Lecture 21: Strategic Interaction and Game Theory

Office Hours This Friday: 11-12 only, not 10-11.
An additional hour will be added for Friday afternoon and announced online.

Reminders: Graded Homework due Monday at 7pm. No lectures, discussion sections or office hours next week.

Strategic Interaction

- In perfectly competitive markets (like the market for corn), firms do not compete with other firms on an individual basis.
  - If Farmer Jane grows corn, she couldn't care less about what Farmer Jones is doing.
  - Farmer Jane looks up the price of corn in the newspaper or online,…
  - and she bases her business strategy on the price.
  - Farmer Jane does ***NOT*** ***interact strategically*** with her competitors.

- Monopolies, too, have no ***strategic interaction*** with competitors (unless there are potential entrants, they have no competitors ☺).
- But suppose two fancy hotels are located across the street from one another (a duopoly).
  - The owner of each hotel will be concerned about the ***pricing*** strategy of the other owner,…
  - and about the other's business strategy in general.
  - Each owner will base her own business strategy…
  - …on her beliefs about the strategy of her competitor.
  - This is an example of ***strategic interaction***.

- Strategic interaction is very important when a small number of people or firms engage in ***bargaining***, ***conflict*** or ***competition***.
  - Duopoly (two competing firms)
  - Oligopoly (several competing firms)
  - Contracts
  - Legal Disputes
  - Political campaigns

Clicker Question

Game Theory

- ***Game Theory*** refers to a set of mathematical tools used to analyze strategic interaction.
  - Game theory is often applied in economics, political science, and military science,…
  - but game theory is ***not*** commonly applied to ordinary games like chess or tennis.
- In game theory,
  - ***players*** (decision makers)…
  - adopt ***strategies*** (complete plans of action)…
  - and receive ***payoffs*** (rewards or punishments), which depend on the strategies of all of the players.
- There must be at least two players in a game, but games with any number of players can be analyzed.

Strategies

- A ***strategy*** is a **complete plan** that describes the ***action*** a player will take ***in every circumstance*** that she can observe.
  - Sometimes, a strategy will involve only one action:

    ("I'll ask my boss for a raise [salary increase].")
  - But some strategies are complex plans that involve many possible actions *(e.g. military strategies)*.

Coordination in Business

- Sometimes firms can increase profits by coordinating their strategies.
- **Example:** If a men's clothing shop and a women's clothing shop locate in the same mall, both may attract more customers.

- There are many other examples where firms can increase profits by coordinating.
  - One firm supplies inputs to another firm ***precisely when they are needed***.
  - All firms in a shopping center stay open during the ***same hours***. [Why?]
  - All car thieves steal cars on the ***same day***, so that police are spread thin.

Battle of the Sexes

- The ***Battle of the Sexes*** is a game-theory model of coordination in business (or in personal relationships).
- To keep the game simple, only two players are modeled.
- Vanesa wants to go to a football match ***F***, but Miguel wants to go to the opera ***R***.
- If they both do ***F***, then Vanesa gets payoff ***2*** , and Miguel gets ***1***,
- and if they both do ***R***, then Vanesa gets ***1*** and Miguel gets ***2***.
- But if they do different things, then both get **0**.
- Each must buy his/her ticket without knowing what the other is doing. *[Miguel forgot to charge his cell phone.]*

Vanesa \ Miguel	F	R
F	2, 1	0, 0
R	0, 0	1, 2

Game-Theory Terminology

- Vanesa and Miguel are ***players.***
- ***F*** and ***R*** are ***strategies.***
- ***{F, R}*** is the ***strategy space*** (the set of allowable strategies).
- ***2, 1*** and ***0*** are payoffs.

		Miguel	
		F	***R***
Vanesa	***F***	1 2	0 0
	R	0 0	2 1

- Each cell in the table corresponds to a ***strategy profile*** (one strategy for each player), and the contents of the cell are the payoffs corresponding to that profile.
  - For example, the top-right cell represents the strategy profile ⟨***F, R***⟩ (Vanesa chooses ***F***; Miguel chooses ***R***).
  - ***0*** for Vanesa and ***0*** for Miguel are the corresponding payoffs.

