

Game Theory I: Simultaneous-Move Games

When the best choice for one player depends on what the others do, the language of games, and the tool behind most of the rest of this book.

What this chapter covers



13.2–13.4 Foundations

- What a game is
- Dominant strategies & the prisoner's dilemma
- Nash equilibrium



13.5–13.6 More games

- Coordination & multiple equilibria
- Famous games catalog
- Mixed strategies



13.7–13.9 Evidence

- Case: OPEC & cartels
- Empirical: minimax
- Experimental tests

THE BIG IDEA

A strategic situation is one in which your best move depends on what others do. Game theory is the tool for studying them, and it underlies oligopoly, bargaining, and much more.

13.1

Introduction

- OPEC and the quota problem
- Two gas stations matching cuts
- Penalty kicks that match a prediction

Three puzzles, one common thread



OPEC

Produces ~40% of world oil, yet struggles to stop members cheating on quotas.



Gas stations

Two across the street match every price cut, to drivers' gain, their own loss.



Penalty kicks

Pros aim left or right in proportions that closely match a math prediction.

WHAT THEY SHARE

Each is a strategic situation: the best choice for one player depends on what the others do. Most interesting markets lie between competition and monopoly, a few firms whose fortunes depend on one another.

13.2

What Is a Game?

- Players, strategies, payoffs
- The payoff matrix
- Reading a cell

13.2 WHAT IS A GAME?

Every game has three ingredients

1

Players

The decision makers, the people or firms who choose.

2

Strategies

The actions each player can take.

3

Payoffs

What each player earns from every combination of actions.

THE PAYOFF MATRIX

When players choose simultaneously, without seeing the others' choices, we summarize the game in a payoff matrix: rows are one player's strategies, columns the other's, cells the payoffs to each.

Reading a cell

■ Convention

In each cell, the FIRST number is the row player's payoff and the SECOND is the column player's. So a cell reading 3, 1 means the row player earns 3 and the column player earns 1.

THE BEHAVIORAL ASSUMPTION

We assume each player chooses the strategy that maximizes her own payoff, given what she expects the other to do.

13.3

Dominant Strategies and the Prisoner's Dilemma

- A best move no matter what
- The prisoner's dilemma
- Individually rational, collectively worse

13.3 DOMINANT STRATEGIES

A dominant strategy

■ Dominant strategy

A strategy that is best no matter what the other player does. When a player has one, we can predict she will use it, whatever her opponent is up to.

THE CLASSIC CASE

The most famous example is the prisoner's dilemma. Two suspects are questioned separately; each may stay silent or confess. Higher payoffs mean shorter sentences.

13.3 THE PRISONER'S DILEMMA

The prisoner's dilemma

		Suspect 2	
		Silent	Confess
Suspect 1	Silent	3, 3	0, 5
	Confess	5, 0	1, 1

Two suspects. Each may Stay silent or Confess.

Higher is better. Larger numbers = shorter sentences.

The trap. Both confess, though both silent would be better.

Figure 13.1 Each suspect's dominant strategy is to confess, yet both would be better off staying silent.

13.3 THE PRISONER'S DILEMMA

The payoff matrix

Suspect 1 \ Suspect 2	Stay silent	Confess
Stay silent	3, 3	0, 5
Confess	5, 0	1, 1

The prisoner's dilemma. Nash equilibrium (Confess, Confess) is highlighted.

WHY CONFESS DOMINATES

Suspect 1: if 2 stays silent, confessing yields 5 vs. 3; if 2 confesses, confessing yields 1 vs. 0. Either way confessing is better, so it is a dominant strategy. The same holds for Suspect 2.

13.3 THE PRISONER'S DILEMMA

Individually rational, collectively worse

THE TRAGEDY

Both confess and each earns 1, even though both staying silent would have given each 3. Individually rational choices lead to a collectively worse outcome.

- This single structure explains a wide range of behavior.
- Arms races, overfishing, advertising wars, and the cartel problem of Section 13.7.

SELF-CHECK

Each player can Confess or Stay Silent, and Confess pays more no matter what. The dominant strategy is Confess for both, so both confess, even though both staying silent would leave each better off. The pursuit of individual advantage produces a jointly worse outcome.

