

The evolution of sharing networks under conditions of risk and uncertainty

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Motivation

Welcome. This is a work-in-progress on the relationship between environmental risk, uncertainty, reciprocal sharing norms and social structure. Most accounts of human behavior, culture and group dynamics emphasize the ways in which groups working in cooperative and coordinated ways can achieve high payoffs to behavior and promote beneficial results like innovation. Another perspective that might be worth considering more closely is the way in which organizing in groups may aid risk mitigation when in changing environments and uncertain conditions (which is something all of us experience in life). Reciprocal sharing practices (known widely in the anthropological literature as "reciprocity"), in which individuals enter lasting relationships of reciprocal exchange of beneficial goods have been observed in societies around the world, and they are commonly accompanied by systems of norms that implicitly or explicitly mediate them. The following pamphlet shows the results of using a game-theoretic framework to explore the conditions in which reciprocal sharing practices can invade populations of non-sharers, and the effect that they might have on social structure once they have taken hold.

There are two parts to this work. On one side there is the evolution of sharing practices, which will require careful examination of the ways in which we evaluate the cultural fitness of social strategies. On the other side we have the social consequences of sharing and the group dynamics it leads to once it has successfully invaded.

I have included a reference guide for those who are curious about the mathematical formulation of the model that I used to derive the main results. I have kept it sparse because in this pamphlet I want to concentrate on a qualitative understanding of the dynamics rather than their mathematical derivation. For that reason, if you are not interested in the math, you may simply skip the next section. If you are, I apologize for the sparseness, if you want a more complete run-down please do contact me. Overall, there will be minimal math throughout this presentation of the work.

Model reference guide (for the math-curious)

B : Benefits from successful work at niche or finding a resource patch.

$u \in (0, 1)$: Individual security. Individuals' rate of success of niche work / patch search.

$\mu \in (0, 1)$: Group security. Additional security obtained for being part of the group. It may come from group-specific dynamics such as information-sharing.

\bar{k} : Expected degree of the group.

C : Per-connection cost of maintaining social interaction.

z : Minimum proportion of benefit for individual survival.

N : Number of individuals in the sharing cluster.

$\delta \in [0, \infty)$: risk preference.

Strategy expected payoffs ("objective" framework):

$$V_i(Loner) = uB$$

$$V_i(Informers) = \rho B - k_i C$$

$$V_i(Sharers) = (1 - s)uB + suk_i \frac{B}{\bar{k}} - k_i C$$

$$V_i(Sharers - Informers) = (1 - s)\rho B + s\rho k_i \frac{B}{\bar{k}} - k_i C$$

Strategy payoffs ("subjective" framework, perfect information):

$$V_i(Loner) = u^\delta B$$

$$V_i(Informers) = \rho^\delta B - k_i C$$

$$V_i(Sharers) = (1 - s)u^\delta B + suk_i \frac{B}{\bar{k}} - k_i C$$

$$V_i(Sharers - Informers) = (1 - s)\rho^\delta B + s\rho k_i \frac{B}{\bar{k}} - k_i C$$

The model

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Changing perspectives: from all-knowing gods to boundedly-rational mortals

The normal way in which we have been calculating the cultural fitness of strategies is analogous to what in Economics is known as Expected Utility Theory (EUT). This is also popular practice in decision theory and risk management, but it is not without critics. The problem with this formulation of decision problems is that it assumes that individuals who make choices by evaluating their possible outcomes are not sensitive to risk factors like payoff volatility (also

even higher-stakes scenario is childcare: a steady source of income is necessary to provide for a child, especially during critical stages of development, which may have a strong impact on the child's future. The point is that for many human affairs, a steady moderate payoff will not be the same, from a decision-making perspective, as the possibility of getting a high payoff accompanied by the possibility of getting a low payoff (or, in this simplified model, nothing). By being blind to this distinction, the standard mathematical framework does not allow for the evolution of sharing. We require a change in perspective. For this, we have to consider the state of knowledge a social learner is in at the moment of deciding which target individual to learn from, as well as the learner's preferences regarding payoff volatility in time. In modeling terms, we have to think about how the observed payoffs and the information we have about them translate into cultural fitness. We need to move from an objective point-of-view to a subjective one.

DIBUJO

We will focus on the risk preference for what remains of this work, so we will assume people's estimates about the rate of success of strategies is accurate (e.g. they look like the actual, objective rates of success). Nevertheless, I believe rate of success estimation and its consequences are very rich subjects that could have important consequences for general social learning dynamics.

The evolution of sharing and the group-level consequences of risk aversion

Under this new framework, in which the social learner's risk preference plays a part, sharing can now invade. The condition for the invasion of the sharing-informing strategy in a group of informers is

$$s\rho(1 - \rho^{\delta-1})B > 0$$

When this condition is satisfied, a networked cluster of sharer-informers will do better, in the eyes of social learners, than plain informers. As a consequence, learners will choose to join the network where sharing is also happening instead of the one where individuals are only sharing information. Similar conditions hold for the invasion of simple sharing and sharing-informing over the loner strategy. Interestingly, this condition requires that individuals are averse to payoff volatility ($\delta > 1$, also known as risk-averse or "pessimistic"). When risk-averse, the possibility of low payoffs negatively affects our perception of higher-risk strategies, even when there's a chance

environments (Winterhalder, 1986; Winterhalder, Lu & Tucker, 1999).

