# Understanding Chit Funds: Price Determination and the Role of Auction Formats in Rotating Savings and Credit Associations

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**Abstract:**

**Price data from 94 Rotating savings and credit associations (Roscas) with a bidding allotment mechanism are analyzed. We develop a model of financial intermediation in Roscas in a certain world without private information and interpret observed average prices in Roscas accordingly. We find that average prices in Roscas with first-price sealed bid auctions are in accordance with the predictions of model of financial intermediation, while prices in Roscas with oral ascending auctions cannot be rationalized the same way. We provide an explanation for this observation based on private information and information revelation in sequential auctions.**

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## 1 Introduction

The Rotating Savings and Credit Association (Rosca) plays an important role as a financial intermediary in many parts of developing countries. They flourish in both urban and rural settings, especially where formal financial institutions seem to fail to meet the needs of a large fraction of the population. Bouman (1979), for example, estimates that, in central African countries, about 20% of household savings are accumulated in informal Roscas. In the South-Indian state of Tamil Nadu with a population of 62 million, the turnover in formal Roscas has been estimated at 100 billion Rupees, about 2.5 billion US dollars, in 2001 (G. Ranga Rao, 2001). Given the extensive economic literature on the peculiarities of finance and financial intermediation in rural settings of developing economies and recently flourishing interest in microfinance institutions such as the Grameen Bank, Roscas have received little attention by economists.

In each part of the world, Roscas come under different names, all of them share, however, some common features. More specifically, Calomiris and Rajaraman (1998) define a Rosca as ‘a voluntary grouping of individuals who agree to contribute financially at each of a set of uniformly-spaced dates towards the creation of a fund, which will then be allotted in accordance with some prearranged principle to each member of the group in turn’. Once a member has received a fund, in South India also called a ‘chit’, she is excluded from the allotment of future chits until the Rosca ends. The term ‘chit’ stems from the Tamil word ‘chitty’, meaning a written piece of paper, which directly points to one important allotment mechanism, where a lot determines each date’s ‘winner’ of the chit. In contrast to such a random Rosca, in a bidding Rosca, an auction is staged among the members who have not yet received a chit. The highest bid wins the chit and the price the winner pays is distributed among the other bidders.

Many empirical studies report that the funds obtained from a Rosca are often used to purchase a lumpy good whose cost cannot be covered by a member’s current income. In this connection, a random Rosca has the merit of allocating the full amount of the chit to one of the members each time the group meets. The bidding allotment mechanism, on the other hand, allows members to obtain a chit when an unforeseen opportunity or emergency arises, albeit at the cost of a discount. Even in a world without uncertainty, the more flexible bidding arrangement allows members with more profitable investment opportunities to obtain funds earlier by compensating the other members through the price determined in the auction. Thus, in a certain world, a random Rosca is preferred by identical individuals desiring to overcome indivisibilities in consumption, while a bidding Rosca is superior in responding to heterogeneity among its members. While an individual which is following a long-term savings objective does not improve by joining a random Rosca instead of saving autarkically, such an individual may benefit from the impatience of other members in a bidding Rosca by taking the last chit and earning an implicit interest through the price each winner of an auction is paying to the other members. Thus, unlike random Roscas, bidding Roscas are capable of providing financial intermediation between individuals with different objectives and thus compete with more familiar intermediaries such as banks and credit cooperatives. While banks provide impersonal intermediation on a large scale, Rosca groups typically do not exceed 100 members, with often no more than ten. Bidding Roscas thus face an issue of strategic interaction as well as one of volatility if the world is not perfectly certain. On the other hand, their limited size makes Roscas particularly suited for settings in which financial intermediation through banks often fails. In an agricultural village, for example, where enforcement is limited or costly for outsiders, Roscas exploit social ties among the group’s members to overcome such problems.

While originating in the informal financial sector, it may come as a surprise that Roscas have become a big business in urban settings, where no social collateral among the members exists. Since the beginning of the twentieth century, so-called “chit-fund companies” have evolved throughout all urban areas of South India. The steady growth of commercial chit funds, which are almost exclusively of the bidding kind, has induced Indian legislators to pass specific legislation ruling that part of the financial sector. Since, apart from the auctions, customers of chit-fund companies typically do not interact with the other members of the Rosca group they belong to, the role of the organizer, or foreman, is more important in such Roscas than in a setting where members can mutually enforce contributions. Instead, the company collects the contributions and is liable for paying the winner of a chit. Members are not even aware of defaults or late payments of other group members. As the first of its kind, the Travancore Chitties Act went into effect in Kerala in 1945. The Tamil Nadu Chit Fund Act was passed in 1961. Among other things, the Act requires each chit-fund company to obtain a license from the state government and rules minimum capital requirements. While the original draft of the Act did not rule the auctions in a Rosca, the currently effective revision of 1993 also puts a ceiling of 30% of the chit’s amount on the bidding.

The objective of this paper is twofold. Abstracting from strategic concerns potentially present in Rosca auctions, it first analyzes how financial intermediation in formal bidding Roscas takes place and how prices determined in the auctions reflect interest rates implicit in the funds from a Rosca. As a benchmark, it characterizes the allocations induced by a bidding Rosca in a world without uncertainty and perfect information. In a dataset of prices in 94 Roscas, we find that average implicit interest rates indeed correspond to those prevalent outside the Rosca and that an arbitrageur systematically reduces the heterogeneity between Rosca members. In a second step, while keeping the assumption of certainty, we address the issue of private information and strategic behavior in Rosca auctions and show how different auction protocols, namely first-price sealed bid (FP) and open ascending (OA) auctions, can result in different allocations, a difference that does not occur in the absence of private information. We find that, in a stylized Rosca of two members, expected bids are higher when an OA auction takes place, while, in a Rosca with more than one auction, information revealed in early auctions can induce impatient bidders to shade their bids in OA auctions, while such bid shading does not occur in FP auctions. The theoretical results imply a higher likelihood of inefficient allocations with the OA format and higher average winning bids under the FP format.

# 2 Theory and Practice of Price Determination in Bidding Roscas

## 2.1 Basic Theory

In this section we outline a benchmark of financial intermediation among heterogeneous individuals in a bidding Rosca. We consider a Rosca with $T$ individuals and, consequently, $T$ meetings, or rounds, where each individual contributes one Rupee per round. Thus, in each round, the chit amounts to $T$ Rupees. In each round $t \in \{1, \ldots, T\}$ except the last one, there is an auction for the chit. The winner of that auction receives the chit and the price determined through the auction, $b_t$ say, is distributed equally to the members. Since the winner himself receives one $T$'th of the price, his net receipt after the auction is $T - (T\text{-}1)b_t/T$. Turning to the members, assume that each of them is endowed with an income stream of one Rupee per round and that member $j$, say, has access to an investment opportunity outside the Rosca yielding an interest of $r_j$ per round on each rupee invested. Each individual's objective is to maximize his wealth in period $T$.

For analytical convenience, we treat the individuals and the timeline as a continuum and assume that each member $j \in [0,T]$ faces an interest rate of $r_j$, where $r$ is distributed according to the distribution function $F(r)$ with support $[\underline{r}, \overline{r}]$, where the shape of $F$ is public knowledge. In that case, of course, there is no scope for strategic behavior and the auction format does not matter.

We can now derive an equilibrium price path $b^*(t)$, $t \in [0,T]$. To this end, re-index the members $j$ by arranging them according to each one's $r$ in descending order. In this order, we index each individual by $t \in [0,T]$ and obtain an interest rate profile

$$r(t) \equiv F^{-1}\left(\frac{T-t}{T}\right).$$

Note that, by definition, the interest rate profile is non-increasing in $t$ and decreasing if there is some heterogeneity among the members.

