Evolving informal cooperatives for a risky activity when networks matter

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Outline

1. Background
2. Model and simulations
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Risk-sharing issue

- When agents perform risky activity
- Agents are risk-averse

In general this model is used in economics to know under which conditions agents choose to belong to a cooperative where they share the income they gain from their activity. In general, in theory, one considers that they know their own risk and the risk of the cooperative.

Related literature

Empirical evidence

- Townsend (1994): in village economy, full insurance statistically rejected, but surprisingly good benchmark (data from India, ICRISAT).
- Fafchamps and Lund (2003): risk-sharing takes place at a lower level than the village (friendship, family) (data from Filipino)

Group formation and Risk-sharing in theory - enforceability

- Génicot and Ray (2003):
  - look for coalition-proof coop when agents are homogeneous and contracts (transfers) not enforceable
  - stability depends on the need for insurance, i.e. on uncertainty and the maximal size of a stable coop is finite
- Bloch, Génicot and Ray (2007)
  - add a network component with 2 roles: bilateral transfers and info
  - define stable transfer scheme depending on punishment

Adding dimensions: not just economic

We want to know if the type of network in which agents are immersed can have an impact on the sharing of risk, in particular in a context of **incomplete information**, when **compassion** and **friendship** are at stake. We are also interested in finding a good formalisation for compassion and friendship.

Note : to construct a non intuitive setting, we want to make agents share although it might be a bad idea, and hence choose to design agents that are **heterogenous in probability of success**. The fact that agents are risk-averse can make them prefer to share with others and earn income 5 at each step, although they would get 4 and 7 every second time-steps (with an average of 5.5).

Embeded agents

Learning risk-sharing agents

- Agents do not know their risk nor others' and learn by observing results
- Agents can create cooperative when single
- Agents choose to belong to a cooperative or not

Embedding risk-sharing agents in social life

- Existence of other-regarding preferences ("compassion")
- What changes when one belongs to a network
  - More accurate information about performance of others
  - Pleasure of being together gives positive utility (not just income) ("friendship")

Agents

Each Agent has:

- possible gain $y \in \{50; 100\}$;
- probability of success $p = P_{high}$ or P_{low};
- belief on probability of success: $P^i(t)$ is the probability of having high success. Initialized at 50%, it is revised after each result is known;
- risk-aversion $\rho \in [1.1; 6]$ (Kimball, 1988) implies utility:

$$u(y(t)) = \frac{y^{1-\rho} - 1}{1 - \rho} \tag{1}$$

  (CRRA)
- compassion *comp*;
- friendship f;
- network (direct links are the list of "friends").

Cooperative

If a cooperative is made of agents $\{a_1, ...a_n\}$ with income $\{y_1, ...y_n\}$, then

$$c(t) = \frac{\sum_j y_j(t)}{n} \qquad (2)$$

is the **consumption** of each agent belonging to the cooperative. When belonging to a cooperative, agents with a high probability of success ($p = P_{high}$) will not get as high a consumption as if they were alone, but they will get a more stable consumption since the risk is shared among all. As a consequence, when ρ is low, an agent with a high probability of success likes it better to be out of the cooperative, when it is high he likes it better to be inside.

Bayesian revision of beliefs

Belief of belonging to high success group (= to have a probability of success of P_{high}): $P^i(t)$ is initialized with $P^i(t) = 50\%$

- if $y^i(t) = 100$

$$P^i(t) = \frac{P_{high}P^i(t-1)}{P_{high}P^i(t-1) + (P_{low})(1 - P^i(t-1))} \quad (3)$$

- if $y^i(t) = 50$

$$P^i(t) = \frac{(1 - P_{high})P^i(t-1)}{(1 - P_{high})P^i(t-1) + (1 - P_{low})(1 - P^i(t-1))} \quad (4)$$

The interest of this learning is that agents keep track of the quality of their belief, which is expressed as a **probability of belonging to one group of another**. Depending on the difference between P_{high} and P_{low} the time to learn is different, i.e: if $P_{high} - P_{low} = 20$, it takes 85 steps to know with a strength of 95% whereas if $P_{high} - P_{low} = 70$ it takes 5 steps.

Staying in a cooperative or leaving (1)

In the basic model, an agent stays in the cooperative he belongs to if:

$$E_i^{ant}(u(y)) - E(u(c)) \leq 0 \quad (5)$$

with the expected utility of c (based on past with forgetting) is:

$$E(u(c)) = \frac{\sum_{t<=T} \delta^(T - t)c(t)}{Z} \quad (6)$$

the expected utility of y when single is

$$E_i^{ant}(u(y)) = P^i(t)u^+ + (1 - P^i(t))u^- \quad (7)$$

where u^+ (resp. u^-) are the expected utility of high (resp. low) success agents:

$$u^+ = P_{high}u(100) + (1 - P_{high})(u(50)) \quad (8)$$

$$u^- = P_{low}u(100) + (1 - P_{low})(u(50)) \quad (9)$$

The inclusion of compassion and frienship are such that Compassion makes the agent matter for his marginal impact on common welfare: he is more reluctant to leave if it is bad for the group. Hence he stays if:

$$E^{ant}(u(y)) - E(u(c)) \leq comp(u(\bar{c}) - u(\frac{n\bar{c} - \bar{y}}{n-1})) \qquad (10)$$

The utility of agent are directly transformed by friendship, and the more friends are present in the cooperative, the higher the agent gets from being part of it. He stays if:

$$E^{ant}(u(y)) - E(u(c + rf)) \leq 0 \qquad (11)$$

where r is the share of friends in the cooperative.