- The Battle of the Sexes is modeled as a ***normal-form game***.
  - Each row represents a strategy for one player (Vanesa),…
  - Each column represents a strategy for the other player (Miguel).
  - The row player chooses up or down;
  - the column player chooses left or right.

		Miguel	
		F	***R***
Vanesa	***F***	1 2	0 0
	R	0 0	2 1

		Miguel	
		F	***R***
Vanesa	***F***	**2, 1**	**0, 0**
	R	**0, 0**	**1, 2**

- In textbooks, the game is usually illustrated in black and white,…
  - with the first number inside each cell representing the payoff to the row player,
  - and the second to the column player.

Applying Game Theory

- Can we use game theory to predict the outcomes of strategic interaction?
- What strategies should we expect Vanesa and Miguel to adopt in their "battle of the sexes"?
- Unfortunately, game theory has a number of different ***"solution concepts"*** that sometimes predict different outcomes.
- The most commonly used solution concept is the ***Nash equilibrium***, named after the mathematician *John Nash* *[Nobel Prize, 1994]*.
  - Sometimes we call it simply "an equilibrium."

Nash Equilibrium

- A [***Nash***] ***equilibrium*** is a strategy profile in which each player has chosen the strategy that is a ***best response*** to the strategies of the other players.
- Equivalently, in a Nash equilibrium, if all players found out what the others were going to do,…
- …***no*** player would want to ***deviate*** *[change]* from her chosen strategy.
- Does the word "equilibrium" make sense for this this situation? Why?

Equilibrium in the Battle of the Sexes

- Suppose both Vanesa and Miguel decide to go to the football match.
  - Is that an equilibrium?
  - Given that Miguel has chosen ***F***, what happens to Vanesa if she deviates from ***F*** to ***R*** ?
    - Answer: she would get ***0*** instead of ***2***.
    - So ***F*** is Vanesa's best response to Miguel's ***F***.
  - Given that Vanesa has chosen ***F***, what happens to Miguel if he deviates from ***F*** to ***R*** ?
    - Answer: he would get ***0*** instead of ***1***.
    - So ***F*** is Miguel's best response to Vanesa's ***F***.
  - Result: the strategy profile ⟨***F, F*** ⟩ **IS** an equilibrium!
  - Likewise, ⟨***R, R*** ⟩ is an equilibrium.

Vanesa \ Miguel	***F***	***R***
F	2, 1	0, 0
R	0, 0	1, 2

- Suppose Vanesa goes to football and Miguel goes to the opera ⟨***F, R***⟩.
  - Is ⟨***F, R***⟩ an equilibrium?
  - Given that Miguel has chosen ***R***, what happens to Vanesa if she deviates from ***F*** to ***R*** ?
    - Answer: she would get ***1*** instead of ***0***, so she ***would*** deviate.
    - ***F*** is ***not*** Vanesa's best response to Miguel's ***R***.
  - Therefore ⟨***F, R*** ⟩ is not an equilibrium!
  - We do not have to ask if Miguel would also deviate.
- Likewise, ⟨***R, F*** ⟩ is not an equilibrium.

Vanesa \ Miguel	***F***	***R***
F	2, 1	0, 0
R	0, 0	1, 2

- In the “Battle of the Sexes” coordination failure is not an equilibrium!
- Miguel would have to do what Vanesa wants, or *vice versa*.
- Both of these equilibria are called ***pure-strategy*** equilibria, because neither player chooses his strategy randomly.
- There is a ***mixed-strategy*** equilibrium also: Vanesa goes to football with probability ***2/3*** and to the opera with probability ***1/3***. Miguel does the opposite. *[You are not required to know this.]*
  - Extra credit: prove that this is an equilibrium **!**

Clicker Question

The Fiat-Money Game

- Acceptance of fiat money is also a coordination game.
- If ***Ma*** and ***Huang*** both accept dollars ***(A)*** in exchange for goods, then both benefit from voluntary exchange.
- But if ***Ma*** accepts dollars ***(A)*** and ***Huang*** rejects them ***(R)***, then ***Ma*** loses.
  - He sells his goods, but he cannot buy anything with the money he receives.