13.4

Nash Equilibrium

- Mutual best responses
- A natural resting point
- Finding it: the best-response method

A more general solution concept

■ Nash equilibrium

A combination of strategies in which each player is doing the best she can, given what the other is doing, so no player can gain by changing her strategy alone. A point of mutual best responses.

WHY IT MATTERS

It is a natural resting point: only there does no one regret her choice. Most games have no dominant strategy, so we need this more general idea.

13.4 NASH EQUILIBRIUM

Nash equilibrium in the prisoner's dilemma



(Confess, Confess) IS Nash

Given that the other confesses, each does best to confess too.
No one can gain by deviating alone.



(Silent, Silent) is NOT

It would make both better off, but each is tempted to deviate and confess, so it is not an equilibrium.

A KEY WARNING

A Nash equilibrium need not be the best outcome for the players. This gap between what is individually stable and what is collectively best recurs throughout economics.

13.4.1 THE BEST-RESPONSE METHOD

A reliable recipe for finding Nash equilibria

1

Step 1

Take each player in turn. For every choice the OTHER might make, find this player's best response.

2

Step 2

Mark those best responses in the matrix.

3

Step 3

A cell where BOTH players play a best response, both marks land together, is a Nash equilibrium.

WHAT THE METHOD REVEALS

The method also reveals when a game has MORE THAN ONE equilibrium (the coordination game of 13.5) or NONE in pure strategies (the penalty kick of 13.6, where no cell collects both marks, then we turn to mixed strategies). Practice it until it becomes automatic.

13.5

Coordination Games and Multiple Equilibria

- Players do better when choices align
- Two Nash equilibria
- A catalog of famous games

13.5 COORDINATION GAMES

When players gain by matching

■ Coordination game

Not every game pits players against each other. In a coordination game, players do better when their choices align. Two firms must each adopt one of two incompatible standards, and both gain only if they choose the same one.

Figure 13.2 casts this as a game, the payoffs are on the next slides.

13.5 COORDINATION GAMES

A coordination game

		Firm 2	
		Standard A	Standard B
Firm 1	Standard A	3, 3	0, 0
	Standard B	0, 0	2, 2

Two standards. Each firm picks A or B.

Match to win. Both gain only if they pick the same one.

Two equilibria. (A, A) and (B, B), in each, neither wants to switch alone.

Figure 13.2 Two Nash equilibria: both choose standard A, or both choose standard B.

13.5 COORDINATION GAMES

The payoff matrix: two equilibria

Firm 1 \ Firm 2	Standard A	Standard B
Standard A	3, 3	0, 0
Standard B	0, 0	2, 2

A coordination game. Both (A, A) and (B, B) are Nash equilibria.

WHY THIS MATTERS

Coordination games explain why industries converge on common standards (one plug shape, a dominant file format) and why it is hard to leave an inferior one: no one gains by moving alone. History, expectations, or a focal point may decide which equilibrium is reached.

Four games worth recognizing



Battle of the sexes

A coordination game where the two prefer DIFFERENT equilibria, concert vs. game. Coordinate, but tussle over whose favorite wins.



Chicken

Two drivers speed toward each other, each hoping the other swerves. Rewards committing not to back down, strikes, crises.



Stag hunt

The tension between a safe, low payoff and a rewarding outcome that requires trusting others to cooperate.



Prisoner's dilemma

Individually rational defection ruins a jointly better outcome, cartels, arms races, overfishing.

13.6

Mixed Strategies

- Games with no pure-strategy equilibrium
- Randomizing to avoid being outguessed
- Where mixed strategies appear

When there is no pure-strategy equilibrium

THE PENALTY KICK

Consider a penalty kick: the kicker aims left or right; the keeper dives left or right. The kicker wants to go where the keeper does NOT; the keeper wants to go where the kicker does.

- Whatever the players are doing, one of them always wants to switch.
- So there is no resting point in pure strategies, no cell where both play a best response.

