Introduction to Game Theory

General Principles

Dante Yasui

2024

Outline

- Introductions
- What is EC327?
  - Syllabus
  - Schedule & Assignments

Introductions

Welcome to the Class!

About Me:

- **Preferred Name**: Dante
- **Preferred Pronouns**: he, him
- 4th year Econ Phd student
- Davis, CA -> Portland, OR -> Eugene, OR

Introduce Yourselves

IntroQuiz

- Your preferred name, pronouns; to help me get to know you
- Why did you choose this class?
- Song recommendation for class playlist

What is EC327?

Syllabus Document

- Most up to date version on github
- I will also upload to Canvas
- print, sign, and upload as your first assignment

Class Expectations

Prerequisites

- **Courses:** EC201 *or* EC202
- **Knowledge:** This class will require you to use some simple algebra and graphing skills. If you felt uncomfortable with the level of math in EC201, I recommend that you review how to solve simple systems of equations, inequalities, and fractions.
  - There are great free resources out there like Khan Academy, but always feel free to reach out for help or other suggestions.

Student Expectations

- **Come to class**
  - Pay attention to lectures, take notes, review topics at home
  - Participate in group work & activities
  - **Ask questions!**
- **Read the textbook**
- **Communicate respectfully**
  - With your classmates
  - With me & grader
- **Have academic integrity** [1]
  - Verify that all submitted work is your own
  - Provide sources for *all* information that you found outside this class

Instructor Expectations

- **Provide course material**
  - Slides will be updated on github
  - I will also try to post them on Canvas, but not as regularly
  - Assignments posted on Canvas w/ due dates, submission entry
- **Face-to-face Interaction**
  - **Classes**
    - Ask me to clarify if something doesn't make sense
    - Ask me to slow down if I'm going too fast
  - **Office Hours**
    - Use them!!

Admin Stuff

Problem Sets

You will practice what we learn in class on independently.

Each homework assignment will include a few problems that will be similar to what you will see on exams.

- Learning something new takes practice, so these are designed to help you keep up with the concepts
- You will be graded not only on whether you got a certain answer, but also more importantly on *how you communicate your understanding*
  - See Canvas rubric for more info

Class Activities

- Sometimes I will ask you to play the types of games we discuss in lectures
  - Record the strategies you chose and the outcomes
  - Reflect on how you played the game
  - Relate it to lecture concepts

Exams

You will demonstrate how well you understand concepts individually on a **midterm** and a **final** exam

- **Midterm**
  - sometime around week 5 (Oct. 28th or 30th)
  - Will test you on definitions, solution concepts, and apply them to critical thinking problems
- **Final**
  - finals week of December 9 (check duckweb for specific date)
  - Covers everything we learned in the quarter, with more focus on concepts from the 2nd half

Grading

Problem Sets	30%
In-class Activities	10%
Midterm	30%
Final	30%

Policies

- **No make-up exams!**
  - if you absolutely cannot attend midterm, you can add its weight to final exam
- Problem set keys posted automatically after deadline
  - -> no late submissions accepted

Campus Resources

- **Accessible Education Center**
  - aec.uoregon.edu
- **Support for vicitms of assault, harassment, stalking**
  - safe.uoregon.edu
  - 24/7 hotline: (+1) 541-346-SAFE (7244)
- **Health and Wellbeing**
  - University Counseling Services
  - Basic Needs Program
- **Religious Observance Accomadations**
  - Provost website

Course Pages

https://canvas.uoregon.edu/courses/251353 - submit your assignments - check deadlines

github.com/dyasui/EC327 - Find up-to-date versions of slides/assignments - *let me know if links are broken*

What is Game Theory?

Motivation

What is the goal of **Game Theory**?

> To understand social behavior

Why do economists study Game Theory?

> We are *social* scientists

> To make models, predictions, hypotheses, etc. on which to base our research

Motivation

Why should **you** study game theory?

> Practice your strategic decision-making in a safe environment

> Develop your intuition for social interactions in a systematic way

> Feed your curiosity for economics, social science, or philosophical questions!

What is theory?

What is the point of *theory*?

> **Simplify complex systems** - understanding one part at a time is easier than trying to

> **Generate *falsifiable* hypotheses** - good econometrics is informed by good theory

Theory in a data-driven world?