The model we're examining here has a clear conceptual link with the above-mentioned literature, while examining the dynamics of sharing in a cultural evolutionary scenario where the decision-makers are the social learners. It also has the benefits of parsimony, mathematical tractability and easy interpretability.

So reciprocal sharing can evolve in a cultural population. That is nice, but is it the full story? The answer is **not at all**. Once sharing has invaded, sharing networks will inevitably grow with respect to loners and informer networks. Where does this growth take us? Turns out the answer is far from straightforward, and it reveals a side of sharing that is not cooperative, but competitive. This will push us into the territory of cultural anthropology, where many reciprocity-fueled social systems around the world have been given careful observation and analysis.

Sharing networks' internal competition, group destabilization and fission

If we are a social learner that has decided to imitate a sharer's strategy, we are acquiring a bundle of cultural attributes. We are accepting to conform to a sharing norm with our network peers, and to provide them with information on available exploitable niches. We are quite possibly adopting social markers that identify us as part of the sharing group and that let us coordinate ourselves with other sharers we might meet. But, crucially, we will likely also identify the target individual's sociability as a non-trivial part of their strategy. Why's that? Because it turns out that the number of network peers a sharer accumulates has an impact on the shared benefits they receive. The more peers one has, the more shared benefits one can accumulate. This means that, within the sharing cluster, we are more likely to imitate high-degree individuals, and so we will go ahead and make around the same number of connections that they exhibit. In other words, we will imitate their sociality patterns, beyond just the norms and markers necessary for coordination.

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inconvenienced by high degree individuals accumulating ties. This drives them to imitate high degree individuals and become high degree themselves. If left unchecked, this situation leads the club's expected degree to increase, which means that a person entering the club seeking to form connections (or a current club member choosing to obtain more connections, which is formally equivalent in this framework) will increasingly perceive that the other club members that they can potentially befriend already have many friendships themselves, and thus will have very little time to dedicate to new friends. Because connections have a non-trivial cost of maintenance (perhaps because I live in a low-density suburban sprawl with little options of public transportation and high gas prices), there will be a point in this dynamic in which the mean degree of the network grows so large that the costs (both the current costs being payed and the new costs that getting more connections would entail) will overtake any benefits that I could be obtaining from this whole ordeal. At this point, I (and probably many others, with the possible exception of the highest-degree individuals) will seriously consider just leaving the club behind and concentrating on myself. Eventually, if enough people choose to abandon the club, the club's mean degree will decrease to a point in which new potential members might actually start seeing benefits to joining once more. The dynamic then repeats itself, leading the club's mean degree to cycle chaotically around a critical point: the point at which joining the club goes from beneficial to detrimental. In ecological terms, this critical point is something akin to a "population carrying capacity" but it applies to mean degree instead of population size.

The key is to realize that the network's degree is not directly controllable by individuals. In other words, there is a very real tension between an individual's want of reciprocity ties and the social consequences of forming them. Within the group, the individuals that acquire the most ties are

reciprocity relations:

"Conflicts are reduced to a minimum within a lineage or co-resident group of agnates who stand, after all, as a virtual lineage (...) The phrase *iba dibi sai* (my real people) is an expression of this solidarity, as is the sharing of food and services, and the proximity of their dwellings and garden plots. The closeness and cooperation between co-resident agnates, made evident with a simple glance at a village's 'economic map,' are even more apparent when compared with the situation of people who have no agnates nearby. Agnatically isolated men may not be economically deprived, but they lack the comfort and security of counting on their relatives for whatever needs arise. Men who have no close agnates or live apart from them are more prone to accusations of theft, adultery, and other abusive acts. The phrase *iba ai dibi* (my others) denotes the ambivalence that exists in the relationship between affines and distant kin. They are both 'my people' (*iba dibi*) and 'other people'. The discomfort that accompanies much of their interactions can be observed in certain situations." (Ramos, 1995, p. 90)

"As villages grow larger, internal order and cooperation become more difficult, and eventually factions develop: Certain kin take sides with each other, and social life becomes strained. There appears to be an upper limit to the size of a group that can be cooperatively organized by the principles of kinship, descent, and marriage (...) kinship-organized groups can only get so large

give outsiders more than they can possibly reciprocate. In well delineated big-man polities, we find leaders negating the reciprocal obligations upon which their following had been predicated. Substituting extraction for reciprocity, they must compel their people to "eat the leader's renown," as one Solomon Island group puts it, in return for productive efforts. Some center-men appear more able than others to dam the inevitable tide of discontent that mounts within their factions, perhaps because of charismatic personalities, perhaps because of the particular social organizations in which they operate.¹⁵ But paradoxically the ultimate defense of the center-man's position is some slackening of his drive to enlarge the funds of power. The alternative is much worse. In the anthropological record there are not merely instances of big-man chicanery and of material deprivation of the faction in the interests of renown, but some also of overloading of social relations with followers: the generation of antagonisms, defections, and in extreme cases the violent liquidation of the center-man." (Sahlins, 1963)

in more connections than low-yield individuals, since the higher, more secure benefits that their niches provide them allows them to put aside more benefits for sharing. There is a limit, yes: this is only true as long as a high-yield individual does not accumulate too many connections that even their higher shared benefits become too diluted through their ego networks. However, this limit can be much higher than that of a low-yield individual. Mathematically, and only considering the case of high and low securities (which assumes equal potential benefits across all niches):

who are mostly connecting with one another, and who only connect with low-yielders if they happen to have additional room for more connections once they have connected with each other. Facing this bleak panorama, most low-yielders will connect with other low-yielders, as that is still