Assume a member indexed by $t'$, say, faces some decreasing, exogenous price path $b^{\#}(\ )$ and that he has the choice at which $t \in [0,T]$ to obtain the chit. If the Rosca has proceeded $t^+$ rounds and he has not yet taken the chit, his marginal gain from waiting another round is $-b'(t^+)$ because, under the assumption of a decreasing price path, the price he has to pay for the chit decreases by $-b'(t^+)$ if he waits until the next round. On the other hand, he forgoes the profit he would earn on the funds from the chit in the meantime. At the margin, the said profit is equal to $r(t')(T-b(t^+))$ because $r(t')$ is the interest rate at which he can invest and $T-b(t^+)$ is what he would receive from the Rosca at time $t^+$ apart from the compensation $(T-1)b(t^+)/T$ if he took the chit at time $t^+$. Equating the marginal costs and benefits from waiting and requiring that the individual indexed by $t$ receives the chit at time $t$, we obtain the differential equation

$$-\frac{\partial b(t)}{\partial t} = r(t)(T-b(t))\,. \tag{1}$$

The boundary condition is given by the fact that, in the last round, there is no auction and thus, for member *T*, the price is equal to zero, formally $b(T) = 0$. The solution to this boundary value problem is

$$b^*(t) = T\left(1 - Exp\left[-\int_t^T r(t)dt\right]\right). \tag{2}$$

We note that the allocation generated in this equilibrium is efficient in the sense that members receive subsequent chits in decreasing order of the profitability they face. It is further easy to check that, in equilibrium, each individual's wealth at time *T* is pseudoconcave in the time of receipt of the chit, and that it is thus optimal for individual *t* to obtain the chit at time *t*.

We now turn to the question whether participation in a Rosca is advantageous. Recall that, by assumption, $r(t)$ is non-increasing in *t*. It is readily verified that, if all members are identical and thus $r'(t) = 0$ for all *t*, each of them is just as well off with as without the Rosca. It is moreover straightforward to show that, in equilibrium, any degree of heterogeneity among the members generates an allocation that increases each individual's wealth at time *T*. We thus have

**Proposition 1**

In the absence of private information, in the bidding equilibrium characterized by (2) each of a set of individuals indexed by $t \in [0,T]$ and characterized by the non-increasing interest profile $r(t)$ improves her wealth at time *T* by participating in a bidding Rosca if, and only if

$$r(0) > r(T). \tag{3}$$

Suppose we observe some price path *b*( ) in an actual bidding Rosca. Can any such path be rationalized by some interest rate profile *r*( ) and the efficient equilibrium we have derived?

Solving (1) for $r(t)$, differentiating the resulting equation with respect to $t$, and imposing $r'(t) < 0$ yields the following condition regarding the curvature of $b(\ )$.

**Proposition 2**

A price path $b(t)$ can be rationalized by some non-increasing interest rate profile $r(t)$ if, and only if,

$$b'(t) = 0 \text{ and } -(T - b(t))b''(t) \ \leq \ (b'(t))^2 \text{ for all } t \in [0,T]. \tag{4}$$

Condition (4) limits the degree of concavity of $b(t)$ at any point in time. The reason driving this result is that, thinking backwards with respect to $t$, efficient allocations imply that the interest rate the recipient of the pot at time $t$ faces may not be smaller than that of the recipient at time $t+dt$. When $b(\ )$ is too concave at $t$, however, the gains from waiting are higher than the costs for any $r(t) \geq r(t+dt)$. On the other hand, any globally convex path satisfies (4). To illustrate these results, Figure 1 depicts price paths for a Rosca with $T = 40$. In Panel (i), all face an interest rate of two percent per round, Panel (ii) depicts the case where $r$ is uniformly distributed on [0, 0.04], while in Panel (iii) $F(r) = 1 - \sqrt{1 - (r/0.04)^2}$, $r \in [0, 0.04]$.

## 2.2 Rosca Auction Price Formation in Practice

This section first presents the setup in which the sample Roscas operate and gives some descriptive statistics. As an application of our modeling framework, we show how the simple theory so far developed provides an understanding for the arbitraging of an institutional investor, a peculiarity of these data.

### 2.2.1 The Data

In this section, we analyze price data obtained from one branch of a chit-fund company that operates throughout the South of India. Unlike in bigger cities such as the state capital Chennai, the company has only one branch in this comparatively small urban agglomeration (the Census of 1991 reports a population of about 285,000), which ensures a more stable base of customers. This makes inference derived from several subsequent Rosca groups more reliable. All the company's groups meet once per month, however, in total, the company operates no less than 100 different denominations, that is combinations of the number of members per group and the amount of the contribution paid by each member in each round. In this paper, we focus on one particular denomination, 40 members who contribute Rs. 250 at each meeting, which amounts to a chit of Rs. 10,000. This equals about 12 US Dollars in 1992. For means of comparison, the daily minimum wage for an agricultural laborer in the state of Tamil Nadu, at that time, was equal to Rs. 30. The 94 groups in our dataset were started between August 1990 and June 1993. With each chit spanning over 40 months, the data thus cover a time period of six years. Later in 1993 the revised Chit Fund Act came into place and ruled that bidding in each auction may not exceed 30% of the chit's value. While this is an interesting issue in its own right, in this paper we focus on Roscas with unrestricted bidding.

We now turn to the institutional details of the groups administered by the company. The company itself acts as a special member of each group and is entitled to obtain the first chit at a price of zero. This practice is in accordance with the provisions of the Chit Funds Act and has a tradition in the rural history of Roscas, where the organizer gets the first chit to have hot cash for settling potential defaults or late payments later in the life of the Rosca. Our groups thus involve 38 auctions. On top of receiving one 40'th of the price in each round, the company also deducts six percent commission from each round's chit, in our data Rs. 600 per group and month. In each auction, the minimum bid is Rs. 600 and if no bid is received at that price, a lottery among the active members[1] determines the recipient of that round's chit, who then, in our case, receives Rs. 9,400.

The bulk of the 94 groups in our data involves oral ascending price auctions, which is the traditional auction format of village Roscas in South Asia. Eight groups, however, involve sealed-bid auctions, where the highest bid wins and the price is the bid submitted by the winner. In accordance with the theory presented in the previous section, we initially disregard the auction format.

### 2.2.2 Interpreting the Data

To give a flavor of price determination in the sample, Figure 2 depicts the price path of three randomly chosen Roscas in the sample. While prices are declining on average, there is no single Rosca in the sample where the price decreases in each round. On average, 38% of the auctions generate a higher price than in the round before. While the theory in section 2.1 does not account for such fluctuations, it still applies to average bids in each round if the interest rate an individual observes in each round is the sum of an individual-specific component and a round-specific stochastic component, a 'shock', that all bidders in that round face. Since some prices may be misreported and robustness is a concern in this analysis, the kinky line in Figure 3 depicts the path of the median price in the sample. The smooth line in the same diagram, which generates the same price in the second round as the sample median, corresponds to the predictions of our theoretical model with an interest rate profile of identical individuals facing an interest rate of 1.2

[1] In accordance with the literature, we refer to those members who, in a given round, have not yet received a chit and are thus eligible to receive the current or a future chit, as 'active'.

percent per month. The convex subsection of the path of the sample median suggests that, in terms of our framework, the underlying distribution of revenues is not perfectly concentrated

Turning to the aspect of financial intermediation in the sample Roscas, according to the medians the recipient of the first chit lends at an interest rate of 1.6% while the recipient of the last chit earns an interest of 0.7% per month.[2] This compares to lending rates of pawn brokers accepting gold as collateral of 1.5% percent and bank deposit rates between .5 and 1%.[3] Taking into account the comparatively low collateral requirements of the company,[4] Roscas appear to be a comparatively cheap source of funds for potentially credit-constrained customers. On average, intermediation as provided by the sample Roscas reflects the interest rates of the more well-known financial intermediaries.

### 2.2.3 Arbitrage in the Sample Bidding Roscas

Figure 3 immediately suggests that there is scope for arbitrage in the Roscas of our sample. Comparing the reference line to median prices reveals that late recipients act as if not having any investment opportunity with positive return. Consider an arbitrageur with access to a perfect capital market with interest rate $r' > 0$. Given that bids in early rounds are higher than those on a

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[2] Calculating implicit interest rates for intermediate recipients is flawed by the fact that they are neither pure borrowers nor lenders, so that, for many of the intermediate rounds, the corresponding polynomial does not have a real-valued root.

[3] Note that informal money-lenders charge 3% and more.

[4] The recipient of a chit before the 20th round has to provide three grantors with a monthly wage income of at least Rs 1,500. He does not have to furnish a physical security.

reference line corresponding to *r´*,[5] the arbitrageur can make a profit by obtaining a chit when the price has dropped below his reference level.

In fact, in our sample, a single institutional investor is present and accounts for about one sixth of the 3760 chit recipients in our sample. Thus, on average, he holds six and a half shares in each Rosca in our sample. As far as the data allows to track this, no other customer ever holds more than one share in any group and does not appear in more than 4 Roscas of the sample.[6] Figure 4 illustrates that the institutional investor follows exactly the rationale outlined in the previous paragraph: he takes nearly none of the early and last chits, but instead obtains those where, on average, the price path drops most dramatically, namely between rounds 22 and 34. Moreover, Figure 5 shows that, within each round, his bids are much more concentrated than those of the other customers and inspection of Figure 6 shows that the polynomial fitted to the prices when he obtained a chit resembles very closely an interest rate profile of identical bidders with an implicit interest rate of about 1.2% per month.

