

World Cup Game Theory

What economics tells us about penalty kicks.

By [Tim Harford](#)

Source: http://www.slate.com/articles/arts/the_undercover_economist/2006/06/world_cup_game_theory.2.html

Now the [World Cup](#) starts in earnest. The mini-leagues of the group stage are over, and the first knockout match takes place today between Germany and Sweden. Soccer being a famously low-scoring game, such matches often finish in a draw and must be decided by penalty shootouts—a competitive form at which my own team, England, has a particularly harrowing record. Perhaps England's players should study a little more economics.

In soccer, penalty kicks pit the goalkeeper against a lone striker in a mentally demanding contest. Once the penalty-taker strikes the ball, it takes 0.3 seconds to hit the back of the net—unless the goalkeeper can somehow get his body in the way. That is simply not enough time for the keeper to pick out the trajectory of the ball and intercept it. He must guess where the striker will shoot and move just as the ball is being struck. A keeper who does not guess correctly has no chance.

Both striker and keeper must make subtle decisions. Let's say a right-footed striker always shoots to the right. The keeper will always anticipate the shot and the striker would be better off occasionally shooting to the left—because even with a weaker shot it is best to shoot where the goalie isn't. In contrast, if the striker chooses a side by tossing a coin, the keeper will always dive to the striker's left: Since he can't guess where the ball will go, best to go where the shot will be weak if it does come. But then the striker should start favoring his stronger side again.

So, what to do? The answer comes from a wartime collaboration between economist Oskar Morgenstern and mathematician John von Neumann. They produced a "[theory of games](#)," which mathematically analyzed situations of strategic interaction—that is, any situation where participants have to take into account the other side's responses. A free throw in basketball is not a strategic interaction, but a soccer penalty is. A "game" is a mathematical description of how all the possible payoffs to the different players vary with their different strategies—so if the goalkeeper jumps to his left while the striker shoots to the keeper's right, the striker will get a high payoff and the goalkeeper will get a low one.

Von Neumann and Morgenstern did not, in fact, analyze penalties, although von Neumann did produce a [simple analysis of poker that still influences that game today](#). But rather than aiming to help footballers or gamblers, von Neumann and Morgenstern believed that game theory could illuminate anything from pay negotiations to waging war. The strategic question could be translated into game theory's mathematical language, solved like any old mathematical problem, and then translated back into the real world to explain what to do.

The trouble is that for these real applications, the wrinkles of reality always obscure whether ordinary people actually follow the strategies that game theory predicts they should. Yet penalty taking is different. The objective is simple, the variables easy to observe, and the results immediate.

Game theory, applied to the problem of penalties, says that if the striker and the keeper are behaving optimally, neither will have a predictable strategy. The striker might favor his stronger side, of course, but that does not mean that there will be a pattern to the bias.

The striker might shoot to the right two times out of three, but we cannot then conclude that it will have to be to the left next time.

Game theory also says that each choice of shot should be equally likely to succeed, weighing up the advantage of shooting to the stronger side against the disadvantage of being too predictable. If shots to the right score three-quarters of the time and shots to the left score half the time, you should be shooting to the right more often. But as you do, the goalkeeper will respond: Shots to the right will become less successful and those to the left more successful. It might sound strange that at this point any choice will do, but it is analogous to saying that if you are at the summit of the mountain, no direction is up.

Ignacio Palacios-Huerta, an economist at Brown University, found that individual strikers and keepers were, in fact, master strategists. Out of 42 top players whom Palacios-Huerta studied, only three departed from game theory's recommendations—in retrospect, they succeeded more often on one side than the other and would have been better altering the balance between their strategies. Professionals such as the French superstar Zinedine Zidane and Italy's goalkeeper Gianluigi Buffon are apparently superb economists: Their strategies are absolutely unpredictable, and, as the theory demands, they are equally successful no matter what they do, indicating that they have found the perfect balance among the different options. These geniuses do not just think with their feet.

The Undercover Economist appears on Saturdays in the Financial Times Magazine.

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