Variations of Rotating Savings and Credit Associations for Community Development

Article *in* IEEE Transactions on Computational Social Systems · January 2022

DOI: 10.1109/TCSS.2022.3167266

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Variations of Rotating Savings and Credit Associations for Community Development

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***Abstract*—Informal financial cooperation strategies have emerged as a solution to improve the resilience of low-income communities, being one of the most popular ones the Rotating Savings and Credit Associations (ROSCAs). In this paper, using computational tools and dynamical systems modeling, we study the performance of two variations of ROSCAs that can potentially increase the resilience of communities. First, we propose a strategy that saves a percentage of the contributions of each member of the ROSCA to reduce the impact of individuals who stop contributing to the association and study how this strategy impacts the financial life of the individuals and trust among community members. Second, we study a decentralized version of the ROSCA in which individuals contribute to more than one association and analyze the impact of the size of the cooperation scheme and the number of associations where each individual participates. Through mathematical and simulation analyses, we show how the cooperation strategies impact the resilience of low-income communities.**

***Index Terms*—Cash reserve ratio, cooperation, humanitarian engineering, rotating savings and credit associations, social dilemmas, trust.**

I. Introduction

HUMAN beings have a complicated decision-making task to manage their financial life. This decision process is critical for all human beings, mainly for those who do not have access to health, education, and financial services [1]. For low-income individuals, an excess of consumption, or a loss of working capital due to adverse events, which sometimes are unpredictable, would have an important impact on their lives. Several informal financial cooperation strategies have emerged in several parts of the world as a solution to minimize this problem [2], [3]. These strategies look for an increase in the resilience, seen as the ability of each member of the community to recover from the effects of adverse shocks to which they are inherently exposed [4], by promoting cooperation between individuals. One of the most representative examples of this type of strategy is the Rotating Savings and Credit Associations (ROSCAs) [2], [3], [5], [6]. ROSCAs are an agreement between members of the community to cooperatively save a pool of capital typically paying a fee during each week or month. A percentage of this pool is assigned randomly to a member of the association during each period [7]. In this way, this strategy allows individuals to access some financial services that formal institutions are not able to provide, increasing their resilience [6], [8].

One of the main issues that ROSCAs have is that there could be members who leave the association without paying the benefit that they have received [8]. This issue would be exacerbated in eROSCAs where members do not have face-to-face contact [9]. Although individuals in ROSCAs tend to pay their fees, some of them would suffer a situation that forces them to avoid the payments. This default of a person causes a loss in the general pool that must be assumed by all the members and a reduction in the trust of the association and the motivation of the members to continue cooperating. To minimize the impact of this scenario, variations of the functioning rules in traditional ROSCAs could be explored. However, the design and implementation of observational experiments on real communities to evaluate the medium and long-term impact of this type of strategy require significant time and effort.

In this paper, our contribution is the introduction of two variations of the conventional ROSCAs that we hypothesize increase the resilience of the community, and the use of computational tools to simulate a community that implements them to evaluate their performance. Here, we employed models of human dynamics that have been recently proposed to simulate scenarios where financial cooperation strategies are implemented [10]–[14]. First, we propose a cash reserve ratio (CRR), as it is used in formal financial institutions [15], to reduce the impact of individuals who left the association. From this perspective, we analyze which is the best CRR for a given trust between the members of the ROSCA to maximize the development of all the individuals. Second, we propose a decentralized ROSCA where individuals can participate in several associations at the same time and analyze the impact of the number of associations per individual and the number of members per ROSCA in the performance of the community.

We start this paper by introducing related work that uses computational tools to study informal financial cooperation strategies (Section II) and defining the conventional behavior of ROSCAs and their members (Section III). Then, we introduce a mathematical model of an individual's financial dynamics and the decision-making policy (Section IV). After that, we introduce a model of individual's trust and analyze the impact of adding a CRR on different levels of trust between members of the associations (Section V). We later present the decentralized

This work was partially supported by Google through the Google Research Award for Latin America, and University of los Andes and Universidad de Ibagué through Convocatoria Conjunta Unibagué-Uniandes.

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cooperative associations and analyze their impact on the performance of the community (Section VI). We end this paper with some conclusions and future directions in this recently proposed research area (Section VII).

II. Related Work

Evaluating the impact of new cooperation strategies in real communities requires significant time and effort. For this reason, recent research has proposed the use of computational tools to model human dynamics in scenarios where this type of strategy is implemented [10]–[14] and mathematically analyze the welfare and benefits of mutual aid financial organizations [3], [16]. For example, the work in [12] proposes a model of human financial dynamics based on working capital, savings, health, education, consumption, and the transfers between each asset. This work also proposes a strategy based on donations and generosity as an alternative to ROSCAs. Based on this model of individual financial dynamics and the donations strategy, the work in [12], [14] showed that cooperation strategies based on altruism and generosity would potentially increase the resilience and the development of the community. However, if some individuals do not cooperate with the community, which is a common phenomenon known as free riding, individuals lose the motivation to continue cooperating [17], [18]. Therefore, the impact of the strategy will be the opposite of the desired one.