In general, in the absence of fees an arbitrageur *A* who faces *r´* can gain whenever there is one member with an interest rate different from *r´* by taking all other *T*-1 shares in the Rosca. In the presence of a percentage fee, however, there is a tradeoff between the number of shares held, which implies a decrease of arbitrage revenue per share, and the constant marginal cost of each share represented by the percentage fee. Thus, although the institutional investor ‘smoothes’ the

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[5] In the present case this reference line is given by the function 10,000(1-Exp[-(40-*t*)*r´*]), which corresponds to a horizontal interest rate profile with $r(t) = r'$.

[6] The data include members’ names and residence. These seem to be frequently miscoded, however.

center section of the schedule of bid paths where typically a drop occurs, Figure 1 still implies considerable heterogeneity among members.

# 3 The Role of the Auction Format for Price Determination in Roscas

## 3.1 Comparing Price Paths for Different Rosca Auction Formats in Practice

The following analysis is guided by the question whether, on average, observed bid paths can be rationalized in terms of our benchmark model, which abstracts from any issues of strategic behavior. It can be argued that strategic behavior should not play an important role when 40 individuals interact. It is well known that irrespective of the auction protocol, as the number of bidders grows large, competition increases and hence individual bid functions converge to each bidder's true valuation for the item auctioned.

The key feature of the theoretical model is an interest rate profile underlying subsequent recipients of chits, where efficiency of allocations requires that the said profile be non-increasing in *t*. Figure 7 depicts $\hat{r}(t) \equiv \frac{-\Delta b(t)}{10000 - b(t)}$, where $\Delta b(t) = b(t) - b(t-1)$, the discretized version of *r*(*t*) as given by equation (1). The smooth line is obtained from a cubic spline fitted to the path of median bids. It is clearly seen that the resulting interest rate profile is not non-increasing. Instead, in terms of our model, the bell shape implies inefficient allocations.

Looking at the prices obtained under the two auction formats of OA and FP separately, however, it is evident that the S-shape of the price curve, which drives the bell shape of the $\hat{r}$-curve, stems from the Roscas with OA auctions, which account for 86 of the 94 Roscas in the sample. Going from right to left, the curve for the FP-Roscas nearly coincides with the one of the OA-Roscas until, approximately, round 23 where the schedule of the OA auction bends down while the FP prices follow more or less a straight line, thus resulting in significantly higher median prices in early rounds than observed in OA-Roscas. Although the FPA groups are much less frequent in the sample than OA-groups, the result should be robust. The distribution of the starting dates for groups with either of the two auction formats is very similar and also the extent to which the arbitraging investor is involved is similar in both kinds of groups.

## 3.2 Theoretical Considerations

As pointed out in the previous subsection, the main difference of the schedule of median bids in Roscas with OA and FP auction format occurs during early auctions, with prices in the OA auctions being significantly lower. In this section, we present a simple model of bidding in Rosca auctions that provides an explanation for that empirical observation.

### 3.2.1 Background

Unlike standard auctions, where the seller extracts the price from the bidders, the price remains within the group of bidders in a Rosca auction. Such auctions have been called “auctions with price-proportional benefits to bidders” and have first been analyzed by Engelbrecht-Wiggans (1994). They play a role in so-called knockout auctions, a form of collusion in bidding rings, and in toehold buyout and dissolution of partnership situations where several partners who own an enterprise jointly stage an auction among themselves where the price goes to the losing bidders. One result of this literature is that, as long as bidders are symmetric, the expected price in second price auctions is higher than in FP auctions. In such second-price auctions, any bidder who does not observe the highest possible value, in equilibrium, is confronted with a positive probability of not winning the item auctioned. Consider the most simple case of only two bidders. If he, *j* say, does not win, his bid determines the price paid by the winner and thus the benefit accruing to him, *j*. In the first-price auction, on the other hand, the winner himself determines the price and thereby the benefit accruing to the losing bidder. Thus, in the equilibrium of such second-price auctions, only a bidder who observes the highest value bids truthfully while all other bidders, somewhat loosely speaking, overbid. This argument applies to Rosca auctions as long as information on bidders' valuations is symmetric in each auction. Notice that this result is opposed to the present empirical observation of higher prices in FP Roscas.

In the existing literature, auctions with price-proportional benefits have been analyzed in only a one-shot scenario. In Roscas, however, there is the additional complexity that a whole sequence of such auctions occurs. As is well-known from the literature on sequential standard auctions with multi-unit demand, information revealed through the price a winner of an early auction pays, causes information asymmetries in later auctions, thus complicating the analysis considerably. In the case of Rosca auctions, the feature of price-proportional benefits causes even further complications because here a bidder who is in fact not interested in obtaining a chit in a given round has an incentive to raise the price because a higher price paid by the winner implies a higher benefit for him as a loser. When a sequence of auctions occurs and a bidder's valuation in each round has a component that is fixed over the life of the Rosca and privately observe, the price obtaining in a FP Rosca in any round reveals information on the winner's valuation. This does not introduce asymmetric information, however, because the winner of a chit does not bid in future auctions. In an OA Rosca, however, of which we might for a minute think as a Rosca with second price auctions, the price conveys information on the second highest bidder of that auction and thus on a member who is a bidder in the following auction. If his valuation is completely revealed, profit maximizing bidders with a lower valuation than himself will drive the bid up exactly to the point of his valuation. Notice that, in the language of our benchmark model, this price corresponds precisely to $b^*$, which was derived under the assumption of public information. When information is private, on the other hand, a bidder tries to extract a rent from the fact that the others do not observe his valuation.

Thus, to summarize, in a Rosca with OA auctions a bidder faces two forces pulling his bidding in opposite directions. Price-proportional benefits create an incentive to overbid relative to his valuation, while the fact that he may reveal his valuation to other bidders if he participates in the bidding process until shortly before the end associated with being bid up himself in one of the following auctions creates an incentive to bid less high.

### 3.2.2 A Model of Bidding in Rosca Auctions

In this subsection, we present a model consistent with the observation on the two auction formats in the data. To capture the potential effect of information revelation in early auctions, we consider a Rosca with three members and thus two auctions. One of the members is known to have no yielding investment opportunities outside the Rosca. Index this member by zero. Before the beginning of the Rosca, each of the two other members indexed by 1 and 2, respectively, privately observe an interest rate $R_i$, $i$ = 1, 2, of either $r$ or 0 per round with probability $p$ and 1-$p$, respectively. As in section 2.1, each member contributes one Rupee per round. Notice that $r_0$ never gains from winning a pot, but only from positive prices in the first two rounds.

According to the rules of the company, bidding occurs in discrete increments (in our sample groups it has to be a multiple of 50). For the model, we assume that bids belong to some countable infinite, ordered set $\hat{B} = \{\hat{b}_0, \hat{b}_1, ...\}$ of equally spaced points in the set of non-negative real numbers, where $\hat{b}_0 = 0$. For analytical convenience, we consider sufficiently small increments. We denote the element of $\hat{B}$ that is closest to but not bigger than the real-valued number $x$ by $\hat{b}(x)$.

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In such a Rosca, before each auction each bidder submits a bid in a sealed envelope. The highest bid determines the winner and the price. In case of a tie, a fair lottery between the tying high-bids determines the winner.

We solve the auction game backwards. For the time being, assume an efficient outcome in the first round. Without loss of generality, assume that member one received the chit in the first round and that thus, in the second round, members 0 and 2 remain as bidders. In this situation, it is a non-dominated strategy for 0 to submit a bid of zero. When 2 had observed $R = 0$, he also submits zero, while it is his best response to 0's strategy to bid $\hat{b}_1$ if he had observed $r$.