> "The theory of economics does not furnish a body of settled conclusions immediately applicable to policy. It is a method rather than a doctrine, an apparatus of the mind, a technique of thinking which helps its possessor to draw correct conclusions." — Keynes

What are the limits to theory?

- Our models will never be perfect representations of reality
- But we should know how well they *approximate* the parts of the world we want to understand
- Theory is very useful for generating *falsifiable hypotheses*, which we can then use to guide experimental or statistical tests
- As we play games in class, we will observe the data and compare to our theoretical predictions

What is a *game* of strategy?

> Game theory: It's not all fun and games!

Examples of *strategic games*:

Where in the goal should you kick a penaly shot?

Examples of *strategic games*:

Where in the goal should you kick a penaly shot?

- Left, Right, Center? Up or Down?
- Is there one best place to kick?
- What if you always choose top right corner?
- Besides soccer;
  - Which offensive play in football?
  - Where to serve in a tennis court?

Examples of *strategic games*:

If 100% of your grade in this class is decided by a *curve*, how much should you study?

- If you can all agree to take a chill quarter and not study, you could all get A's
- But what if there's at least one try-hard?
- Now how much should you study, even if you already promised you wouldn't?
- Do you think everyone else will keep their promise?

Examples of *strategic games*:

Should you give an engagement ring to the person you want to marry?

- Why buy an expensive trinket when you could save the money for a house, etc?
- Does it matter if your recently engaged friends gave (or received) engagement rings?
- Does your paycheck vs. how much your fiancee makes matter?

Examples of *strategic games*:

In economics, why do we say there is a ***law of one price***?

> Imagine I set up a competing Starbucks franchise in the EMU

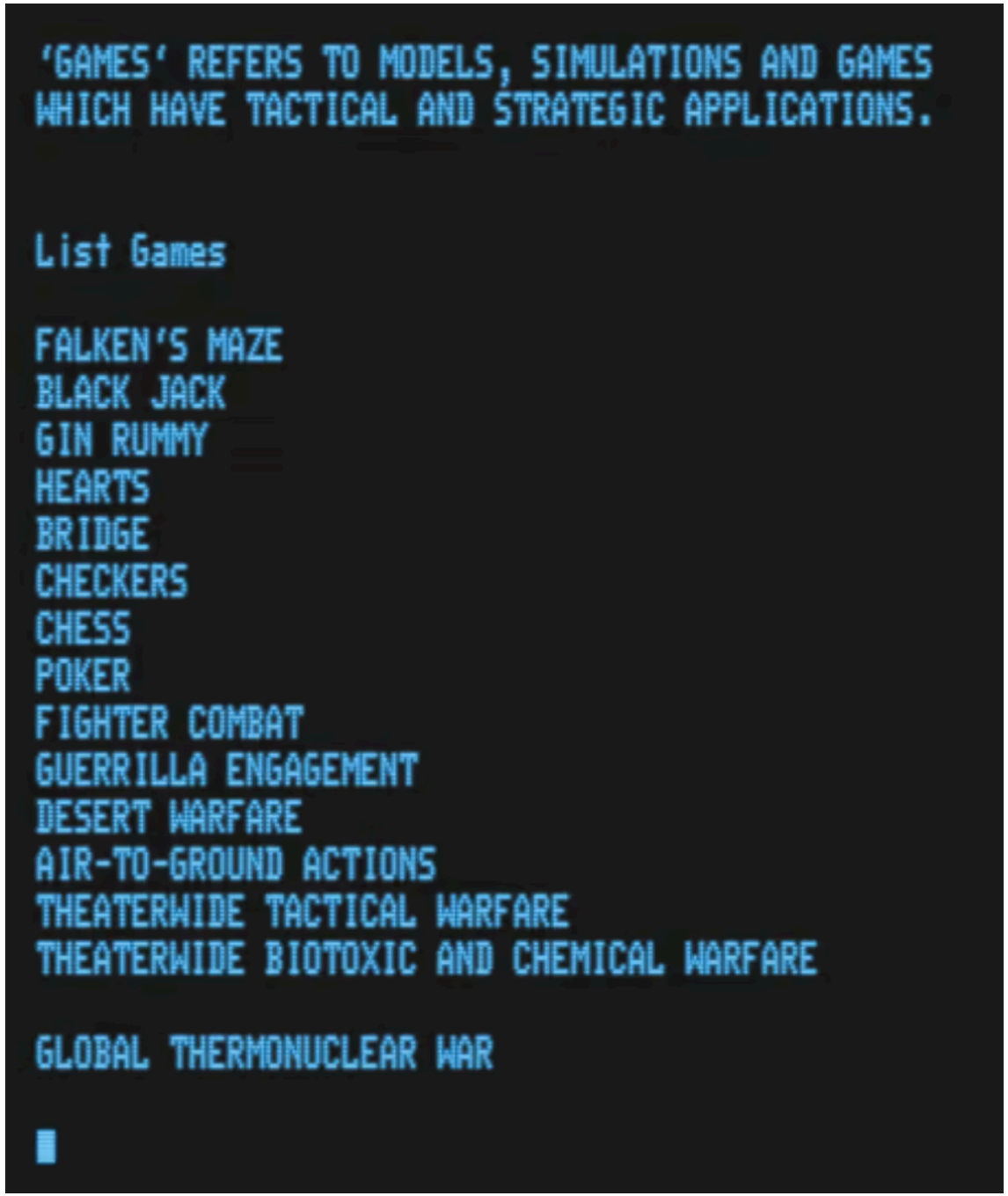
- If they sell PSL for $6.50, what happens if I sell them for $6.49?
- What if I sell for $6.51?

