Evolution of behaviors of economic entities with bounded rationality

The assumption of rationality of players is central for classical game theory. It states that all individuals interacting inside the frame of a given game (namely, players) are perfectly aware of their goals and are able to evaluate the utility of all possible strategies as the means to achieve them. As a result of this type of interactions, social institutions and norms are created. In the language of game theory such outcomes are known as Nash equilibria, i.e. solutions of the game where no player has an incentive to unilaterally deviate from them.

Despite the fundamental importance of the concept of Nash equilibrium in game theory, the assumption of full rationality of players, on which it is based, is rarely satisfied in real life situations. As numerous experiments have shown, due to incomplete information people often misjudge the attractiveness of their goals and potential effectiveness of available strategies. Only after several repetitions of the same interaction, individuals involved *learn to* strategize better by observing the results of undertaken actions and comparing them with others' achievements.

Dynamic modeling of such a learning process is the subject of research in both evolutionary and algorithmic game theory. These theories do not assume that players have full information about the rules of a given game, possible strategies or the consequences of their choice. Their behavior changes in subsequent repetitions of the game (interaction) based on a given learning algorithm. As a result we obtain the dynamics of the game, namely a dynamical system representing how the strategies chosen by players evolve in time. Therefore we can model not only long-term behavioral trends, but also the way they arise. Such a dynamic approach to analyzing the actions of boundedly rational players is a common feature of all research streams that make up our project.

In many cases, long-term learning dynamics converge to a single system of players' behavior, i.e. an emerging social convention that is beneficial or at least acceptable for each player. However, as recent research suggests, more complex (and less desirable) long-term behavior might also emerge: periodic oscillations between multiple different solutions, convergence to a suboptimal solution or a complicated dynamics of chaotic changes of players' strategies. Therefore, the first goal of our research will be to analyze when dynamic systems based on widely used learning algorithms (such as FTRL and EWA), as well as revision protocols that are the basis for economic applications of evolutionary game theory, exhibit complex and unpredictable behavior, and then to formulate the conditions guaranteeing convergence to the optimal solution. The results obtained in this direction might be applied to diagnose the situations when natural social interactions potentially give rise to outcomes which are undesirable for all players and the need arises for a careful external mechanism design.

The research direction described above focuses on the analysis of the behavior of boundedly rational players who use a certain fixed learning algorithm to choose an appropriate strategy. However, note that in many real life situations, the decision-making processes of individual players may differ significantly. These differences may result, among others, from heterogeneous ways of learning and comparing achieved results, or different beliefs and willingness to take risks. This observation motivates the second line of our research, which is to construct and analyze (co-)evolutionary models, where heterogeneous players use learning algorithms in the economic environment. We will apply the obtained results to important economic problems like spreading innovations or integration of a group in a population.