Going back to the first round, for 0, again, it is a non-dominated strategy to submit a bid of zero. The same line of reasoning applies to each of the other two bidders, whenever he observes $R = 0$. On the other hand, as is know from the theory of auctions with discrete valuations, when bidder $i$ observes $r$, an equilibrium only exists in mixed strategies, where $i$ is indifferent between submitting any bid that is an element of some set $\tilde{B} = \{\hat{b}_1, \ldots, \hat{b}(\bar{b})\}$ and, in equilibrium, submits each element of $\tilde{B}$ with a certain probability. If the strategy space were continuous, which is a reasonable approximation for determining the equilibrium randomization distribution if the bid increments are sufficiently small, we can write the wealth in $t = 3$ of bidder $i$ who observed $r$ as

$$\Pi_1^i(b \mid r) \equiv (1+r)^2\left(3 - \frac{2}{3}b\right)\left((1-p) + pG(b)\right) + p\left(1 - G(b)\right)\left((1+r)^2 \frac{1}{3}E[B \mid B > b] + 3(1+r)\right), \quad (5)$$

where $G(\ )$ is the cumulative distribution function of according to which the bidder randomizes his bid. $(1+r)^2\left(3 - \frac{2}{3}b\right)$ is his payoff if the wins the first auction. This event occurs whenever the other bidder, $j$ say, has observed zero, which has probability 1-$p$, and also when $j$ has observed $r$ but $j$'s random bid is smaller than $b$, the probability of this event being $pG(b)$. If, on the other hand, $j$ has submitted a higher random bid then $i$, $i$ receives a third of the winning bid in $t = 1$, in expectation $\frac{1}{3}E[B \mid B > b]$, and, as he can project, a payoff of roughly 3 in $t = 2$ because, as argued above, there is no competition in the second auction and, provided bid increments are small, $\hat{b}(3)$ is arbitrarily close to 3. Multiplying those payoffs with $(1+r)^2$ and $(1+r)$, respectively gives the term in the last bracket on the RHS of (5). The probability of this event is, of course, $p(1-G(b))$.

Differentiating (5) with respect to $b$ together with the boundary condition $G(0) = 0$ gives the equilibrium distribution function

$$G(b) = \frac{1-p}{p}\left(\left(\frac{3r}{(1+r)(3-b)-3}\right)^{\frac{2}{3}} - 1\right), \tag{6}$$

which has support $(0, \bar{b})$, where

$$\bar{b} = \frac{3r}{1+r}\left(1-(1-p)^{\frac{3}{2}}\right). \tag{7}$$

Notice that ex ante, that is before the first auction, the expected wealth in $t = 3$ with such a Rosca for a bidder who observes $r$ is

$$EU(r) = 3 + r\left(4 + 2(1-p)^{\frac{3}{2}}\right) + r^2\left(1 + 2(1-p)^{\frac{3}{2}}\right). \tag{8}$$

Defining efficiency as allotting chits first to members who observe $r$, we can summarize the results derived thus far in

**Proposition 3**

In a Rosca with first-price auctions,

a) bidders who have observed $r$ randomize their bids according (approximately) to (6) in the first auction and bid $\hat{b}_1$ in the second auction.

b) bidders who have observed zero submit a bid of zero in both auctions.

c) the sequential equilibrium induces efficient allocations.

d) the expected price in the first auction is $\frac{r}{1+r}\left(1+3(1-p)^2-4(1-p)^{\frac{3}{2}}\right)$ and in the second auction $p^2\hat{b}_1$.

**Equilibrium in a Rosca with Oral Ascending Auctions**

In this subsection, under some further assumptions, we present a somewhat extreme equilibrium where bidders do not bid at all in the first round. Roughly speaking, this is because, if a member who has observed *r* starts to bid, he reveals this information and bidder 0 will exploit this to extract higher benefits for himself. In the equilibrium, a bidder with *r* prefers to incur a lottery instead being bid up in the way just described. Consequently, there is a positive probability of inefficient allocations.

We first need to specify how the ascending auction proceeds. In our sample Roscas, the rules of the Rosca company limit the bidding in each auction to five minutes. We follow the setup of Roth and Ockenfels (forthcoming) on ascending ebay auctions by assuming that during these 300 seconds, each bidder always has time to react to the bid of each other bidder. Thus, while the reaction time, *g* say, is strictly positive, it is sufficiently small to ensure that when a bid is submitted at instant $y < 300$ (measured in seconds), $y + g < 300$. Thus, as long as $y < 300$, infinitely many reactions and re-reactions can occur. After this process has come to an end, at the last instant, i.e. at $y = 300$, each bidder can submit one more bid. We allow for one-time reaction in that, if bidder 1, say, bids $\hat{b}_n$ in the last instant, each of the other bidders can give one more bid bigger than $\hat{b}_n$, where, again, if 2, say, outbids $\hat{b}_n$ by $\hat{b}_m$, say, where $m > n$, bidder 3 can outbid $\hat{b}_m$. Then the auction is over. Thus, in this example, bidder 1 cannot react to bidder 2 and 3 in the last instant.

To give some intuition for modeling last-minute bids that way, imagine one of our sample Roscas and the auction in round 36. Bidder one says '3000' in the last second of that auction. Saying '3000' takes the rest of that second. Bidder 2, when hearing 1 starting to say '3000' rushes to say '3500' before 1 has finished saying '3000'. When bidder 3 hears 2 starting to say '3500', he in turn rushes to say '3700'. There is no time for any of the bidders to start saying another number before the auction is over.

Without going into the details of the derivation we state the equilibrium in

**Proposition 4**

In a Rosca with oral-ascending auctions, if $½ < p < 2/3$,

a) in the sequential equilibrium, a bidder who has observed *r* does not bid in the first auction. In the second auction, he bids $\hat{b}_1$ when the other bidder is member 0, and he bids 0 when the other bidder is not member 0.

b) bidders who have observed zero do not bid in any of the two auctions.

c) the sequential equilibrium induces inefficient allocations with positive probability.

d) the expected price in the first auction is zero and in the second auction $2p\hat{b}_1/3$.

<u>Proof:</u>

Assume that, in round one, there has been no bidding. Then, in round two, the bidders are either 1 and 2, 0 and 1, or 0 and 2. If 0 and 1 are the bidders, first note that, since there was no information revealed in $t = 1$, before that auction 0's prior probability about 1 having observed *r* is the same as ex ante, i.e. *p*. Assume that 1 follows the following strategy: if $R_1 = 0$, do not bid;

if $R_1 = r$ and before the last instant the standing bid is some $\hat{b}_m < \hat{b}(3r/(1+r))$, bid $\hat{b}_{m+1}$ at the last instant.

What is 0's best response to that? He will certainly not outbid 1 in the last instant since this implies a loss for him. Suppose, however, before the last instant 0 submits some bid $\hat{b}_m < \hat{b}(3r/(1+r))$, say, such that, provided 1 had observed $r$, he would have a higher utility from obtaining chit two at $\hat{b}_{m+1}$ than from not reacting. In this case, 1's best response is to bid $\hat{b}_{m+1}$ at the last instant because, by doing so, 0 cannot bid him further up. On the other hand, if 1 had observed 0, his best response is not to react to $\hat{b}_m$ at all, in which case 0 ends with a loss. In expectation, 0's gain from rising the bid is positive if, and only if, $p > 2/3$. It is further easily verified that 1's strategy posited above is again a best response to such behavior of 0. Thus, whenever $p < 2/3$, this equilibrium implies no bidding when $R_1 = 0$ and 1 winning the auction at price $\hat{b}_1$ when $R_1 = r$. The case where 0 and 2 are the bidders in the second auction is analogous.

What if 1 and 2 are the bidders in the second round? If both of them remain silent, the payoff for a bidder who has observed $r$ is $\Pi_2^i(0\,|\,r) = (3(1+r)+3)/2 = 3+3r/2$ because, in this case, a lottery determines whether he receives the chit now and can thus earn interest or in $t = 3$. If an $r$-type follows this strategy, a 0 type's best response is, of course, to remain silent as well as long as $p < 2/3$, see the argument above. What if an $r$-type, $i$ say, does bid instead? The best he can do is bid $\hat{b}_1$ at the last instant. In this case $j$ will outbid him with $\hat{b}_2$ resulting in a round 3 payoff for $i$ of roughly 3. If, instead, $j$ is a zero type and $i$ bids $\hat{b}_1$ at the last instant, $j$ will not react, which implies round 3 wealth of roughly $3+3r$. Thus $i$'s expected payoff from bidding $\hat{b}_1$ at the last instant is $3 + 3(1-p)r$, which is smaller than $\Pi_2^i(0\,|\,r)$ whenever $p > ½$. Focusing on the case $½ < p < 1/3$ and provided the first auction was non-informative, the following strategies thus constitute an equilibrium. For an *r*-type: bid $\hat{b}_1$ at the last instant when the other bidder is 0; do not bid when the other bidder is $j \in \{1,2\}$. For any zero type: do not bid.