The results of [12], [14] show that conventional ROSCAs can be improved by using other strategies. However, ROSCAs do not depend exclusively on altruism and generosity. The work in [19] shows that the trustworthiness of individuals increases when they are being observed by others and recognizes that their reputation would be at stake. This result, in terms of cooperative development, implies that individuals are more willing to collaborate with others and avoid free-riding when they are being observed. In this way, ROSCAs serve as a mechanism to commit the members of a community looking for an individual benefit as it is also shown in [20]. This commitment role is crucial to encourage an investment policy based on cooperative saving. For this reason, ROSCAs are still a helpful strategy for low-income communities.

III. Rotating Savings and Credit Associations

A ROSCA represents a contract between members of an association to contribute monthly with an established fee, assigning a percentage of the collaborative savings to a member of the association [21]. In the basic model of a ROSCA, all members must contribute each month an amount of money $\alpha > 0$ to the association. The total pool collected each month is assigned to a random member. Turns are usually defined at the beginning of the cooperation strategy giving priority to the administrators and randomly selecting the rest of the turns. In this way, it is guaranteed that each member receives the collected money during each round of the strategy. Figure 1 illustrates the structure of a ROSCA.

If the total pool is given in each month, this strategy can be seen as a way of scheduling savings, in which members with the first turns will receive credit without interest, and those with the last turns are saving their money. However, this supposes two main issues. First, paying the fee for all members is mandatory, even if a member is in an extreme adverse scenario. For this reason, if someone requires those savings before his/her turn, the individual must change his/her turn giving an economical compensation or avoid the fee of that month and go through a possible exclusion of the strategy, losing his/her savings or suffering other social sanctions [22]. This increases the probability of a fatal condition for those individuals who cannot receive a return before having a damaging uncertain event that forces them to use those savings. Second, it is also possible that an individual gets out of ROSCA without paying the amount of money that he/she received. This supposes a general loss of money for all the members who have not received the pool before and would decrease the trust in the strategy. To ameliorate these issues, we explore the implementation of two variations of the ROSCA. In the following sections, we first present the individual decision-making model to later introduce the variations of the ROSCA.

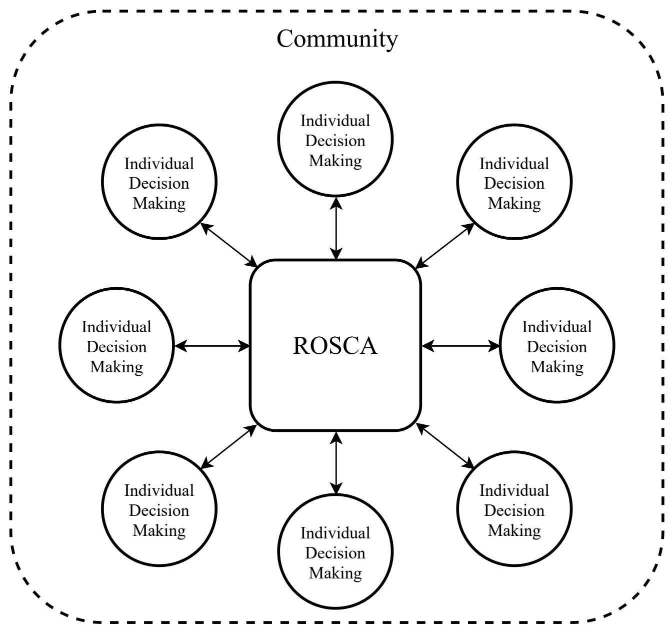


Fig. 1. Individuals associated in a ROSCA. Each individual of the community has an individual decision-making policy and everyone interacts with others through a ROSCA.

IV. Individual Financial Decision Making

Based on the work in [12], [14], we introduce the model of individual financial dynamics and the policy used by each individual to simulate the decision process on how to invest his/her capital on each asset.

A. Individual Financial Dynamics

Recently, the work in [12] proposed a model of human financial dynamics considering four state variables that change over time: working capital $x_1(k) \in \mathbb{R}$, accumulate savings $x_2(k) \in \mathbb{R}$, health capital $x_3(k) \in \mathbb{R}$, and education capital $x_4(k) \in \mathbb{R}$, with $k \in \mathbb{N}$ being time in months. Working capital and savings are measured in US dollars using the purchasing power parity rate (US\$PPP). Health uses the body mass index (BMI) as indicator, and education is measured in months of school (MS). The individual's decision variable u_1 represents the consumption of non-capital goods. Decision variables u_2, u_3 and u_4 correspond to transfers between working capital and savings, health capital, and education capital respectively. Based on this model, the work in [14] introduced slight modifications in the incomes and expenses or transfers of individuals to each of their assets by including cooperation associations in the model. According to this, the mathematical model of an individual's behavior is given by

$$x_1(k+1) = (x_1(k)(1-s(k)) + \sigma(k) - \psi(k))\,(1+r(k)), \tag{1}$$

$$x_2(k+1) = (x_2(k) + u_2(k))(1+d_2), \tag{2}$$

$$x_3(k+1) = x_3(k)(1-d_3) + c_3u_3(k), \tag{3}$$

$$x_4(k+1) = x_4(k)(1-d_4) + c_4u_4(k), \tag{4}$$

where $\sigma(k)$ represents the total income that the individual receives from the associations, $\psi(k)$ is the total transfers or expenses, $r(k)$ represents the return on investments (ROI) on education and health at time k, d_2 is a net return of savings, d_3 and d_4 are depreciation rates of health and education, and c_3 and c_4 are conversion terms between monetary units and kg/m^2 and MS, respectively. Decision variable u_2 can be negative if the individual needs to use his savings. The total expenses $\psi(k)$ and income $\sigma(k)$ are given by