13.6 MIXED STRATEGIES

Matching pennies: the penalty kick

		Goalkeeper	
		Dive left	Dive right
Kicker	Aim left	0, 1	1, 0
	Aim right	1, 0	0, 1

Win = mismatch (kicker). Score when the keeper guesses wrong.

Win = match (keeper). Save when the dive meets the shot.

Always switch. One player always regrets, no pure equilibrium.

Figure 13.3 No pure-strategy equilibrium; each player randomizes between left and right.

13.6 MIXED STRATEGIES

The matching-pennies payoff matrix

Kicker \ Keeper	Dive left	Dive right
Aim left	0, 1	1, 0
Aim right	1, 0	0, 1

A penalty kick (matching pennies). Kicker scores (1) when the keeper guesses wrong.

READ THE MATRIX

No cell is a mutual best response. If both pick the same side, the kicker wants to switch; if they differ, the keeper wants to switch. One player always wants to move, there is no pure-strategy equilibrium.

13.6 MIXED STRATEGIES

The solution: randomize

■ Mixed strategy

Each player randomizes, choosing left or right with carefully chosen probabilities. In this symmetric example, each goes left half the time and right half the time, so neither can be outguessed.

WHERE THEY APPLY

Mixed strategies are how rational players behave when being predictable would be fatal, in sports, poker, military tactics, and pricing tricks meant to keep rivals guessing.

13.6.1 WHERE MIXED STRATEGIES APPEAR

They describe real behavior



Tennis serve

A server who always aimed at the same corner would be returned every time, so good servers randomize.



Tax audits

An authority that audited on a fixed schedule would be gamed, so it audits at random.



Military timing

A force that always attacked at dawn would be ambushed, so it varies its timing.



Firm promotions

Unpredictable sales keep rivals and bargain-hunters guessing.

The common thread

THE PATTERN

Each is a situation where one side wants to be where the other is NOT, server vs. returner, auditor vs. cheater, attacker vs. defender, so any predictable pattern can be exploited.

Game theory predicts not a single action but a probability distribution over actions. Section 13.8 tests this with penalty kicks.

13.7

Case Study: OPEC and the Cartel's Dilemma

The prisoner's dilemma in a barrel of oil.

13.7 CASE STUDY

A cartel faces a prisoner's dilemma

■ Cartel

A group of producers that agree to restrict output and raise prices. It faces a prisoner's dilemma, which is why cartels are so hard to hold together.

OPEC

OPEC, the Organization of the Petroleum Exporting Countries, produces about 40% of the world's crude oil and sets production quotas meant to keep prices high. Figure 13.4 casts two members' choice as a game.

13.7 CASE STUDY

The cartel game

		Member 2	
		Limit	Overproduce
Member 1	Limit	10, 10	4, 14
	Overproduce	14, 4	6, 6

All limit output. Prices stay high; all earn 10.

Each is tempted. At the high price, extra barrels are very profitable.

Both overproduce. Prices fall; all earn just 6.

Figure 13.4 Limiting output keeps prices high, but each member's dominant strategy is to overproduce.

The cartel payoff matrix

Member 1 \ Member 2	Limit output	Overproduce
Limit output	10, 10	4, 14
Overproduce	14, 4	6, 6

The cartel game. Overproduce is a dominant strategy; the Nash equilibrium is (Overproduce, Overproduce).

THE DILEMMA

Overproducing pays whether the others limit output or not, a dominant strategy. So the Nash equilibrium has everyone overproducing, prices falling, and all earning less (6 each) than if they had cooperated (10 each).

13.7 CASE STUDY

OPEC in practice

- Members regularly exceed their quotas, one was alleged to pump hundreds of thousands of barrels a day over its limit.
- Disputes over quotas have led members to leave the group entirely.
- The cartel's central problem is not setting the right quota but stopping members from cheating on it.

THE LESSON

The prisoner's dilemma in a barrel of oil, individually rational cheating undermines the collectively profitable agreement.

Turning the dilemma against cartels

■ Leniency program

Offers the FIRST cartel member to come forward full immunity from fines, while those who stay silent face heavy penalties if the cartel is later exposed. Regulators fight cartels by sharpening the dilemma.