Turning to the first round, when all bidders do nothing, anticipate the above-derived outcome of round 2, and a lottery determines the recipient of the chit , the payoff for an *r*-type is

$$\Pi_1^i(0\,|\,r) = \frac{1}{3}\Big((1+r)^2 3 + (3+3r/2) + (3+3r)\Big) = 3 + 7r/2 + r^2 \,. \tag{9}$$

If an *r*-type bids and $p > 1/2$, basically the same happens as in $t = 2$, where he is outbid in the last instant. On the other hand, for an *r*-type, it is not profitable to overbid 0 in case the latter starts to bid because by doing so he is either bid up to a level where he is indifferent between obtaining chit 1 or not obtaining it and being 'exploited' in $t$=2 because his type has been revealed. Clearly the latter scenario is worse than a lottery. Thus if 0 starts to bid, he ends in loss, so this will not happen. ?

If valuations, or interest rates in our case, are not distributed dichotonomously, bid shading may take a more complex form than obtained in our model, possibly implying outcomes analogous to those observed in the data.

### 3.2.3 Comparing the Auction Formats

In accordance with the schedules of median prices in our sample Roscas, we find that average prices in early auctions are higher in our model Rosca with first-price auctions, while bids in the second round are approximately equal under both formats, depending on the extent of bid increments. The bid-shading in the OA Roscas comes at the cost of inefficient allocations. Accordingly, in our model, the expected payoff is bigger for both zero and *r*-types. While we can not statistically test whether the difference in shape of the observed median price schedules is actually due to bid shading, our model provides a consistent interpretation of the observed facts.

## 4 Concluding Remarks

In this paper, we have investigated prices resulting from auctions in rotating savings and credit associations. While most of the existing literature has looked at Roscas which are operated among a group of homogenous individuals with similar financial objectives like peasants in a village, we find considerable heterogeneity among members of formal bidding Roscas in a South-Indian city. We analyzed theoretically how financial intermediation in formal bidding Roscas takes place and how prices determined in the auctions reflect interest rates implicit in the funds from a Rosca. As a benchmark, we characterized the allocations induced by a bidding Rosca in a world without uncertainty and perfect information as a function of the profitability rates faced by the members outside the Rosca. We found that, in such a setup, prices decrease monotonically and that each member improves his welfare by joining the group compared to autarky.

In a dataset of prices in 94 Roscas, we found that average implicit interest rates indeed correspond to those prevalent outside the Rosca. Our theoretical framework provided an understanding of the actions of an arbitrageur present in the sample Roscas who systematically reduces the heterogeneity between Rosca members. The benchmark model allowed a consistent interpretation of bidding in Rosca groups with a first-price auction format but not of groups with open ascending auctions. We provide a rationale for this observation by keeping the assumption of certainty, but introducing private information and strategic behavior in Rosca auctions. We show how different auction protocols can result in different allocations, a difference that does not occur in the absence of private information. We show that, in a Rosca with more than one auction, information revealed in early auctions can induce impatient bidders to shade their bids in OA auctions, while such bid shading does not occur in FP auctions.

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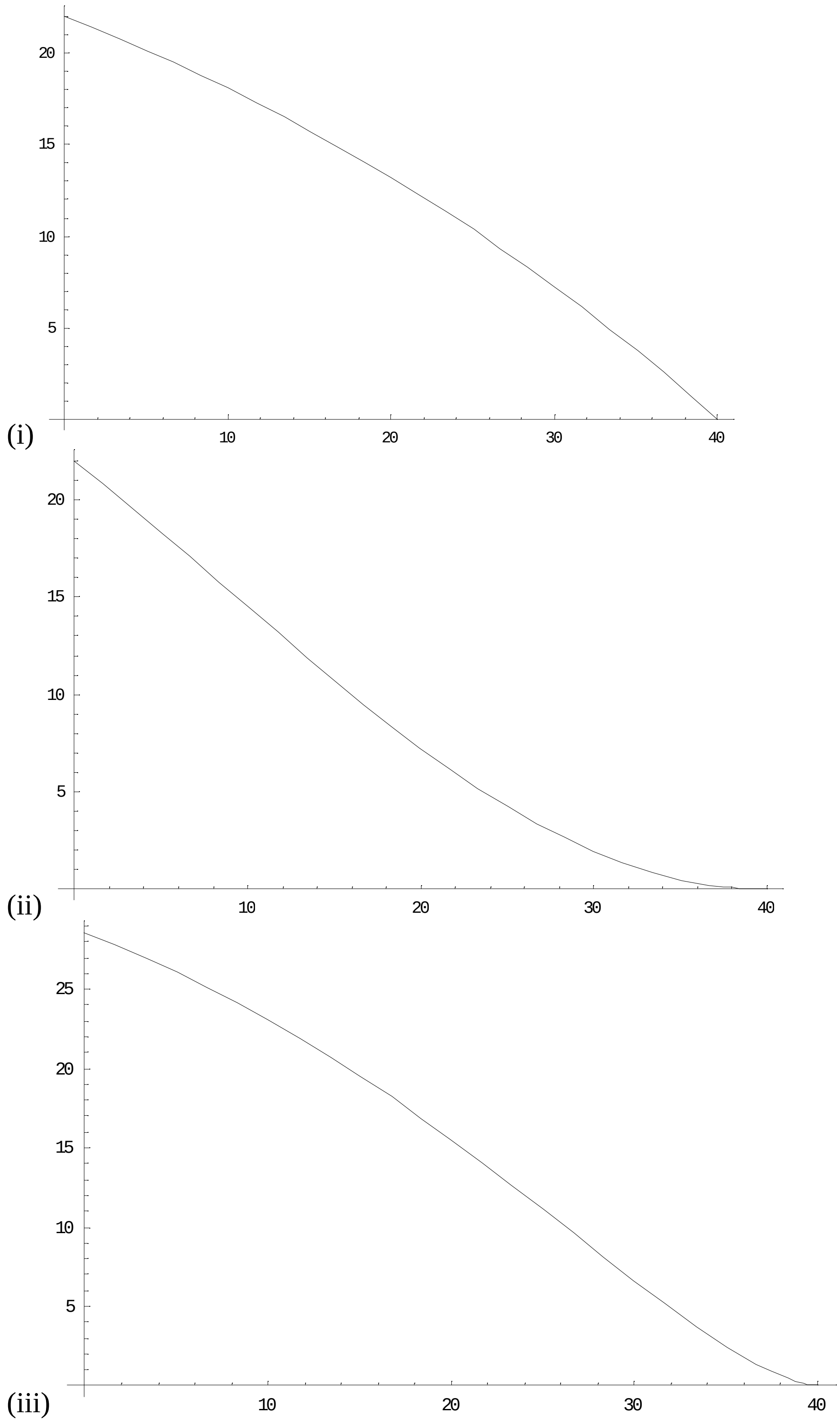