$$\psi(k) = \sum_{m=1}^{4} u_m(k) + N\phi(k), \tag{5}$$

$$\sigma(k) = \sum_{n=1}^{N} \rho_n(k), \tag{6}$$

where N is the number of cooperation associations where the individual is participating in, $\phi(k)$ is the amount of transferred money of the individual to each association, and ρ_n is the return of the association n. Equation (5) shows that the expenses, which decrease the capital according to Equation (1), are the sum of the individual's decision variables and the mandatory fee to participate in each association. Similarly, Equation (6) shows that the incomes of the individual depend on the return of each association, which can be 0 or an agreed value as we explain in the following sections. Finally, incomes from the associations are not the only return that individuals can receive. They also have a return (ROI) based on their investments in education and health. According to [12], the ROI is modeled as

$$r(k) = a_1 + a_3x_3(k) + a_4x_4(k) + z(k), \tag{7}$$

where a_1, a_3, and a_4 are nonnegative scalars representing the basic return and the returns on health and education respectively. This refers to the individual's capability to generate income based on his abilities and knowledge. We use a zero-mean random variable $z(k) \sim \mathcal{N}(0,\sigma)$ to model the uncertainty of the returns. The main purpose of this model is to easily characterize the financial dynamics of individuals to analyze the implications of several associations strategies when an individual has a set of policies to invest and consume, and to determine which variations of Rotating Savings and Credit Associations (ROSCAs) can potentially promote development in low-income communities.

B. Individual Decision Policiy

Based on the model of individual financial dynamics, it is possible to implement and test several policies that are conducted by individuals in real contexts. Individuals of low-income communities tend to invest their money in non-capital goods looking for an instantaneous reward. People with this behavior tend to consume their resources immediately or use them to pay previous debts without saving or investing in other assets, such as health or education capital, which would represent a higher return in the future [23]. Several studies have concluded that one of the main motivations for joining ROSCAs is to find a commitment device to avoid procrastination in savings and investments [24]. Ideas such as "you cannot save alone" [25] or "I can start saving tomorrow, not today" [26] are common in these communities. Following this rationale, in Table I, we propose a decision policy that prioritizes the investment in non-capital goods. We denominate this policy as consumption policy. For this policy, we define a percentage of the working capital to invest in each asset U_m, for $m = 1, 2, 3, 4$, depending on the total capital $(x_1 + x_2)$ that individuals have. When individuals have less than 250 US\$PPP, they invest the minimum required capital in their health capital to survive. If their total capital surpasses 250 US\$PPP, they start to consider paying the ROSCAs fee D and prioritize investment of 5% of their capital on consumption U_1. By increasing their total capital, they start to invest in health and education and increase their consumption to 10% and 15% of their total capital. We select these thresholds based on the parameters of our individual financial dynamics model.

V. Financial Cooperation Strategies based on Reserve and Trust

One of the concepts that have been implemented in some observed ROSCAs and that we hypothesize can potentially improve the performance of the community is the cash reserve ratio (CRR). In this section, we explain the CRR and propose a mathematical model of trust and trustworthiness for members of the ROSCA. Finally, we show the simulation results for a community that implements a ROSCA with a CRR.

A. Cash Reserve Ratio and Trust

To decrease the negative impact of those who leave the association before paying the money that they received, a typical solution is the Cash Reserve Ratio (CRR). CRR corresponds to a percentage of the total income of the ROSCA during each month that is saved to increase the resilience of the association. In this way, the association will have savings to guarantee the agreed return to each member, even if someone drops out. Although CRR increases the resilience of the strategy, it supposes an important problem: the existence of a CRR in the association implies that everyone will receive less money

TABLE I
INDIVIDUAL CONSUMPTION POLICY

Total Capital (US$PPP)	U_1	U_2	U_3	U_4	ϕ_n	Concept
$x_1 + x_2 < 250$	0	0	0	0	0	Survive
$250 < x_1 + x_2 < 500$	5	0	0	0	D	Low consumption
$500 < x_1 + x_2 < 750$	5	0	1	0	D	Low consumption and eating
$750 < x_1 + x_2 < 1000$	10	0	1	0	D	Consumption and eating
$1000 < x_1 + x_2$	15	5	1	1	D	Max consumption, saving, eating and studying

than the saved amount. Therefore, CRR can be seen as a percentage that everyone is losing or paying to ameliorate the effect of those unreliable individuals. When an individual either avoids the payment of the ROSCAs fee, contributes less than the established fee, or has a delayed contribution, the other members of the community can decrease their trust in the association, and their motivation to continue cooperating with others can be reduced.

