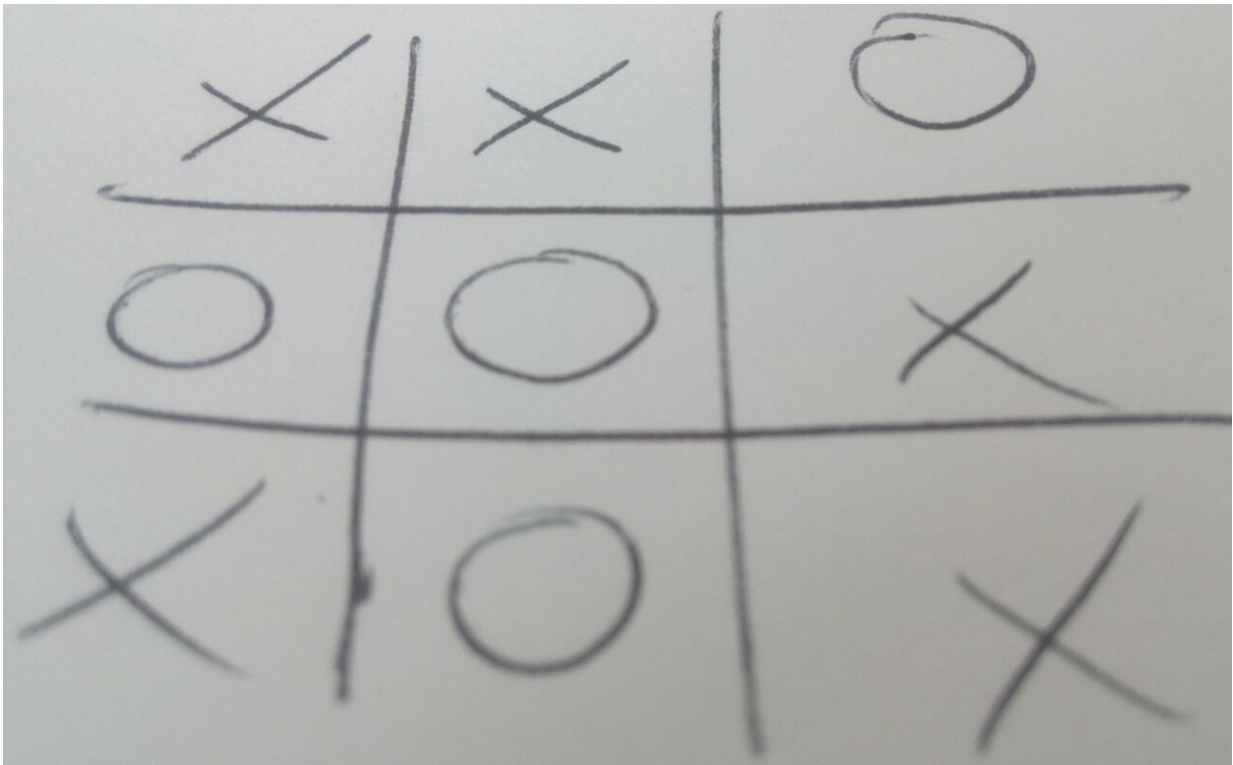


# When does one of the central ideas in economics work?

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Noughts and crosses -- the games people play. Credit: University of Oxford

The concept of equilibrium is one of the most central ideas in economics. It is one of the core assumptions in the vast majority of economic models, including models used by policymakers on issues ranging from monetary policy to climate change, trade policy and the

minimum wage. But is it a good assumption? In a forthcoming *Science Advances* paper, Marco Pangallo, Torsten Heinrich and Dooyne Farmer investigate this question in the simple framework of games, and show that when the game gets complicated this assumption is problematic. If these results carry over from games to economics, this raises deep questions about when economics models are useful to understand the real world.

Kids love to play tic-tac-toe, but when they are about 8 years old they learn that there is a strategy for the second player that always results in a draw. This strategy is what is called an [equilibrium](#) in economics. If all the players in the game are rational they will play an equilibrium strategy. In economics, the word rational means that the player can evaluate every possible move and explore its consequences to their endpoint and choose the best move. Once kids are old enough to discover the equilibrium of tic-tac-toe they quit playing because the same thing always happens and the game is really boring. One way to view this is that, for the purposes of understanding how children play tic-tac-toe, rationality is a good behavioral model for eight year olds but not for six year olds.

In a more complicated game like chess, rationality is never a good behavioral model. The problem is that chess is a much harder game, hard enough that no one can analyze all the possibilities, and the usefulness of the concept of equilibrium breaks down. In chess no one is smart enough to discover the equilibrium, and so the game never gets boring. This illustrates that whether or not rationality is a sensible model of the behavior of real people depends on the problem they have to solve. If the problem is simple, it is a good behavioral model, but if the problem is hard, it may break down.

Theories in economics nearly universally assume equilibrium from the outset. But is this always a reasonable thing to do? To get insight into this

question, Pangallo and collaborators study when equilibrium is a good assumption in games. They don't just study games like tic-tac-toe or chess, but rather they study all possible games of a certain type (called normal form games). They literally make up games at random and have two simulated players play them to see what happens. The simulated players use strategies that do a good job of describing what real people do in psychology experiments. These strategies are simple rules of thumb, like doing what has worked well in the past or picking the move that is most likely to beat the opponents recent moves.

Pangallo and his colleagues demonstrate that the intuition about tic-tac-toe vs. chess holds up in general, but with a new twist. When the game is simple enough, rationality is a good behavioral model: players easily find the equilibrium strategy and play it. When the game is more complicated, whether or not the strategies will converge to equilibrium depends on whether or not the game is competitive. If the incentives of the players are lined up they are likely to find the equilibrium [strategy](#), even if the game is complicated. But when the incentives of the players are not lined up and the game gets complicated, they are unlikely to find the equilibrium. When this happens their strategies always keep changing in time, usually chaotically, and they never settle down to the equilibrium. In these cases equilibrium is a poor behavioral model.

A key insight from the paper is that cycles in the logical structure of the game influence the convergence to equilibrium. The authors analyze what happens when both players are myopic, and play their best response to the last move of the other player. In some cases this results in convergence to equilibrium, where the two players settle on their best move and play it again and again forever. However, in other cases the sequence of moves never settles down and instead follows a best reply cycle, in which the players' moves keep changing but periodically repeat - like "ground hog day" over and over again. When a game has best reply cycles convergence to equilibrium becomes less likely. Using this result

the authors are able to derive quantitative formulas for when the players of the game will converge to equilibrium and when they won't, and show explicitly that in complicated and competitive games cycles are prevalent and convergence to equilibrium is unlikely. Many of the problems encountered by [economic](#) actors are too complicated to model easily using a normal form game. Nonetheless, this work suggests a potentially serious problem. Many situations in economics are complicated and competitive. This raises the possibility that many important theories in economics may be wrong: If the key behavioral assumption of equilibrium is wrong, then the predictions of the [model](#) are likely wrong too. In this case new approaches are required that explicitly simulate the behavior of the players and take into account the fact that real people are not good at solving complicated problems.

**More information:** "Best reply structure and equilibrium convergence in generic games" *Science Advances* (2019).  
[advances.sciencemag.org/content/5/2/eaat1328](https://advances.sciencemag.org/content/5/2/eaat1328)

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