**Figure 1. Equilibrium price paths in a bidding Rosca**

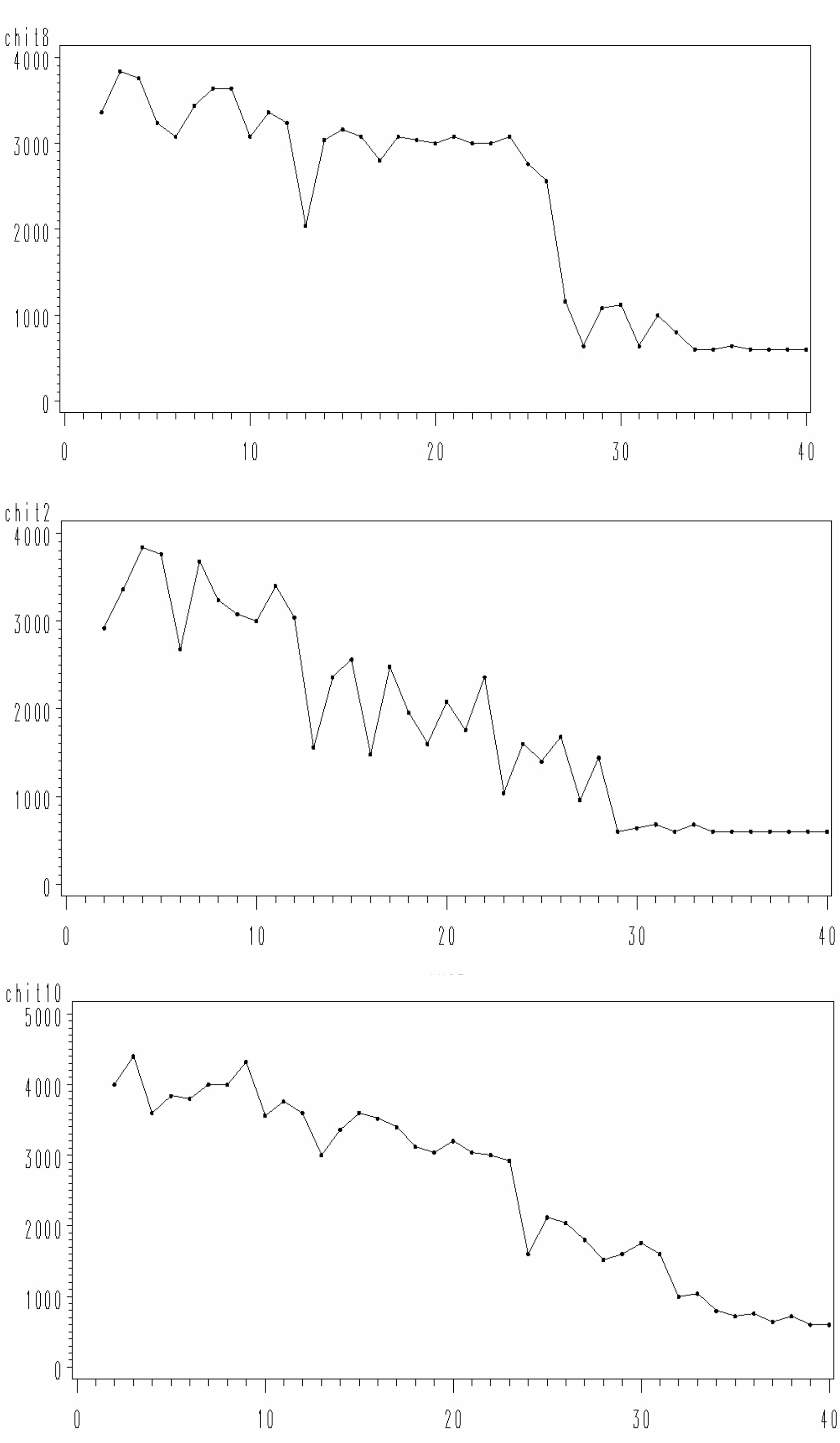



**Figure 2. Observed price paths in three sample Roscas**

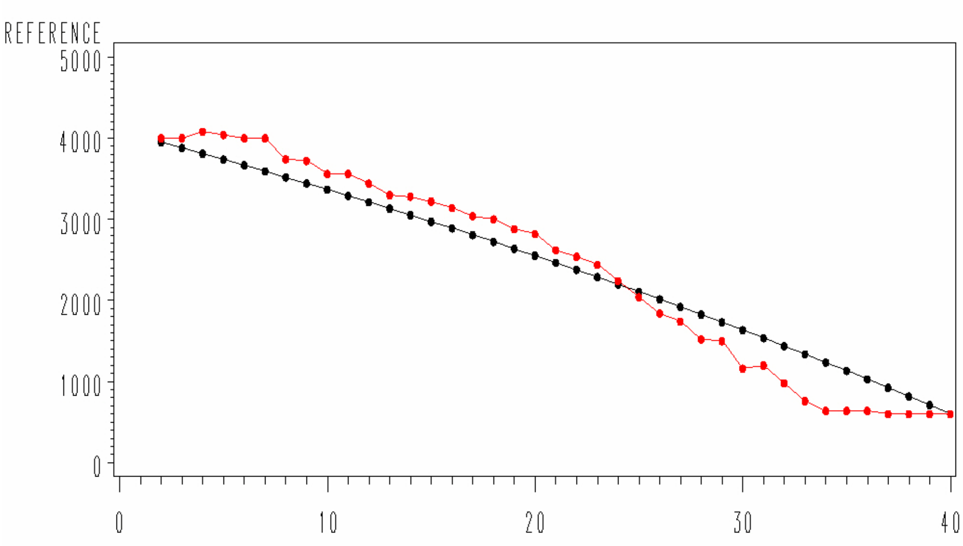



**Figure 3. Median price path for the sample Roscas**

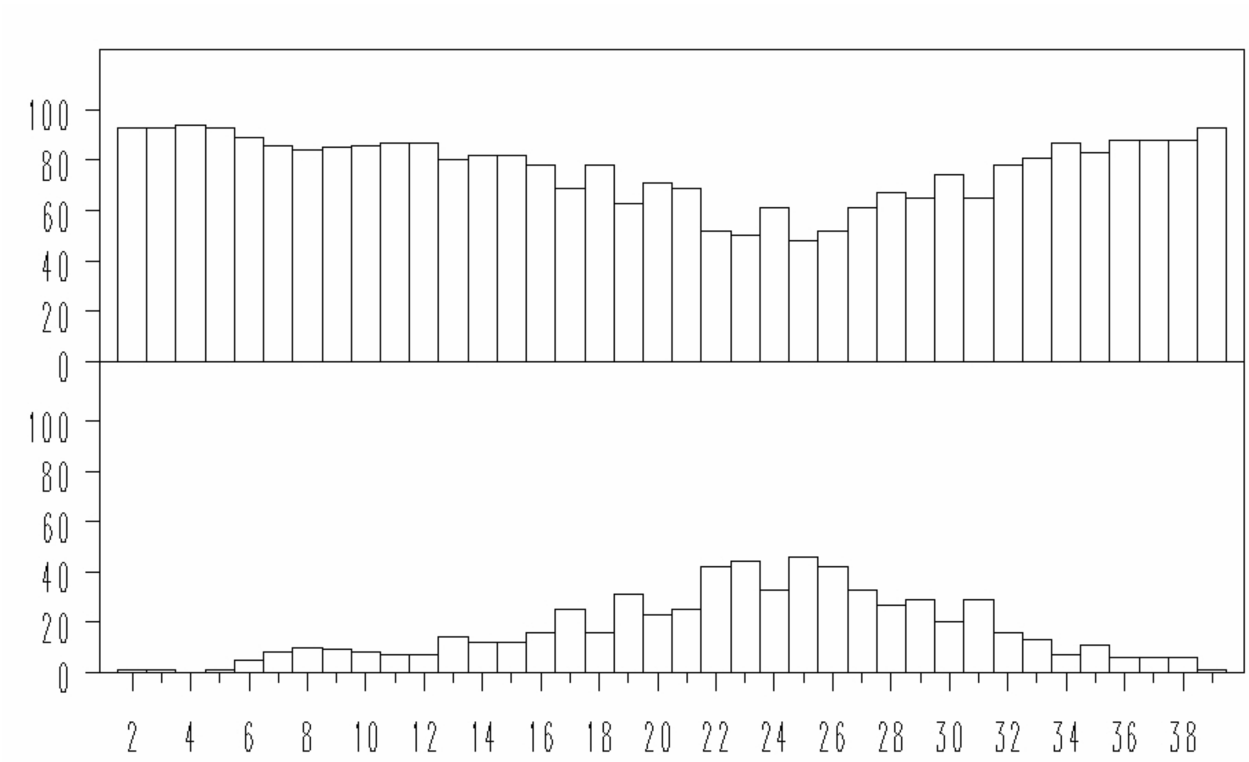
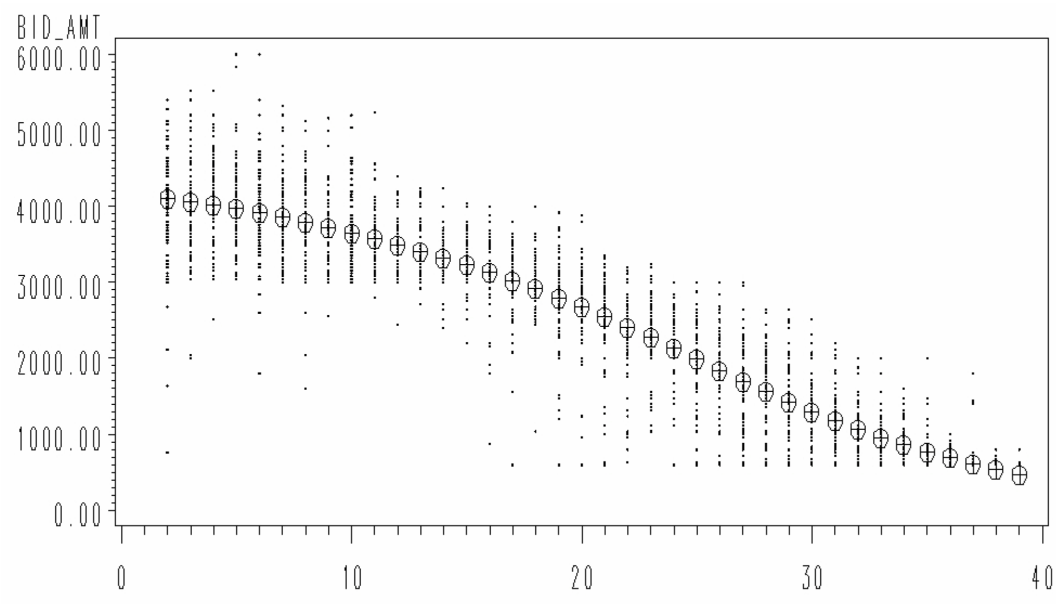
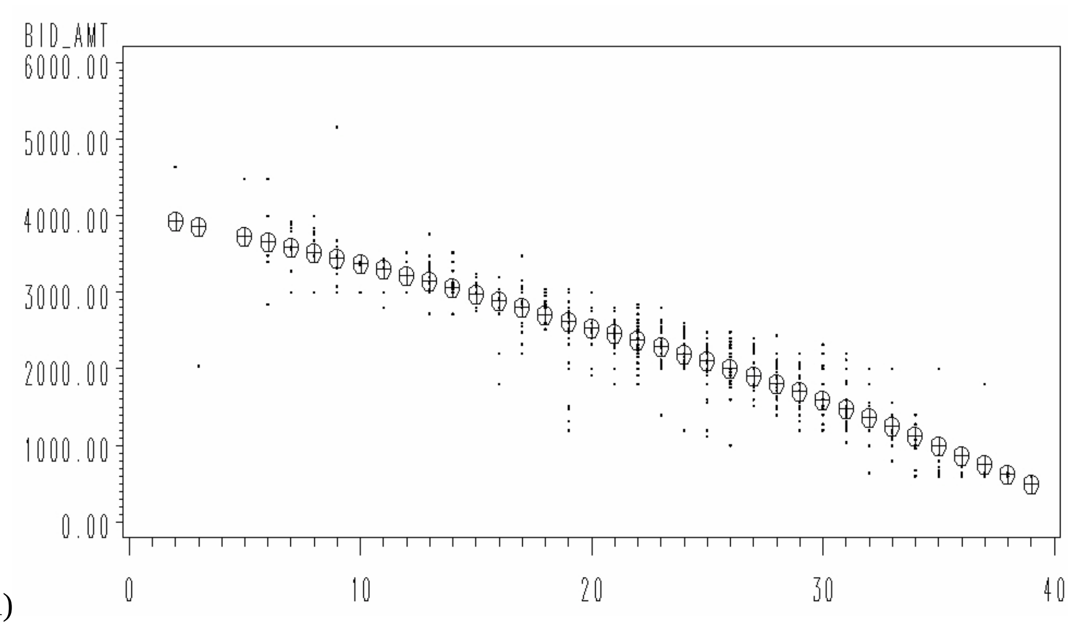



