Jakub Bielawski
Uniwersytet Ekonomiczny w Krakowie

Unpredictable dynamics in congestion games: memory loss can prevent chaos

We study the dynamics of simple congestion games with two resources where a continuum of agents behaves according to a simplified version of the well known Experience-Weighted Attraction (EWA) algorithm. The dynamics is characterized by two parameters: the (population) intensity of choice $a > 0$ capturing the economic rationality of the total population of agents and a discount factor $\sigma \in [0, 1]$ capturing a type of memory loss where past outcomes matter exponentially less than the recent ones. Finally, our system adds a third parameter $b \in (0, 1)$, which captures the asymmetry of the cost functions of the two resources. This parameter describes the proportion of the agents using the first resource at equilibrium, with $b = 1/2$ capturing a symmetric network.

Within this simple framework, we show a plethora of bifurcation phenomena where behavioral dynamics destabilize from global convergence to equilibrium, to limit cycles or (formally proven) chaos as a function of the parameters a, b and σ. Specifically, we show that for any discount factor σ the system will be destabilized for a sufficiently large intensity of choice a, but dependent on the asymmetry of costs, and its relation to the discount factor, the system will stay predictable or become unpredictable. Although for discount factor $\sigma = 0$ the system with asymmetric cost (i.e., $b \neq 1/2$) will always become chaotic for large enough a, as σ increases the chaotic regime will give place to the attracting periodic orbit of period 2. Therefore, memory loss can simplify game dynamics and make the system predictable. We complement our theoretical analysis with simulations and several bifurcation diagrams that showcase the unyielding complexity of the population dynamics (e.g., attracting periodic orbits of different lengths) even in the simplest possible potential games.