To study this effect, inspired by the models of reputation and generosity proposed in [13] and [14] that measure the desire of an individual to cooperate in a social task, we included a new variable $x_5(k)$ to the dynamics of individuals. This variable models the probability of an individual to continue participating in the ROSCA based on the trust and trustworthiness of each individual i. Trust refers to how much an individual i believes that the other individuals will cooperate with him/her, or how much they will avoid a defection to the community [27]. On the other hand, trustworthiness corresponds to the trust that other individuals have in individual i [27]. Based on these concepts, the work in [28] proposed a game to measure trust and trustworthiness. We adapt the rationale of this work to calculate both variables. First, the trust of an individual i is measured by using the total collected amount of money of all members of the ROSCA. In this way, if members cooperate, the individual i will increase his/her trust in the ROSCA. Similarly, we calculate trustworthiness based on the particular cooperation of individual i to the association. Both variables are normalized and considers the value of $x_5(k)$ to calculate $x_5(k+1)$. If trust, or trustworthiness, calculated at month k, is higher than the expected one by the individual i, he/she increases the probability to continue cooperating. On the other hand, if trust and trustworthiness are lower, the probability of participation decreases. The dynamics of this variable are then modeled as

$$x_5^i(k+1) = \mu^i(k)\Bigg[x_5^i(k) + \underbrace{\tau_1\left(\frac{u_5^i(k)}{D} - x_5^i(k)\right)}_{\text{Trustworthiness}} + \underbrace{\tau_2\left(\sum_{j=1}^{\nu}\frac{u_5^j(k)}{\nu D} - x_5^i(k)\right)}_{\text{Trust}}\Bigg], \tag{8}$$

where μ^i is the percentage of the benefit that the individual i received in his/her turn, τ_1 and τ_2 are the importance of trustworthiness and trust respectively, $\tau_1 + \tau_2 \leq 1$, $u_5^i(k)$ is the transfer of the individual i to the ROSCA, and ν is the number of participants of the ROSCA where the individual i is participating in. The decision variable $u_5^i(k)$ affects the definition of $\phi(k)$ to consider the probability $x_5^i(k)$ of an individual to continue participating in the ROSCA as

$$P(u_5^i(k)) = \begin{cases} x_5^i(k) & \text{if } u_5^i(k) = \phi(k) \\ 1 - x_5^i(k) & \text{if } u_5^i(k) = 0 \end{cases}. \tag{9}$$

Note that in Equation (8) the trustworthiness component x_5^i increases if the individual pays the fee D, that is $u_5^i(k) = D$, according to the definition of $\phi(k)$ in Table I, and decreases if $u_5^i(k) = 0$. Similarly, the trust component x_5^i increases if the percentage of participation of all members in the ROSCA is greater than his/her probability to continue in the ROSCA, and decreases if that percentage is lower. As it represents trust and trustworthiness, we denominate the variable $x_5(k)$ as trust for the following sections.

The state of a ROSCA n based on the contributions $u_5(k)$ of its ν members is defined as

$$x_n(k+1) = x_n(k) + \sum_{i=1}^{\nu} u_5^i(k) - \rho_n,$$

where ρ_n is the money given by the ROSCA n to each member on his/her turn. The CRR is represented by the proportion γ that is retained on each month to all individuals to consolidate the savings of the ROSCA intended to increase its resilience.

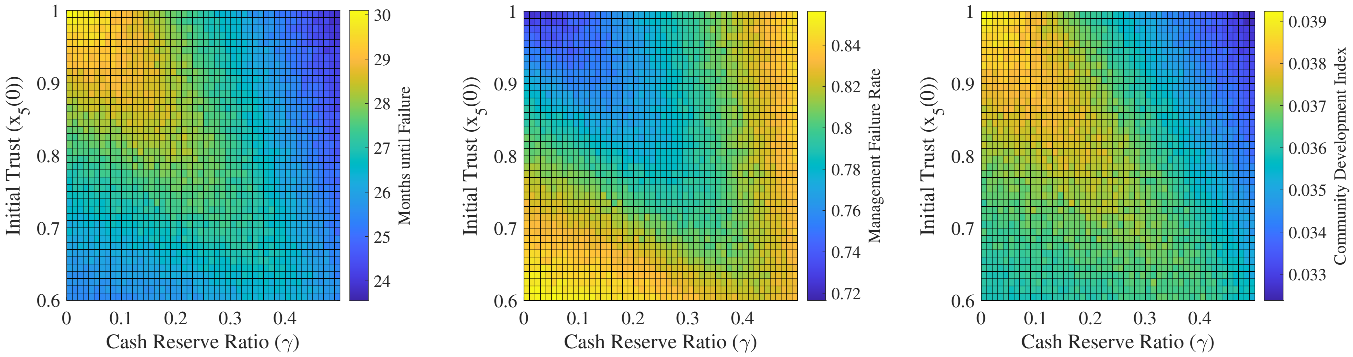
The benefit received by each member is agreed as $\rho_n = (1-\gamma)\nu D$. However, if the ROSCA does not have enough capital to pay this amount, that is $x_n(k) < (1-\gamma)\nu D$, the benefit ρ_n received by the individual on that turn is the total savings of the association $x_n(k)$. When this happens, and the individual partially loses his/her savings, he/she decreases his/her motivation to continue participating in the ROSCA. The parameter $\mu^i(k)$ in Equation (8) models this behavior. This parameter is calculated as

$$\mu(k)^i = \begin{cases} \min\left(\frac{\rho_n}{U_5^i(k)}, 1\right) & \text{if } k \text{ is the turn of } i \\ 1 & \text{if } k \text{ is not the turn of } i \end{cases}, \tag{10}$$

where $U_5^i(k)$ is the cumulative transfers from individual i to the ROSCA that has not been received in his/her turn, that is, the total amount of savings lost. Note that Equation (10) only decreases the trust if the individual receives less money than his/her cumulative savings, otherwise $\mu = 1$ and trust does not change because of μ.

