

## Bootstrapping back the climate with self-organization

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Countries and citizens often raise significant expectations every time a new International Environmental Summit is settled. Unfortunately, few solutions have come out of these meetings. This represents a challenge on our current understanding of models on decision-making: more effective levels of discussion, agreements and coordination must become accessible (Barrett, 2005).

Mitigating the effects of climate change requires cooperation, and arguably the welfare of our planet accounts for the most important and paradigmatic example of a public good game humans face: a global good from which every single person profits, whether she contributes or not to maintain it. However, these summits failed to recognize the well-studied difficulties of cooperation in public-good games. Indeed, in most cooperation problems faced by humans, individuals, regions or nations opt to be free riders, hoping to benefit from the efforts of others while choosing not to make any effort themselves driving the population into the tragedy of the commons. When dealing with such an essential public good as climate, many efforts are made to avoid this, so that efforts are shared for all and balanced measures can then be taken.

One of the multiple flaws often appointed to such agreements is a deficit in the overall perception of risk of widespread future losses, in particular the perception of those occupying key positions in the overall political network that underlies the decision process (Santos, Santos and Pacheco, 2008; Santos and Pacheco, 2011). Another problem relates to the lack of sanctioning mechanisms to be imposed on those who do not contribute (or stop contributing) to the welfare of the planet. Moreover, agreeing on the way punishment should be implemented is far from reaching a consensus, given the difficulty in converging on the pros and cons of some procedures against others, and (occasionally) narrow impact of punishment in promoting cooperative actions (Vukov et al., 2013). The impasse over these measures is expected since their consequences do not have a solid theoretical or even experimental background.

Here we discuss *i*) the effect of group size and risk awareness in the decision making process and *ii*) the emergence and impact of different types of sanctioning in deterring non-cooperative behavior in climate agreements, as reported in (Vasconcelos, Santos and Pacheco, 2013; Santos,

Vasconcelos et al. 2012). To this end, climate agreements are defined as Collective Risk Dilemmas (**CRD**), a simple Public Goods game with uncertainty that mimetizes the problem at stake (Santos and Pacheco, 2011). We model the decision making process as a dynamical process, in which behaviours evolve in time, taking into consideration decisions and achievements of others, which influence one's own decisions. We implement such behavioural dynamics in the framework of Evolutionary Game Theory, in which the individuals are simulated to respond to the most successful (or fit) behaviours. This way, one is able to describe strategic interactions between individuals, complemented by evolutionary principles. In particular, we do so in finite populations, where such fitness driven dynamics occurs in the presence of errors (leading to stochastic effects), both in terms of errors of imitation as well as in terms of behavioral mutations ( $\mu$ ), the latter accounting for spontaneous exploration of the possible strategies. Therefore, instead of resorting to complex and rational planning or rules, individuals revise their behavior by peer-influence, creating a complex dynamics akin to many evolutionary systems.

We consider, a population of finite size  $Z$ , in which individuals engage in the aforesaid  $N$ -person dilemma. Here, each individual is able to contribute or not to a common good, i.e. to cooperate or to defect, respectively. Game participants have each an initial endowment, or benefit,  $b$ . Cooperators contribute a fraction of their endowment, the cost,  $c < b$ , while defectors do not contribute. Irrespectively of the scale at which agreements are tried, they demand a minimum number of contributors to come into practice. Hence, whenever parties fail to achieve a previously defined minimum of contributions, they may fail to achieve the goals of such agreement (which can also be understood as the benefit  $b$ ), being this outcome, in the worst possible case, associated with an appalling doomsday scenario. To encompass this feature in the model we require a minimum collective investment to ensure success: if the group of size  $N$  does not contain at least  $M$  contributors, all members will lose their remaining endowments with a probability  $(1-r)$ , the risk; otherwise, everyone will keep whatever they have. Hence,  $M < N$  represents a coordination threshold necessary to achieve a collective benefit. We obtain an unambiguous agreement with recent experiments, together with several concrete predictions:

we address the impact of risk in several configurations, from large to small groups, from deterministic towards stochastic behavioral dynamics. Overall, we show how the emerging dynamics depends heavily on the perception of risk.

We find that the impact of risk is enhanced in the presence of small behavioral mutations and errors and whenever global coordination is attempted in a majority of small groups under stringent requirements to meet co-active goals (Santos, Vasconcelos et al. 2012). This result calls for a reassessment of policies towards the promotion of public endeavors: instead of world summits, decentralized agreements between smaller groups, possibly focused on region-specific issues, where risk is high and goal achievement involves large quorums for agreement, are prone to significantly raise the probability of success in coordinating to tame the planet's climate.

We also show how individuals may effectively self-organize their actions towards cooperation, by creating community enforcement institutions that are able to punish those who row against collective interest. We present the effects of punishment via institutions when playing against defectors (which leads to higher-order cooperation dilemmas). Moreover, we offer insights on the scale at which such institutions should be implemented, providing better conditions both for cooperation to thrive and for ensuring the maintenance of such institutions (Vasconcelos, Santos and Pacheco, 2013). This result is particularly relevant whenever perception of risk of collective disaster, alone, is not enough to provide the means to achieve a cohesive configuration – in this case, sanctioning institutions may provide an escape hatch to the otherwise tragedy of the commons that humanity is falling into.

This model provides a “bottom-up” approach to the problem, in which collective cooperation is easier to achieve in a distributed way, eventually involving regions, cities, NGOs and, ultimately, all citizens. Moreover, by promoting regional or sectorial agreements, we are opening the door to the diversity of economic and political structure of all parties, which, as showed before can be beneficial to cooperation. Naturally, we are aware of the many limitations of a bare model such as this, in which the complexity of human interactions has been overlooked. From higher levels of information, to non-binary investments, additional layers of realism can be introduced in the model. Moreover, even from a modeling perspective, several extensions and complex aspects common to human socio-economical systems could be further explored. On the other hand, the simplicity of the dilemma introduced here, makes it generally applicable to other problems of collective cooperative action, which will emerge when the risks for the community are high and high-level institutions may self-organize, something that repeatedly happened throughout human history, from ancient group hunting to voluntary adoption of public health measures. In light of our results in which bottom-up approaches are clearly favored by evolution and self-organization, the widely-repeated motto “Think globally but act locally” would hardly appear more appropriate.

## References

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