This has been your EC201 review!

Examples of *strategic games*:

Should the US try to defeat its rivals through `global thermonuclear war`?

- Why did the US and USSR amass massive nuclear stockpiles?
- Why has a nuclear weapon never been used in anger since Nagasaki?
- Are anti-ballistic missiles destabilizing to international relations?


'GAMES' REFERS TO MODELS, SIMULATIONS AND GAMES
WHICH HAVE TACTICAL AND STRATEGIC APPLICATIONS.
List Games
FALKEN'S MAZE
BLACK JACK
GIN RUMMY
HEARTS
BRIDGE
CHECKERS
CHESS
POKER
FIGHTER COMBAT
GUERRILLA ENGAGEMENT
DESERT WARFARE
AIR-TO-GROUND ACTIONS
THEATERWIDE TACTICAL WARFARE
THEATERWIDE BIOTOXIC AND CHEMICAL WARFARE
GLOBAL THERMONUCLEAR WAR

Examples of *strategic games*:

What do these examples have in common?

What is a Game? Definitions

What do all these questions have in common?

- They all involve people making choices which depend on the choices of others
- In other words, they are questions of **strategy**:

> **Strategic interdependence** is present in a social situation when what is best for someone *depends* on what someone else does. [1]

Strategic Choice vs. other types of choices

- Economics is the study of **constrained choice**; in EC311, we introduce the *utility maximization problem* as the workhorse model
  - These types of problems usually only involve one agent; the consumer, who is only constrained by their budget
- We use the term ***strategic games*** to distinguish from these single-agent optimization problems

A ***game*** is a type of problem featuring multiple agents, called **players**,

- in which their optimal choice **depends on the optimal choices of other players**.

A definition of a game [1]

A **Game** consists of:

- a collection of decision-makers, called **players**;
- the set of **information** available to each player;
- the **strategies** available to each player in each information state;
- a mapping from the intersection strategies of all players to outcomes;
- **preferences** of the individual players over all possible outcomes

Who are the players?

What defines a player?

- **Preferences**:

- In economics, we say people have *unlimited* wants and *limited* needs
- Therefore, we have to think about how people *prioritize* what they want more

- **Beliefs**:

What defines a player?

- **Preferences**:
- **Beliefs**:

- My beliefs about the world define how I act
- If I am exposed to new *information* it can potentially change my beliefs, and therefore change my actions
- Information and beliefs of players will define later game theory topics

Preferences

Preferences describe the subjective ranking that we put on different alternatives.

