions, but also help design context-appropriate innovative financial instruments for development.

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