**Figure 4. Frequency distribution of rounds when a chit was obtained, institutional investor (lower panel) vs. rest of the sample (upper panel)**




(i)




(ii)

**Figure 5. Prices obtained by the institutional investor, panel (ii), vs. the rest of the sample, panel (i); balls obtained by fitting a polynomial of degree four**

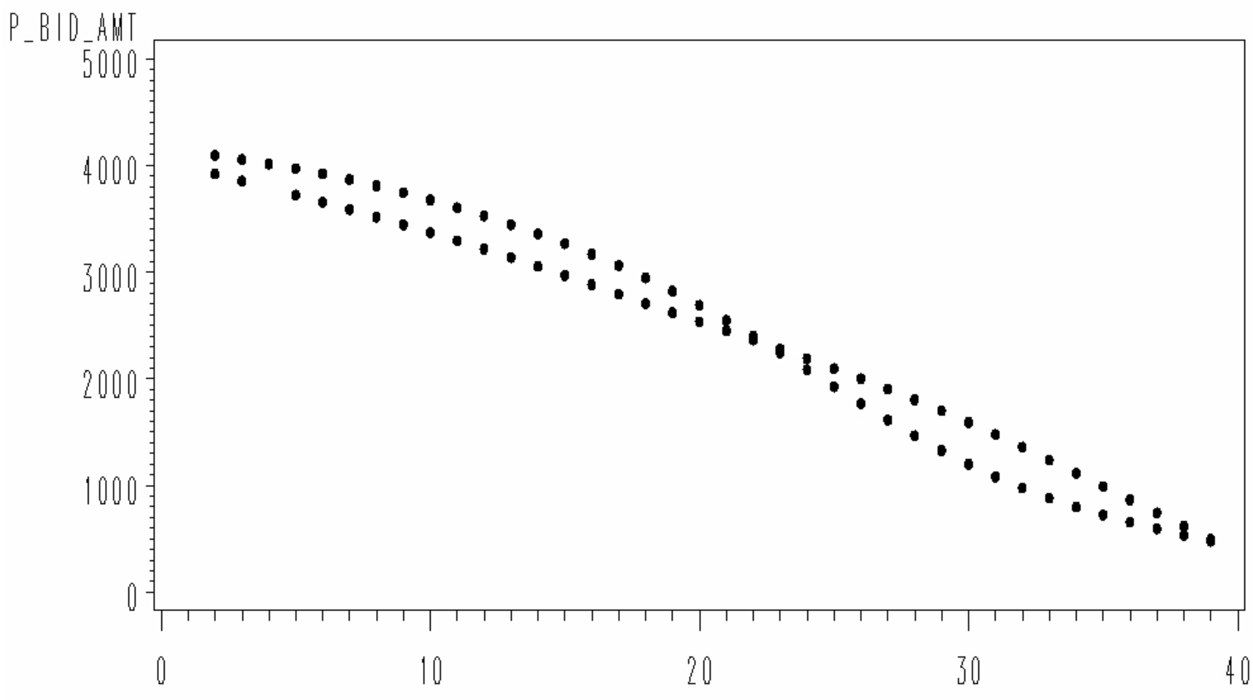



**Figure 6. Fitted average price obtained by the institutional investor (concave curve) vs. the rest of the sample (S-shaped curve)**