		Huang	
		A	***R***
Ma	***A***	1 / 1	0 / −1
	R	−1 / 0	0 / 0

- If both ***Ma*** and ***Huang*** reject the dollar, then neither benefits from voluntary exchange, but neither loses anything either.

Clicker Question

Cooperation versus Competition

- Sometimes cooperation is more profitable or productive than competition.
- But cooperation can be hard to maintain.
- If all other firms (or players) are cooperating, it may be profitable for an individual firm to "defect" or cheat.

- **Example:** Coke and Pepsi could each earn more if they could both spend less on advertising.
- **Example:** The U.S. and Russia would both be better off if they could commit to keeping fewer nuclear weapons.

- The game-theory model of cooperation vs. competition is called the "***Prisoners' Dilemma***"

Prisoners' Dilemma

- Thelma and Louise have been caught by the police.
  - Police have evidence to put them behind bars for 5 years each,…
  - but with a confession, the police could get 20-year sentences.
  - So the police offer them the following terms:
    - If only one person confesses, she will get only 2 years in prison, but the other gets 20 years,
    - …but if both confess, each gets 15 year in prison.
- Thelma and Louise each has two possible strategies:
  - Silence (S) *[Try to cooperate with the other player.]*
  - Confession (C) *[Follow narrow self-interest.]*
- Each has to make her choice without knowing what the other will do.

Thelma \ Louise	***S***	***C***
S	Thelma −5, Louise −5	Thelma −20, Louise −2
C	Thelma −2, Louise −20	Thelma −15, Louise −15

Equilibrium in the Prisoners' Dilemma

- Suppose both Thelma and Louise decide to stay silent (**S**).
  - Is that an equilibrium?
  - Given that Louise has chosen ***S***, what happens to Thelma if she deviates from ***S*** to ***C*** ?
  - Therefore, ⟨***S***, ***S*** ⟩ **IS NOT** an equilibrium!
- Is ⟨***C***, ***S*** ⟩ an equilibrium?
  - Louise would get ***−15*** instead of ***−20*** if she deviated to ***C***, so it is NOT.
  - Similarly, ⟨***S***, ***C*** ⟩ is NOT an equilibrium.

Thelma \ Louise	***S***	***C***
S	Thelma −5, Louise −5	Thelma −20, Louise −2
C	Thelma −2, Louise −20	Thelma −15, Louise −15

- Is ⟨***C***, ***C***⟩ an equilibrium?
  - Given that Louise has chosen ***C***, will Thelma prefer to play ***C*** too?
    - Yes, she will lose more from deviating to ***S***
    - So ***C*** is Thelma's best response to Louise's ***C***
  - Given that Thelma has chosen to play ***C***, Louise's best response is to play ***C*** as well.

		Louise	
		S	***C***
Thelma	***S***	Louise −5 / Thelma −5	Louise −2 / Thelma −20
	C	Louise −20 / Thelma −2	Louise −15 / Thelma −15

- ⟨***C***, ***C***⟩ **is** an equilibrium—the ***only*** equilibrium, even though both would be better off ***if they could commit*** to silence ***S***!
- For each player, confession **C** is a ***strictly dominant strategy***—i.e. it is better to play C, no matter what the other person does.
- For each player, **S** is a ***strictly dominated strategy***—i.e. another strategy is better than **S** no matter what the other person may do.

Cooperation and the Prisoners' Dilemma

- The prisoners dilemma illustrates how difficult it is for competing firms to cooperate with each other, even when cooperating is Pareto efficient.
- Whatever they have agreed to, each player can do better by cheating (following narrow self-interest).
- That is why OPEC countries cheat and overproduce.
- That is why firms and political candidates employ negative advertising.
- Too bad (for them) that they cannot make a binding commitment.

Clicker Question

- **Example:** Prisoners Dilemma--OPEC
  - OPEC is an organization of petroleum-producing countries that promise to cooperate.
  - OPEC sets production limits for each member country, which pushes up the petroleum price.
  - But a number of countries cheat and produce more petroleum than OPEC rules allow.
  - Some analysts believe that OPEC is completely ineffective…
  - and the price of petroleum ends up at the competitive price.

End of File