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Under high stakes and uncertainty the rich should lend the poor a helping hand

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HIGHLIGHTS

- We model the effects of heterogeneity on decisions using a collective-risk dilemma.
- We aim to understand the natural behavior and to infer which strategies are particularly stable in asymmetric collective-risk games.
- Using an evolutionary model with heterogeneity and multiple rounds we analyze contributions and the natural state of these contributions.
- We explore when players contribute the same amount or when the rich players contribute on behalf of the poor.
- Under a certain degree of uncertainty we observe the rich maintain cooperation by assisting the poor.

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ABSTRACT

In social dilemmas, there is tension between individual incentives to optimize personal gain versus social benefits. An additional cause of conflict in such social dilemmas is heterogeneity. Cultural differences or financial inequity often interfere with decision making when a diverse group of individuals interact. We address these issues in situations where individuals are either rich or poor. Often, it is unclear how rich and poor individuals should interact – should the poor invest the same as the rich, or should the rich assist the poor? Which distribution of efforts can be considered as fair? To address the effects of heterogeneity on decisions, we model a collective-risk dilemma where players collectively have to invest more than a certain threshold, with heterogeneity and multiple rounds. We aim to understand the natural behavior and to infer which strategies are particularly stable in such asymmetric collective-risk games. Large scale individual based simulations show that when the poor players have half of the wealth the rich players posses, the poor contribute only when early contributions are made by the rich players. The rich contribute on behalf of the poor only when their own external assets are worth protecting. Under a certain degree of uncertainty we observe the rich maintain cooperation by assisting the poor.

1. Introduction

Social dilemmas arise when it is costly for the individual to cooperate, but mutual cooperation is beneficial for the group (Gordon, 1954; Hardin, 1968). A typical assumption in social dilemmas is that all individuals have the same potential to contribute. However, social dilemmas in reality often involve diverse individuals with different power to contribute and different risk preferences. Such differences can alter the way decisions are made (McNamara et al., 2004; McNamara, 2013). This kind of diversity is captured by asymmetric social dilemmas that describe a group in which members possess different levels of wealth (Rapoport, 1988; Rapoport and Suleiman, 1993; Ledyard, 1995; Chan et al., 1999; De Cremer, 2007; Wang et al., 2010; Milinski et al., 2011). Such asymmetric interactions can model the behaviors between two individuals of different social status, large and small firms, local municipalities and federal authorities, or among countries of different economic power. The diversity in wealth between these actors causes additional conflict (Chan et al., 1999; Milinski et al., 2011; Tavoni et al., 2011; Jacquet et al., 2013). Differences in wealth can alter decisions because the diverse incentives cause overall uncertainty (Raihani and Aitken, 2011) and result in the inability to coordinate on a solution. For example, additional difficulties in negotiating targets for reducing global green house gas emissions arise because the costs and effects differ between rich and poor countries. Developing (poor) countries are concerned with short term gains since insufficient time has passed to build up assets. On the other hand, developed (rich) countries can consider long term gains since they have sufficient

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capital earned (Landis and Bernauer, 2012). Additionally there is no guarantee that countries can rely on each other and uncertainty can arise when there is a delay between paying the cost and obtaining the benefit of cooperating (Raihani and Aitken, 2011; Abou Chakra and Traulsen, 2012; Barrett and Dannenberg, 2012; Hilbe et al., 2013).

To address the effects of heterogeneity on decisions, a collective-risk dilemma was used in an experimental study between rich and poor individuals (Milinski et al., 2011). Subjects were provided with two types of endowments, a working account and external assets. The incentive behind these two funds is to mimic real life scenarios, individuals can access and use their working money instantaneously, whereas, their external assets can only be obtained in the future (at the end of the game). Rich subjects were given twice the working and external funds with respect to the poor subjects. Subjects had to collaborate and invest towards a certain target amount into a common pool; they had ten consecutive rounds in which they can invest 0€, 2€, or 4€ from their working endowment. If the group failed to reach the target, they risked losing their external funds with 90% probability, while retaining their remaining working endowment. However, if the group's total contributions met the target, then all group members retained their remaining working endowment and their external endowment (Milinski et al., 2008; Dreber and Nowak, 2008; Milinski et al., 2011; Jacquet et al., in press). Additional conflict arises between these two types of individuals, as rich players have more wealth at stake than poor players, but immediate investments hurt poor individuals more by depleting their already low working funds. Both types of subjects have an incentive to protect their wealth, however should the poor invest the same as the rich, or should the rich help and compensate for the poor?