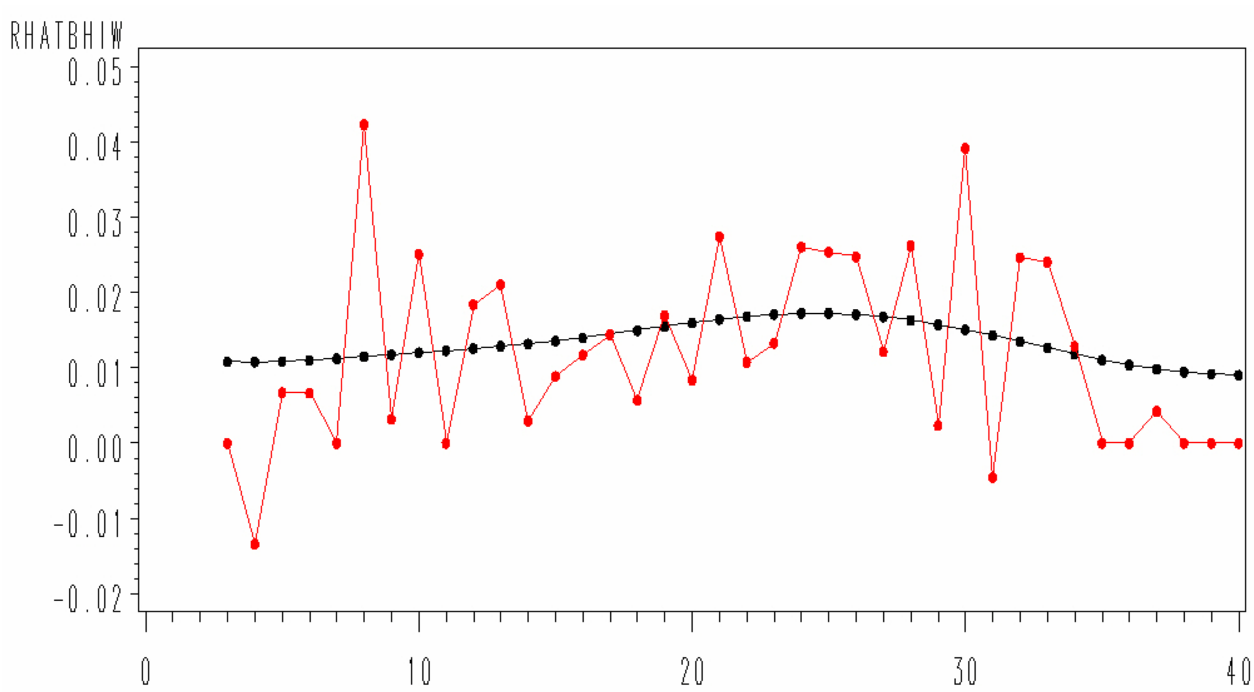



**Figure 7. Interest rate profile implicit in median prices, actual and smoothed**

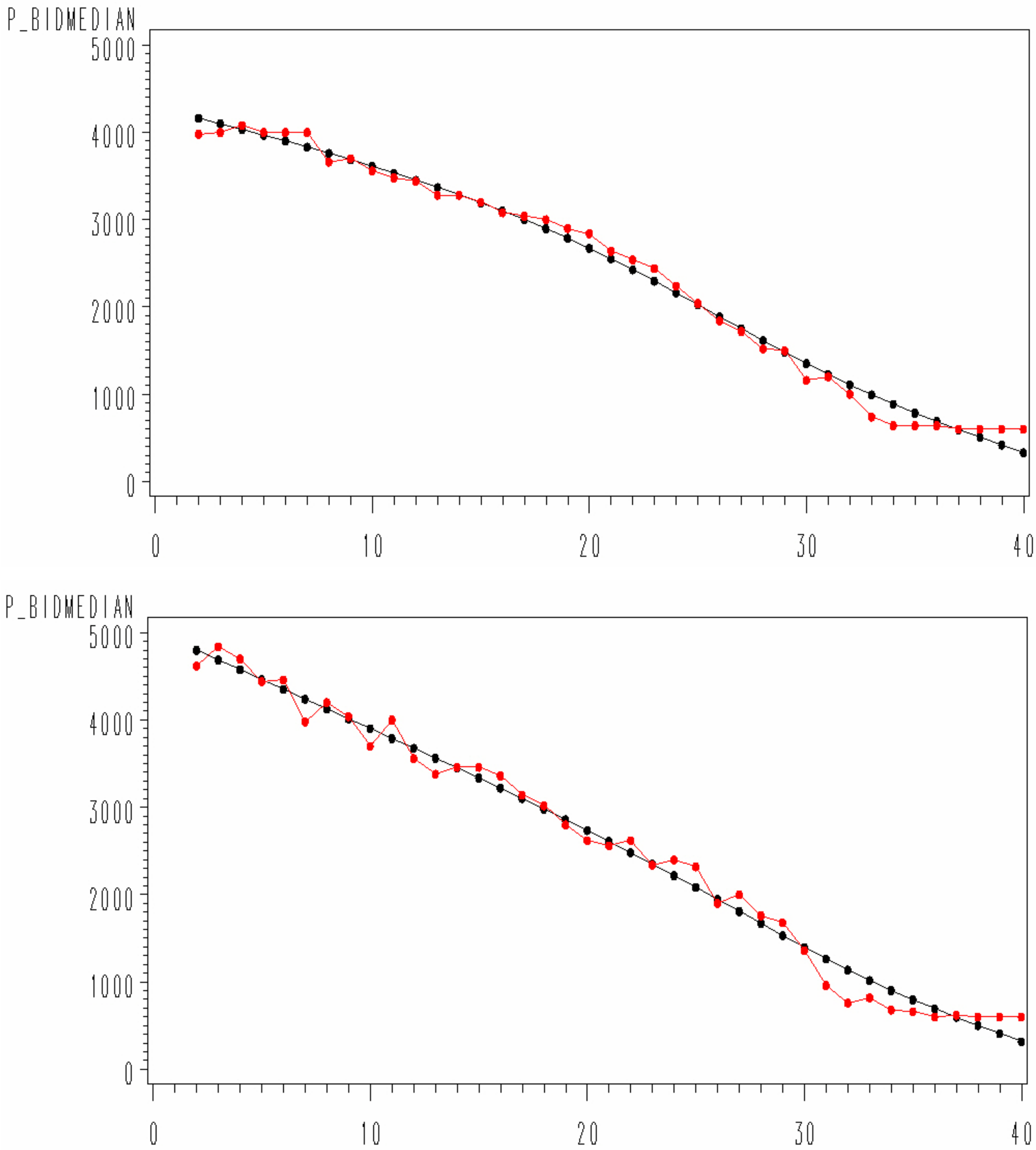



**Figure 8. Median prices in sample Roscas with OA (upper) and FP auctions (lower panel), actual and smoothed**

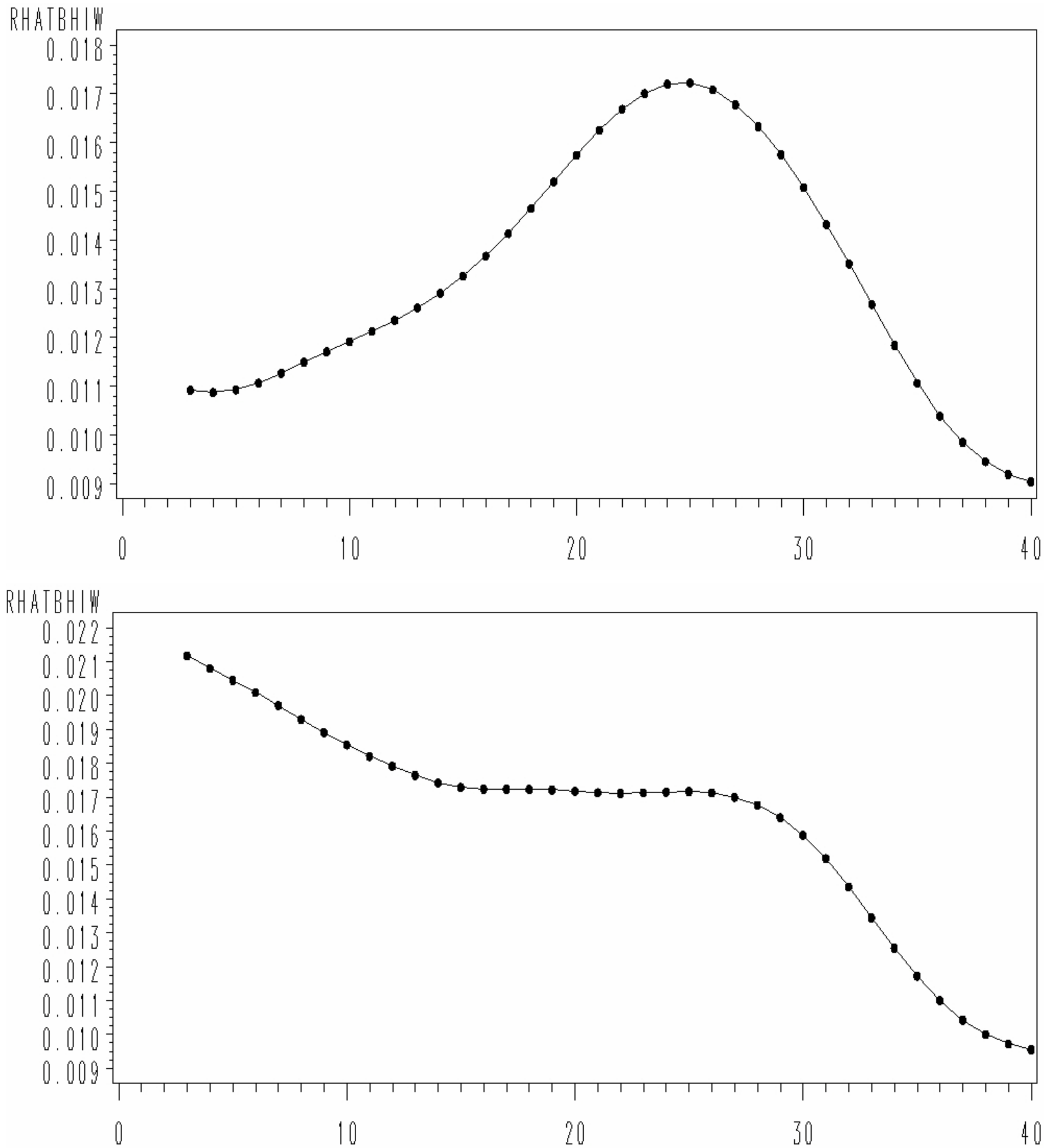



**Figure 9. Interest rate profile implicit in smoothed median bids in Roscas with OA (upper) and FP auctions (lower panel)**