B. Measuring Performance of the Community

To measure the performance of the community, we use three indicators. First, the management failure rate (MFR), introduced by [12], indicates the percentage of people who fail in the simulation. A failure occurs when the individual crosses



(a) (b) (c)

Fig. 2. Performance indicators for different initial trust and cash reserve ratios: a) average Month until Failure, b) Management Failure Rate, and c) Community Development Index.

the minimum level of BMI or losses all his/her working capital. The second indicator is the average months until the individual has a failure. For those individuals who do not fail, the months until failure are equal to the months of the simulation. Finally, the last indicator is the community development index (CDI), which is based on the Human Development Index used by the United Nations and proposed by [12], takes inequalities in the distribution of health, wealth, and education among the members of the community to estimate community development [12]. Given a community, its CDI is calculated as

$$CDI = \left((1 - A_w) \left(\frac{\bar{\bar{w}}}{\hat{w}} \right) (1 - A_h) \left(\frac{\bar{\bar{h}}}{\hat{h}} \right) (1 - A_e) \left(\frac{\bar{\bar{e}}}{\hat{e}} \right) \right)^{\frac{1}{3}},$$

where A_w, A_h and A_e are the Atkinson inequality index of wealth, health, and education [29]. Variables $\bar{\bar{w}}$, $\bar{\bar{h}}$, $\bar{\bar{e}}$ are the mean of the state variables on all individuals, and ,$\hat{w}$, $\hat{h}$ and $\hat{e}$ are the maximum of each welfare characteristic reached by an specific individual in the community. More details on calculating CDI can be found in [12].

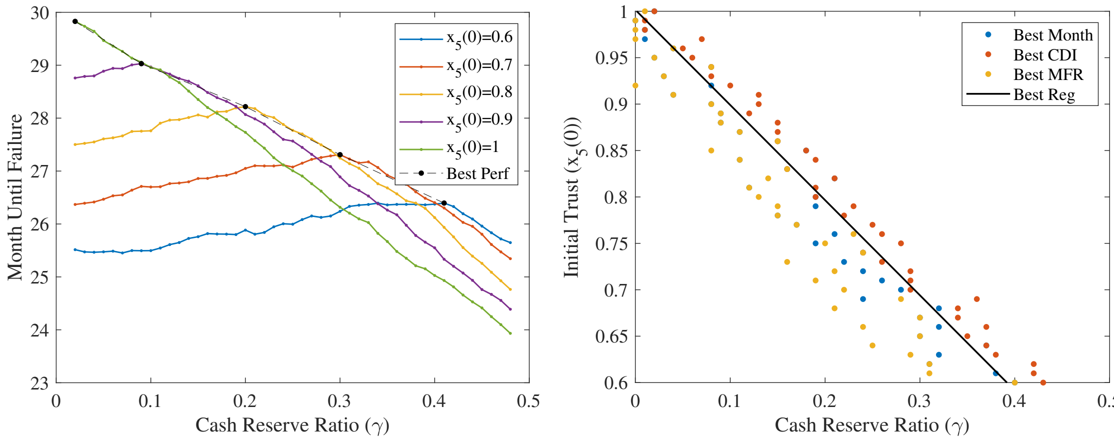
C. Simulation Results

To determine the impact of the CRR and initial trust on the performance of the community, we simulated 3000 communities with 100 individuals on each one for initial trust from 0.6 to 1 and CRR from 0 to 0.5. Each community has 5 ROSCAs with 20 members and was simulated for a time period of 5 years (60 months). Each turn was randomly defined at the beginning of the simulation. The initial trust of each individual was calculated with a Beta distribution with a mean equal to the desired initial trust and a standard deviation of 0.05. For initial values larger than 0.95, we used a standard deviation of 0.01 because Beta distribution does not allow higher deviations when the mean is near to 1.

Figure 2 shows the average performance indicators for all initial trust and CRR. Lighter colors represent higher values of that indicator but do not imply better performance. A good performance of a community involves a high CDI, a high month until failure and a low MFR. Figure 2a shows that the highest months until failure are obtained in those cases where the initial trust is higher and the CRR is close to 0. When individuals have a high trust and trustworthiness, the community increases its social connectedness, and each member tends to cooperate, save more with ROSCAs and pay the contribution promptly [2]. This reduces the need for a high CRR. As we mentioned below, the CRR can be seen as a percentage that everyone pays to allow for a resilient association. By reducing this payment, the general losses are lower, and the development of all members is higher. These results are also shown in the behavior of the MFR (Figure 2b) and the CDI (Figure 2c).