For example, on the set of Eugene boba stores, my preference ranking goes like this;

1. Tea 4 - major chain, good quality and selection
2. Day & Night - they have mango sago, cute location
3. Bobahead - no more campus location 😔
4. No boba
5. Rabbit Hole - no hate, just not for me

Rational Preferences

The **rational model** of choice is the foundation of all economics.

Its assumptions are that:

- People have **complete preferences**
  - for *every* pair of options, you can either tell me which you prefer or that you are *indifferent*
  - for any pair of deserts, { 🍨 , 🍩 }, either (🍨 ≻ 🍩), or (🍩 ≻ 🍨), or (🍨 ∼ 🍩)
- Preferences are **transitive**
  - if (☕ ≻ 🍵) and (🍵 ≻ 🍶), then (☕ ≻ 🍶) (for any { ☕ , 🍵 , 🍶 } ∈ 🫖)

Rationality

One key proposition of rationality is that we can represent preferences by real numbers.

A **utility function** maps a choice to a single number.

For example, let $\mathrm{u}(.)$ be the utility function from emoji to utils

- I can have $\mathrm{u}(🍺) = 5$, $\mathrm{u}(🌯) = 10$, $\mathrm{u}(🦒) = 25$
- I can also have $\mathrm{u}(🍺, 🌯) = 20$, $\mathrm{u}(🍺, 🌯, 🦒) = 15$

Ordinal vs. Cardinal numbers

- **Cardinal:** amounts which can be measured in meaningful units are *cardinal numbers*
  - examples: $9.99, 80 students, 50:50 odds
- **Ordinal:** all that matters is the *relative ranking*
  - examples: utility; what does 100 utility mean? (it's less than 200)

Don’t worry!

- For this class, you won’t need to worry about utility functions (if you want to, take EC311).
- I will almost always give you specific values of utility which we will call **payoffs**.

Payoffs

What is a player's goal in a game?

> To maximize their expected **payoff**

- A payoff can represent many things which come with a specific outcome
- Whenever you see a payoff, assume that it represents everything about that outcome which an agent cares about
- For example, your payoff to giving to charity would include the emotional benefit you feel towards giving to others

Payoffs

What is true of payoffs?

> Higher numbers are more preferred

> They are **Ordinal**; i.e., the relative units don't matter [1]

> They capture *everything* in a game that a player cares about

Payoffs

- Sometimes my enjoyment of a thing depends on the *state* of the world

socially-dependent preferences

My choice	My friends' choice	My payoff
Duck's game	Duck's game	3
Duck's game	Stay home	2
Stay home	Duck's game	1
Stay home	Stay home	2

- Is this an example of a **strategic** or **non-strategic** choice?

Expected Payoffs

Often games involve some amount of *chance*; with random probabilities of each outcome happening

- We need tools for thinking about how people think about **risk**

Expected Payoffs

> In math, an **expected value** is the average value of a *random variable*, weighted by the probability of each value occuring

Expected Payoffs

For example, suppose X is a random variable which is equal to:

- **1** with **50%** probability,
- **2** with **25%** probability,
- **3** with **25%** probability

What is the *expected value* of X? $(\mathrm{E}(\mathrm{X}))$

$$\begin{aligned}\mathrm{E}(\mathrm{X}) &= .5(1) + .25(2) + .25(3) \\ &= .5 + .5 + .75 = 2.75\end{aligned}$$

Expected Payoffs

An **Expected Payoff** is just the *expected value* of possible payoffs

> An average of the payoffs associated with every possible outcome, weighted by the corresponding probability of each outcome happening

Expected Payoffs

Consider the following choice:

Option A:

I flip two coins; - if both land **heads**, you win $100 - otherwise you get $0

Option B:

You just get $25 for sure

Expected Payoffs

- If you choose **Option A**, we call you **risk averse**
- If you choose **Option B**, you are **risk loving**
- If you are *indifferent* between the two options, you would be **risk neutral**

All of these difference preferences can be incorporated in the *rational* model with the right *utility function*

Beliefs

Our theories will have to make assumptions about what players **know**.

All of our games will at least assume that **all players know all of the rules**.