Building a cooperative (1)

At each step, one single agent is randomly chosen to test if he wants to create a cooperative. For this he gets information from its network at level 2 (all single agents with whom he has a direct link (friends) and all their direct friends). The agents answer their own belief on their probability to be in the high success group. The agent trustes him at a level of 90% if he is a friend (f) and $(90\%)^2$ if he is the friend of a friend (nf). The aggregation of the information is then a probability of success: P_m.

$$P_m(t) = sum_f(0.9P_f(t) + 0.1 * 0.5) + sum_{nf}(0.81P_nf(t) + 0.19 * 0.5) \tag{12}$$

He then knows the chance of success of the group seen as one agent at the next step:

$$\theta_m = P_m(t)P_{high} + (1 - P_m(t))P_{low} \tag{13}$$

Building a cooperative (2)

He already knows his own chance of success at the next step:

$$\theta_i = P_i(t)P_{high} + (1 - P_i(t))P_{low} \tag{14}$$

and the expected utility when associating with the fictitious agent m is then:

$$E^{fic}(u(c)) = \theta_i\theta_m u(100) + (1-\theta_i)\theta_m u(75) + \theta_i(1-\theta_m)u(75) + (1-\theta_i)(1-\theta_m \tag{15}$$

which has to be higher than his own expected utility for the cooperative to be created.
Note 1: The agent has a pessimistic view of the association.
Note 2: Myopic view: do not anticipate on the gain over several time-steps.

A typical simulation run

At time 0:

- N (usually, 200) artificial Agents are created;
- Half of the agents are given probability of success P_{high} and other half P_{low};
- Network is created (small world, complete network, random network)

Afterwards:

- All agents check if they want to stay in the cooperative they belong to;
- One single agent is chosen to check if it wants to create a cooperative;
- We run for 120 steps (each step representing a "month").

Parameters

Parameters	Values
Number of agents	10, 50, 200
$P_{high}; P_{low}$	$\{30; 70\}$, $\{40; 60\}$, $\{45; 55\}$
Risk aversion	1.1, 1.2, ... 3
Compassion	0, 1, 2,... 10
Friendship	0, 0.01, 0.02, 0.03,..., 0.1
Network	Complete, Random, Smallworld
Density	5, 10, 20
Information trust	0.9
Valuation of the past (δ)	0.5 (6 steps memory)

Observed indicators

- when agents cannot create cooperatives
  - final situation - quantity of agents that left the cooperative

  It gives a typology of possible situations when 10 runs of the same simulation are run
- when agents create cooperatives
  - escape rate from cooperatives: 1/ how often do agents leave? 2/ how many agents leave at each time?
  - average size of cooperatives
  - segregation index characterizing the mix of agents of high success and low success in each of the J cooperatives. n^h agents (resp. n^l) are high success agents in the group (resp. low success) and n_j^h (resp. n_j^l) those in cooperative j.

$$D = \frac{1}{2} \sum_{j \leq J} \frac{n_j^h - n_j^l}{n^h - n^l} \qquad (16)$$

Without creation of cooperative (1)

Typology of simulation runs

- Total stability;
- Low escape (less than half leave, both low and high success stay);
- Partial escape (more than half leave, only low success agents stay);
- Complete escape.

Impact of *risk-aversion*: when it increases, stability increases. What we use as a reference point to differentiate among simulations is the value of risk-aversion that is necessary to witness each of the different situations described in the typology.

Impact of $P_{high} - P_{low}$: when the difference increases, risk-aversion needs to be increased to attain stability.

Without creation of cooperative (2)

Impact of friendship (network matters)

- In complete network, as soon as $f > 0$, stability is always attained;
- In random graph of density 5 the increase of f increases predictability of result (one initial setting implies one situation) and stability;
- Random graph: increasing density, when $f > 0$, creates situations where low and high success agents cohabit in the cooperative (rare situation).

Impact of compassion (network does not matter but size of the population does). When increasing compassion:

- 50 agents - increase of compassion stabilizes ;
- 200 agents - changes in compassion have no impact;
- 10 agents - impact of history (realisation of events) is so important that increasing compassion cannot increase stability - either total stability or complete escape.

With creation of cooperative (1)

The situation we are interested in is the value of risk-aversion that enable all created cooperatives to survive. This value exists for all positive values of compassion and friendship.

Impact of friendship depends on network

- Complete Graph: stable as soon as $f > 0$;
- Small-World is equivalent to random graph: increase of friendship increases stability; increase of density increases stability.

Unexplained result: segregation is more important with Small-world (0.4-0.5) than Random Graph (0.2-0.3).

With creation of cooperative (2)

Impact of compassion

- Complete graph: not always stable and compassion has no impact on stability;
- Small-World is equivalent to Random Graph: compassion has an impact on stability. This is explained by the fact that created groups are smaller and compassion impacts on medium size groups.

Unexplained result: segregation is more important with Small-world (0.6-0.8) than random (0.2-0.4). High compassion makes segregation increase.

Conclusions

- The shape of network has an impact in most cases; not just on stability but also on segregation;
- This impact is linked to the role of frienship but not the quality of information that circulate;
- The test of mechanism for frienship and compassion gives interestingly different results;
  - In a way, frienship has a too important impact
  - Compassion can often not "compete" with history: bad realizations make all agents leave, good realizations make them stay