Considering that a lower CRR always reduces the amount paid by the members to avoid a low resilience of the association, it would be concluded that in all scenarios the CRR should be close or equal to 0, but this is not true. According to our results, if no individual withdraws from the strategy without paying the received benefit, the CRR is not required because the behavior of the members consolidates a resilient association. However, if initial trust is lower than 0.8, the CRR recovers vital importance. When individuals do not trust or are not trustworthy, some individuals can betray the ROSCA and avoid its fee after receiving the benefit. This not only impacts the financial state of the community. The major issue occurs in the probability of individuals to cooperate. The impact of indirect reciprocity [13], [30] can motivate individuals to cooperate if everyone is cooperating in a particular social task, which is the cooperative saving in this case. However, if some individuals betray the association, others can lose this motivation to cooperate. When someone avoids his/her payments, and as a result, the other members cannot receive the expected return for their participation, individuals reduce their trust in the association and also avoid their cooperation to the ROSCA condemning the association to failure. For this reason, this type of association should be made between people with high levels of trust and trustworthiness as ROSCAs studied by [31]. If it is not the case, a CRR should be required.

These observations raise a new question to be studied. It is necessary to recognize the ideal CRR for a given initial trust. Ideally, the ROSCAs should be made between families members, friends, or groups where it is guaranteed that everyone will pay the benefit after their turn of receiving it. However, many ROSCAs are implemented by people that are not close. For those scenarios, we analyze when occurs



(a) (b)

Fig. 3. Performance indicators for different initial values of trust and cash reserve ratio: a) average month until failure for 5 levels of initial trust varying the CRR; and b) linear regression to estimate the best CRR for a given initial trust using the 3 indicators.

the best performance indicators and estimate the CRR that maximizes the performance of the community with a given initial trust. Figure 3a shows the month until failure indicator for 5 different levels of initial trust. We applied an average or mean filter to the results with a sample window of 3. As we mentioned before, when the initial trust is 1, the best CRR is the minimum. On the other hand, when initial trust decreases, the CRR increases to get the best performance. This figure suggests a linear relationship between initial trust and the CRR required to maximize the performance of the community. Therefore, we conducted a linear regression estimation to determine the relationship between a given initial trust and the CRR that maximizes CDI and months until failure, and minimizes MFR.

Figure 3b shows the CRR that maximizes the performance of the community based on the three indicators for all given initial trust and its linear regression. According to this estimation, the performance is maximized when $\gamma = 0.92 - 0.92x_5(0)$. This result indicates that the CRR required is equal to the absence of trust and trustworthiness in the members of the association. In other words, the absence of trust between members, which can be measured as the work in [31], must be compensated at an equal level by their money to avoid a low resilience and reduce the probability of failure in the cooperation scheme.

VI. Decentralized Financial Cooperation Strategies

Another important variation for the ROSCA scheme is the number of associations in which an individual decides to participate and the number of individuals that the association allows. Individuals who have a successful experience in this type of association, tend to participate in more than one ROSCA at the same time. On the other hand, although some countries restrict the number of members of the ROSCA to less than 20 members [32], others proposed formal ROSCAs from 20 to 100 members [15]. In general, it is possible to find ROSCAs from less than 10 members to more than 100 members [33], [34]. Therefore, this section is focused on studying the effect of the number of associations per individual and the size of each ROSCA in the development of the community.

A. Decentralized ROSCA

To simulate the decentralized ROSCA, we first randomly assign the desired number of individuals D to each association. Based on the number of ROSCAs N for each individual of the community, we define the number of ROSCAs in the community as $100N/D$ for a community with 100 individuals. Each individual is assigned randomly to D different ROSCAs without repetition. In this way, at the beginning of the simulation, each individual has the same number of ROSCAs and each association has the same number of members. The network composed of these connections is shown in Figure 4a. This figure reflects the connections created for a community with 30 individuals with 2 ROSCAs per individual and 10 members per ROSCA. Black nodes correspond to individuals and blue nodes represent ROSCAs. Figure 4a shows that some individuals share both of their ROSCAs, others share one, and a few members do not share a ROSCA. Similarly, some ROSCAs share several individuals and others have no members in common. This bipartite graph allows us to study those connections from the ROSCAs or individuals' perspectives. Figure 4b shows the connections between ROSCAs and Figure 4c shows the connections between individuals. These initial graphs do not remain constant during each simulation. When an individual suffers a failure or does not continue cooperating in a ROSCA, this individual is disconnected from his/her neighbors. Similarly, if the individuals that two ROSCAs have in common are disconnected from the community, those ROSCAs are also disconnected between them. Finally, for all the simulations in this section, we assume that individuals have a trust parameter $x_5 = 1$. They always cooperate with their ROSCAs, unless they fail if they pay their fees. In this way, the resilience in this analysis is only affected by the topology of the network.