Although several studies have considered heterogeneity between rich and poor individuals, it is unclear how rich and poor individuals should interact: Milinski et al. (2011) compared homogenous groups to heterogeneous groups and found that, indifferent of the type, subjects' total contributions did not differ between these treatments. Several studies showed that the amount of contributions also depends on the implemented risk functions such as linear, nonlinear, or step-level (Ledyard, 1995; Chan et al., 1999; Levati et al., 2007), intermediate targets (Milinski et al., 2011), or communication (Chan et al., 1999; Tavoni et al., 2011). These multifarious results call for a theoretical analysis to help understand the interactions and strategic behaviors between rich and poor subjects.

Previous theoretical models based on evolutionary game dynamics (Hofbauer and Sigmund, 1998; Nowak et al., 2004; Imhof and Nowak, 2006; Nowak, 2006) in collective-risk dilemmas consider either only homogenous groups (Wang et al., 2009; Greenwood, 2011; Abou Chakra and Traulsen, 2012; Barrett and Dannenberg, 2012; Hilbe et al., 2013) or heterogeneous groups with only a single round (Rapoport, 1988; Rapoport and Suleiman, 1993; Wang et al., 2010; Santos and Pacheco, 2011; Santos et al., 2012; Chen et al., 2012; Vasconcelos et al., 2013). However, by allowing for heterogeneity and several rounds, new behaviors can emerge, since players can influence each other and change their own behavior across the rounds (Erev and Rapoport, 1990; Varian, 1994; Abou Chakra and Traulsen, 2012; Hilbe et al., 2013).

Using an evolutionary model with heterogeneity and multiple rounds we analyze the amount contributed and the natural state of these contributions. For instance, our simulations show how the rich or poor players contribute relative to their endowments and whether the players contribute in early rounds or wait and contribute late. This method allows us to infer which strategies are particularly abundant in such asymmetric collective-risk games. We explore when players contribute the same amount or when the rich players compensate and contribute on behalf of the poor.

2. Model

2.1. Individuals

We define an individual strategy using thresholds τ $(0 \le \tau \le T)$ which determines an individual's decision with respect to the collective investments so far (Γ). That is, for every round r a player's strategy is defined as $(\tau_r; a_r, b_r)$, such that the player contributes an amount a_r if Γ is below the threshold τ, otherwise the player contributes b_r. Additionally, individuals are distinguished based on wealth. Individuals' wealth is determined by the amount available for investments and valuable assets they possess. Rich individuals differ in working endowments W and external endowments E from the poor individuals, we assume that $W_{rich} > W_{poor}$.

2.2. Collective-risk dilemma

We model a collective-risk dilemma played among rich and poor individuals. At the beginning of the game, each player receives two types of endowments, a working endowment W and an external endowment E. We assume an asymmetric evolutionary game played among a heterogeneous group of M individuals, half of which are poor players and half of which are rich players selected at random from two mixed populations, a poor one and a rich one. In this game, the external endowment, but not the working endowment, is at stake if the collective target T is not met. Players invest from their working endowment into a common pool, over the course of R rounds. A player i contributes I_i^r in round r resulting in total contribution of $C_i = \sum_{r=1}^{R} I_i^r$. If the group's contribution, $\Gamma = \sum_{i=1}^{M} C_i$, meets the target by the end of the game, then each player i keeps their external endowment and the retained working endowment, receiving $W_i - C_i + E_i$ as payoff, π. However if the target is missed then all players lose their external endowment with some exogenous probability p and thus obtain the payoff $W_i - C_i$. With probability $1-p$, their external endowment is not lost and they receive $W_i - C_i + E_i$ as payoff, π.

2.3. Evolutionary game dynamics

Due to the complexity of the game, we perform individual based simulations instead of working with the replicator dynamics (Taylor and Jonker, 1978; Hofbauer et al., 1979; Zeeman, 1980; Hofbauer and Sigmund, 1998; Nowak, 2006). An asymmetric collective-risk dilemma is played among all individuals chosen from a heterogenous populations. The average payoffs per game (π, average retained endowment) of each player are computed after playing G games in one generation. At the end of a generation, the payoff π_i is translated into a fitness $f_i = \exp[\beta\pi_i]$, where β measures the intensity of selection (Traulsen et al., 2008). The next generation is selected in proportion to the fitness using the Wright–Fisher process (Hartl and Clark, 2007; Imhof and Nowak, 2006; Traulsen et al., 2006). To avoid that strategies that are only beneficial to rich players are adopted by poor players (and vice versa), we assume two different subpopulations, a rich and a poor one. In both of these subpopulations, players are selected in proportion to others of the same wealth type: Rich players compete for the next generation with other rich players. Poor players compete with other poor players. Thus, for each of the two populations there is a separate Wright–Fisher process such that number of rich or poor players remain constant.

Individuals use a single strategy; an offspring inherits the strategy of the selected parent, subject to mutations. We assume