THE REASONING

Each firm reasons: if my partner confesses first, I pay the full fine, so I had better confess too; and even if my partner stays silent, confessing now lets me escape any future penalty.

13.7.1 LENIENCY PROGRAMS

Confessing becomes dominant

		Firm 2	
		Stay silent	Confess
Firm 1	Stay silent	10, 10	-8, 12
	Confess	12, -8	4, 4

Race to confess. Only the first to talk goes free.

Mutual silence breaks. The cartel depended on it, now it unravels.

Engineered defection. The regulator builds a stronger temptation to defect.

Figure 13.5 A leniency program makes confessing to the regulator a dominant strategy, so the cartel collapses.

Among the most effective tools against cartels



United States

DOJ Corporate Leniency Program, strengthened in 1993, grants the first confessor complete immunity from criminal prosecution.



European Union & beyond

The EU adopted a similar policy; dozens of countries have followed. All are deliberate applications of this game theory.

Leniency in the Real World

South Africa, mid-2000s: four of the country's largest bread and wheat flour producers (Premier, Tiger Brands, Foodcorp, Pioneer) secretly agreed to raise a loaf by 30 to 35 cents. Premier broke ranks, confessed under leniency, and won immunity. Tiger Brands was fined about 99 million rand and Pioneer about 195 million rand for the bread case, with further penalties in the related wheat flour proceedings.

13.8

Empirical Evidence: Professionals Play Minimax

A sharp, testable prediction, tested in high-stakes sport.

Do professionals really randomize?

THE PREDICTION

Mixed strategies make a sharp prediction: skilled players should randomize in specific proportions, and an outside observer should not be able to predict their next move.

- Palacios-Huerta (2003), “Professionals Play Minimax,” analyzed 1,417 penalty kicks.
- Theory predicts the exact frequencies for each side, given that players differ in their stronger foot.

1,417
penalty kicks analyzed

$\approx 50/50$
predicted left/right mix, nearly
matched

The data match the theory



Right proportions

Professional kickers and keepers chose left and right in very nearly the predicted proportions.



Serially unpredictable

A player was no more likely to go left after going right than after going left, just as a true mixed strategy requires.

THE TAKEAWAY

Players who spend their careers in these duels, with millions at stake, behave almost exactly as game theory says, even if they have never heard of Nash. It is among the cleanest confirmations that the theory captures real strategic behavior.

13.9

A Look at the Experimental Evidence

Do people play as the theory predicts?

Games are among the most-tested ideas in economics

Study	Game	Theory's prediction	Experimental finding
Güth, Schmittberger & Schwarze (1982)	Ultimatum bargaining	Offer the smallest amount; responder accepts anything positive	Modal offer near half; offers below ~20% rejected about half the time
Many studies	One-shot prisoner's dilemma	Both players defect	A substantial minority cooperate, especially in early rounds
Palacios-Huerta (2003)	Penalty kicks (mixed strategy)	Randomize in specific proportions	Professionals mix almost exactly as predicted, and unpredictably

Table 13.1 Experimental tests of game-theoretic predictions.

A consistent picture, with limits



Theory predicts well

People recognize dominant strategies, settle on Nash equilibria in simple games, and randomize when being predictable would be fatal.



But fairness intrudes

They lean toward fairness and cooperation more than pure self-interest implies, rejecting unfair offers, cooperating in dilemmas.

BEHAVIORAL GAME THEORY

These are the social preferences first met in Chapter 5. This is why behavioral game theory now sits alongside the classical model: one predicts how perfectly rational players WOULD behave, the other describes how real people actually do.

Key takeaways

1

What a game is

Players, strategies, and payoffs, summarized in a payoff matrix.

2

Dominant strategy

Best no matter what the other does, drives the prisoner's dilemma.

3

Prisoner's dilemma

Individually rational choices yield a collectively worse outcome.

4

Nash equilibrium

Mutual best responses; find it with the best-response method.

5

More games

Coordination (multiple equilibria) and matching pennies (mixed strategies).

6

Evidence

OPEC's cartel, leniency programs, minimax in penalty kicks, and lab tests.