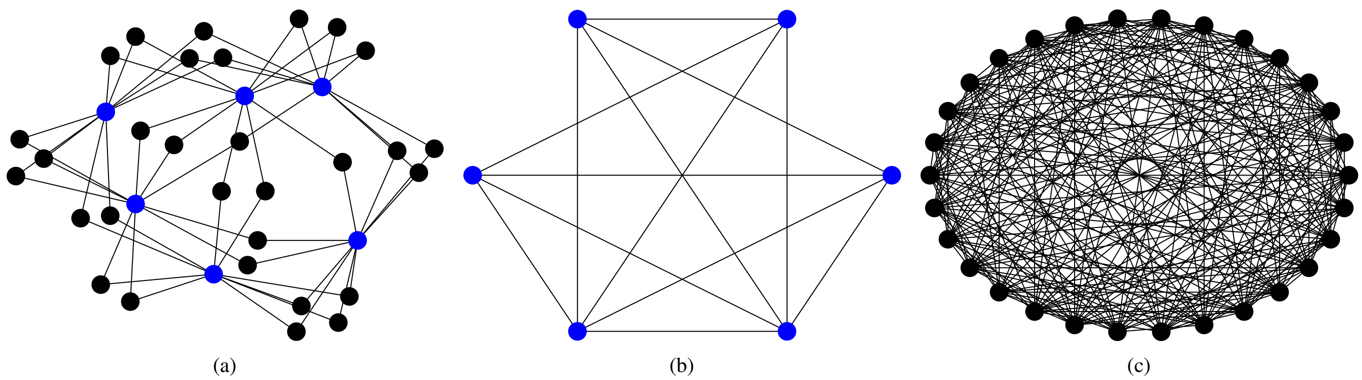


Fig. 4. Graph Example of a community with 30 individuals, 2 ROSCAs per individual, and 10 members per ROSCA. Black nodes correspond to individuals and blue nodes represent ROSCAs. Two ROSCAs are connected if they share a member and two individuals are connected if they share a ROSCA. a) Bipartite graph of the community, b) Graph of ROSCAs, and c) Graph of individuals.

TABLE II
EVOLUTION OF THE GRAPH DEGREE

ROSCAs per Individual	Individuals per ROSCA	Initial Average Degree (ROSCAs)	Final Average Degree (ROSCAs)	#ROSCAs	Initial Average Degree (Individuals)	Final Average Degree (Individuals)	MFR
2	2	1.98	0.56	100	1.98	0.19	0.68
	20	8.2	4.48	10	35.88	3.35	0.71
	100	1	1	2	99	2.86	0.82
10	2	17.82	9.51	500	9.26	2.52	0.44
	20	48.12	40.68	50	87.14	21.24	0.51
	100	9	9	10	99	5.01	0.76

B. Simulation Results

When individuals assign a part of their capital to an association scheme, there are two possible ways to do it. First, an individual can have a desired capital to transfer to his/her ROSCAs. In this case, we assume that each individual divides equally that capital to each of their ROSCAs. For example, if an individual saves 10 USD in 2 ROSCAs, each ROSCA receives 5 USD. If the individual saves the same amount in 5 ROSCAs, each ROSCA receives 2 USD but the total amount of saved resources is the same. The other way to participate in these associations is to pay a specified fee to each ROSCA. For example, if the fee is 10 USD and the individual desires to participate in 5 ROSCAs instead of 2, he/she will save a total of 50 USD instead of 20 USD. We analyze both approaches in this section.

Table II shows the mean evolution of the average degree of the graph of ROSCAs and the graph of individuals over our 3000 simulations. These simulations are conducted using the approach in which individuals have to pay 10 USD per ROSCA. When individuals participate only in two ROSCAs, the initial and final average degrees of both graphs are lower than the case of 10 ROSCAs per individual. The MFR is also better when the number of ROSCAs per individual is higher. This improvement in the performance indicators happens because more ROSCAs per individual allow for more connections between individuals and between ROSCAs, reducing the impact of a particular failure in the community. This result reflects that higher connectivity of individuals can potentially help them increase their resilience. However, when ROSCAs admit more members, for example, 100 instead of 20, the connections between individuals are higher but the performance of the community is worse. This happens because many individuals have to wait an excessive amount of time for their turn and are prone to suffer a management failure before receiving a return of their participation in the association. A similar analysis can be made from the results of the average degrees of ROSCAs. Although the average degree of ROSCAs with fewer members is higher, this is the result of requiring more ROSCAs in the community if each one just allows for a small number of members. By seeing the density of the connections between ROSCAs, when each association admits more members, ROSCAs are strongly connected between them, but again this does not have an important effect on the performance of the community. These results show that connectivity is important to increase the resilience of the community, but higher connectivity has to be accompanied by short periods of time to receive a return on the investment.

Figure 5 shows the months until failure indicator for three different forms of participation in a ROSCA. Remember that better performance of the community is characterized by larger amounts of months until failure. Figure 5a shows the scenario of individuals who desire to assign a total of 10 USD to all their ROSCAs, that is, dividing 10 in the number of ROSCAs to get the fee of each one. From this approach, when individuals participate in more ROSCAs, and each association allows for a low number of individuals, the community performs better. This is justified by a reduced waiting time to receive a return from their ROSCAs and an increase in the connectivity of the individuals.

