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Prospect dynamics and loss dominance

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ABSTRACT

This paper investigates the role of loss-aversion in affecting the long-run equilibria of stochastic evolutionary dynamics. We consider a finite population of loss-averse agents who are repeatedly and randomly matched to play a symmetric two-player normal form game. When an agent revises her strategy, she compares the payoff from each strategy to a reference point. Under the resulting dynamics, called *prospect dynamics*, risk-dominance is no longer sufficient to guarantee stochastic stability in 2×2 coordination games. We propose a stronger concept, *loss-dominance*: a strategy is loss-dominant if it is risk-dominant and a maximin strategy. In 2×2 coordination games, the state where all agents play the loss-dominant strategy is uniquely stochastically stable under prospect dynamics for any degree of loss-aversion and all types of reference points. For symmetric two-player normal form games, a generalized concept, *generalized loss-dominance*, gives a sufficient condition for stochastic stability under prospect dynamics.

1. Introduction

Loss-aversion captures the tendency of people being more sensitive to losses than to gains. It is a type of reference-dependent preference which describes a person's assessment of choices by comparing the corresponding outcomes to a reference point. Pioneered by Kahneman and Tversky (1979)'s seminal work on prospect theory, loss-aversion has been widely accepted as a common psychological departure from standard expected utility theory that can affect individual decisions. For example, Kőszegi and Rabin (2006) applied loss-aversion to explain some well-known phenomena in individual consumption behavior and daily labor supply decisions.[1]

However, little is known about how and to what extent loss-aversion affects the long-run behavior of people in society. Answering this question would enable us to better understand societal phenomena such as the emergence of social conventions, norms and traditions. In this paper, we attempt to answer this question via an evolutionary approach. We employ stochastic stability analysis as the main analytical tool for two reasons. 1) It offers models to examine the long-run equilibrium of games played by boundedly rational agents. Hence, it is natural to incorporate psychological biases such as loss aversion into evolutionary models. 2) It often gives sharp equilibrium selection results when there are multiple Nash equilibria. We compare the long-run equilibrium for settings where the value of a strategy equals the probability-weighted

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[1] See also Thaler (1980), Knetsch and Sinden (1984), Samuelson and Zeckhauser (1988), among many others.

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average of its outcomes with the long-run equilibrium for settings where the value of a strategy is affected by loss aversion. This allows us to examine whether the predictions coincide or differ under the two theories, expected utility theory and prospect theory.

We consider a finite population of loss-averse agents who are recurrently and randomly matched to play a symmetric two-player normal form game.[2] In each discrete-time period, one agent is given an opportunity to revise her strategy. When an agent receives a revision opportunity, she compares the payoff of each strategy to her reference point and switches to the one with the highest value (with probability close to one). We call the evolutionary dynamics generated by such loss-averse agents the *prospect dynamics*.

We analyze stochastic stability of the population states under prospect dynamics. To make a more relevant comparison to the extant literature, we mainly focus on 2×2 coordination games and characterize long-run equilibria of the games. Our results provide a new insight to evolutionary equilibrium selection in coordination games. Kandori et al. (1993) and Young (1993) showed that a risk-dominant equilibrium is uniquely selected in a population of agents who do not have loss-averse preferences. In contrast to those studies, we find that risk-dominance is no longer sufficient to guarantee stochastic stability under prospect dynamics. Moreover, even if an equilibrium is both payoff-dominant and risk-dominant, it may not be always selected in the long run. Therefore, we propose a stronger concept, *loss-dominance*: a strategy is loss-dominant if it is both the risk-dominant strategy (Harsanyi and Selten, 1988) and the maximin strategy (von Neumann and Morgenstern, 1944). The strategy is less risky and is associated with the largest payoff in the worst case scenario. This concept captures the tendency of people to avoid not only risks but also losses. Our main result, Theorem 3.2, shows that the state in which all agents play a loss-dominant strategy is uniquely stochastically stable under prospect dynamics for any degree of loss-aversion and for any type of reference points.

The assumption of the 2×2 coordination game is relaxed in Section 4, where we generalize the concept of loss-dominance for symmetric two-player normal form games. A strategy is a *generalized loss-dominant* strategy if it is half-dominant and a *globally pairwise maximin* strategy, an extension of the notion of maximin. This new concept captures the essence of the concept of loss-dominance. Our second main result (Theorem 4.4) shows that, in a class of symmetric two-player normal form games, the generalized loss-dominance guarantees stochastic stability under prospect dynamics for any degree of loss-aversion and for any type of reference points.

We then consider two models with endogenous reference points that naturally arise in a game theoretical context: The first model is called the social comparison model. Pioneered by the research of Festinger (1954), social psychologists have found that social comparison often serves as a driving force in determining a person's beliefs and decisions.[3] More specifically, people derive extra utility when they believe that they are doing better than other individuals, while they incur disutility when they believe that they are falling behind others. In this context, the social average payoff can serve as a natural reference point for an agent to evaluate whether each possible outcome she would get is a success or a failure comparing to the other agents.

The second model is called the status-quo bias model. Status-quo bias is one of the most well-studied psychological biases (Samuelson and Zeckhauser, 1988), and it may appear in a variety of decision-making situations. For example, it offers an explanation for the endowment effect found by Thaler (1980). Experimental studies have shown that peoples' decisions are biased toward adhering to status-quo choices, and it is as if people were to take the status-quo as a reference point. Hence, this bias can also be modeled by loss aversion (see Kahneman et al., 1991, for example). In a dynamic context, an agent may regard the payoff obtained in the latest game she played as her status-quo, and may use it as her reference point.

Our main result implies that loss-dominance is a sufficient condition for stochastic stability in 2×2 coordination games under these two models. However, necessary conditions differ in the two models. We are interested to which extent they differ. To this end, we investigate games that have no loss-dominant strategy, i.e., the risk-dominant strategy differs from the maximin strategy. For each model, we characterize the precise condition for a state to be stochastically stable for all degrees of loss-aversion. We find that the state in which all agents play the risk-dominant strategy will be stochastically stable if the largest payoff associated with the risk-dominant strategy is larger than a threshold. In other words, the payoff advantage of the strategy in the best case scenario compensates the perceived loss brought by the strategy in the worst case scenario. We call such a strategy the *compensation-attractive* strategy.

Finally, we extend the model to allow agents to have diminishing sensitivity to gains and losses, which is another important element of prospect theory besides loss-aversion. We find that loss-dominance still guarantees stochastic stability as long as agents' degree of diminishing sensitivity to gains/losses is not sufficiently small.

Related studies in the literature on stochastic evolutionary games are Norman (2009) and Sawa (2015), both examined stochastic stability with behavioral biases that are similar to what we consider in this paper. Norman (2009) introduced a switching cost for strategy revisions, which can be viewed as a status-quo bias. Sawa (2015) considered stochastic stability in bargaining games with players obeying prospect theory. Our model differs from these studies in two aspects. First, we do not restrict reference points to one particular type, but provide a general condition that guarantees stochastic stability

[2] We assume that agents are identically loss-averse in most part of the paper. We relax the assumption and consider heterogeneity in the degree of loss-aversion in Section 7.1.

[3] In economics, the ideas of inequality aversion (Fehr and Schmidt, 1999) and status competition (Veblen, 1899; Hopkins and Kornienko, 2009) also capture people's tendency to make comparison with others.