Beliefs

We will assume that all players know[1]:

- Who else is playing,
- all of the strategies each player could *potentially* choose,
- everyone's payoffs for all possible combinations of strategies by all players,
- and that everyone else is maximizing their payoffs

Taxonomy of Games

General Categorical Terms

- **Sequential** or **Simultaneous**?
- **Zero-sum** or not
- **Perfect** or **Imperfect** information?
  - is info **symmetric** or **asymmetric**?
- **One-shot** or **Repeated**?
- '**Noncooperative**' or '**Cooperative**'?

Sequential vs. Simultaneous

Sequential Games

- players make their moves one after the other
- **Chapter** 3
- **Visual tool**: *game trees*
- **Solution Method**: *backwards induction*

Simultaneous Games

- players make their moves at the same time
- **Chapter** 4 & 5
- **Visual tool**: *payoff tables*
- **Solution Method**: *best responses*, deletion of *dominated strats*

Sequential Games

In **sequential** games, you have to think about how what you do ***now*** will affect what your opponent will do in the ***future***.

> This hierarchy of thinking will make these types of games a little easier for us to think through, so they will be our first category of games.

- We'll see that sometimes **moving first** can be adventageous
- While other times it's best to **wait and see** what someone else does

Simultaneous Games

In **simultaneous** games, you have to figure out what to do ***now*** while also thinking about what your opponent is thinking you will will do ***now***.

> This circular thinking can get confusing, so we'll try to develop some new methods for organizing these games in chapter 4.

Conflicting vs. Common Interests?

Many games you are familiar with have distince *winners* and *losers*.

But in other types of games, it's possible for everyone to come out ahead.

Zero-sum (or constant-sum) Games

When the *total payoffs of all players sum to 0* [1]

- i.e, one player's gain is another player's loss
- Examples: NCAA Football Championship, Scramble for Africa (technically *constant*-sum)

. . .

Not all games are fixed or zero sum;

- Examples: Hiring a tutor (mutual gains), International Trade, etc.

Are strategic interactions Repeated?

A **one-shot** game is played only once by the same set of players.

- If you've never played against someone before, you can't form any **beliefs** about them
- Secrecy or surprise are potentially good strategies in these games

A game is called **repeated** if the same players play it with each other many times.

- If you know your opponent, then your **reputation** becomes valuable if you want to cooperate

Full or Equal Information

How much does each player know when they decide?

- **Perfect Information**: when players know all previous moves and external circumstances
  - players may have ***imperfect info***; uncertainty about the state of the world, previous' moves, or other player's 'type'
- **Asymmetric Info**: when one player has access to information that other players do not
  - Examples: hand in poker, used car salesmen
  - Topics: Signaling, Screening

Can agreements be Enforced?

- Self-interest and common good can often conflict.
- In these situations, players need to form agreements in order to achieve cooperative outcomes.

> But can people actually be held to those agreements?

For example:

- Paris Climate accords; who polices nation-state's carbon reductions?
- Public goods; why do we need the Internal Revenue Service?

Can agreements be Enforced?

Two broad categories of the field are **cooperative** game theory and **noncooperative** game theory [1]

> **Cooperative** games are those in which agreements are enforceable

> In **Noncooperative** games, no-one can be forced not to act in their own self-interest

Equilibrium

In each of these different categories of games, we will want to make predictions as to how rational agents will behave

- Our methods of *solving* each type of game will be to look for different types of **equilibria**

Equilibrium

Where every player's strategy is a **best-response** to the other player(s)

Equilibrium

Why study equilibria?

- They are **stable**: if nobody has anything better to do than what they're doing now then why change?
- We can adapt our models to all types of equilibria
  - Market or non-market
  - Dynamic or static

Equilibrium

A few different types of equilibria in this class:

- **Nash equilibrium**
  - **Subgame perfect** NE
  - **Mixed strategy** NE
  - **Bayes-Nash** equilibrium

Tentative Schedule

Week	Chapter(s)	Topic
1	1, 2	Intro & General Principles
2	3	Sequential Move Games
3	4	Simultaneous Move Games
4	6	Combining Sequential and Simultaneous Moves
5	6	Review & **Midterm**
6	5	Simultaneous Games: Continuous Strategies, Discussion, and Evidence
7	7	Mixed Strategies
8	8	Strategic Moves
9	9	Uncertainty and Information
10	10	Repeated Games