Similar results are shown in Figure 5b. In this scenario, individuals pay a fee of 10 USD in every ROSCA, saving a total of 10 USD multiplied by the number of ROSCAs in which

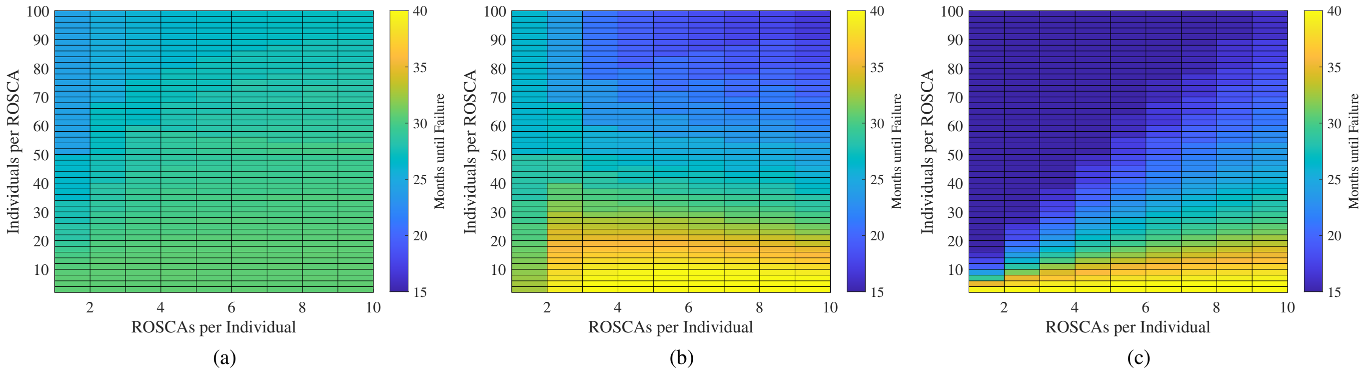


Fig. 5. Month until failure for three decentralized scenarios, varying individuals per ROSCA and ROSCAs per individual. a) Each individual saves 10 USD assigning an equal part to each ROSCA. b) Each ROSCA requires a fee of 10 USD, therefore individuals can save a total from 10 to 100 USD. c) Each individual saves 100 USD assigning an equal part to each ROSCA.

they participate. From this second approach, the community also performs better by increasing the ROSCAs per individual and reducing the number of members of each association. However, the best performance shown in Figure 5b is by far better than the best performance of the Figure 5a. This is the result of a higher amount of total savings when individuals pay a fee of 10 USD in each ROSCAs than only saving a total of 10 USD divided in all associations.

When savings are higher and the time to get the return is not excessive, the community performs better. However, this result does not necessarily imply that a higher amount of ROSCAs per individual is better for the community. When ROSCAs allow for more individuals, individuals perform worse by increasing the amount of ROSCAs per individual. More individuals on each ROSCA implies a higher time to get the return and the investment. The worse performance in this scenario can be the result of increasing this time. When the time to get the return is excessive and individuals invest more money by participating in more associations, they are risking a higher amount of capital. For this reason, the result for some members would be worse.

It is possible to save the same amount of money in lower ROSCAs by increasing the fee of each one. Therefore, we return to the first approach where all individuals divide into equal parts a desired level of savings, but we increase that level to 100 USD. Figure 5c shows that this third approach shows similar results to the second one in those scenarios where the total savings are similar. However, when individuals saved a higher amount of money in a lower amount of ROSCAs, or ROSCAs with more than 20 members, the results are the worst of all three scenarios. This result shows that an increase in the savings would be helpful if the resilience of the ROSCAs is higher, which is the case when each individual participates in more ROSCAs. However, if ROSCAs have a lower resilience, the result would be different. If someone fails or betrays an association with a high fee, all the others will loss more capital. Thus, its consequence would be negative. This is the reason why the scenario in Figure 5b tends to perform better, mainly when individuals participate in a lower amount of associations. If members of a reduced number of ROSCAs risk a higher amount of money, 100 USD in the case shown in Figure 5c, and one of these associations defaults, the economical losses would be higher than individuals that do not risk the same amount of money. Therefore, when individuals only pay a limit fee to each ROSCA, which is the case shown in Figure 5b, the amount of money risk when they participate on a reduced number of associations is lower and the losses in the case of default are fewer. This shows that ROSCAs are similar to investment funds where investors can receive a desired return or loss their money. For this reason, members of ROSCAs should diversify their investment, or in this case, their savings, to reduce the risk.

VII. Conclusion

This paper presented some variations of Rotating Savings and Credit Associations (ROSCAs). First, we incorporate a cash reserve ratio to the conventional ROSCA to decrease the impact of individuals who left the association without paying the credit that they received. We introduce a model of trust and trustworthiness in the analysis and show that the absence of trust between members of the association must be compensated at an equal level by their capital to reduce the probability of failure in the cooperation scheme. Then, we presented a decentralized ROSCA where individuals participate in more than one association. We show that individuals should cooperate in several associations with a low number of members to reduce the time required to receive a return of their cooperation and also reduce the probability of losing their money due to untrustworthy individuals.

Future research directions involved studying the coexistence of several informal financial cooperation strategies in the same community to analyze which are preferred by individuals and how they decide to cooperate with their neighbors. Also, since some variations have shown promising results, it is important to study the process that some strategies can follow to become formal financial strategies.

VIII. Ackowledgement

This work was partially supported by Google through the Google Research Award for Latin America, and the University of los Andes and the University of Ibagué through Convocatoria Conjunta Unibagué-Uniandes.

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