Game Theory for Social Scientists
Experimental Game Theory

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The Sessions

Objective

- Ideally I'd like to provide an introduction to the economic literature on game theory, from the early works to the latest working papers. Effectively it will be an introduction to a sub-theme (but an important one) of this literature.
- Equally importantly, it would be great if you learned something methodologically. To this end I will
  - give an introduction to some key models, discuss the modeling techniques, think about the models' limitations.
  - discuss a wide range of experimental approaches.
  - give special emphasis to discussing how to combine the two!

The Sessions
Spirit

- One appeal: The notes almost certainly contain errors. Please let me know!
- Disclaimer: Obviously most ideas in these slides are not mine, and mostly without proper citation.
- One thing: I hope I'll talk at most half the time. Interrupt me at your convenience!

Outline

1. Introduction
   - Historical Example
   - Theories and data?
2. Bargaining
   - The ultimatum bargaining game
   - Modified Dictator game

Introduction – why experimental game theory?

- Behavioural and experimental approaches are fairly new to economics, let us, therefore, briefly look at the development of experimental studies in other disciplines.
- Today physics is an experimental science. This was not always the case. It is easy to understand how economics works when we have a look at other fields and check how they use experimental methods

Introduction – why experimental game theory?

- Behavioural and experimental approaches are fairly new to economics, let us, therefore, briefly look at the development of experimental studies in other disciplines.
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Historical example

Heliocentric vs. geocentric model of the universe

- Problem: determine position on the open sea.

→ Needed: a precise and simple model that explains movements of stars and planets

Different theories:

- Claudius Ptolemy ca. 100-160: geocentric model

Historical example

- Consistency with established theories
  - Chronicles 1,16:30 "... the world also shall be stable, that it be not moved... ".
  - Psalm 104.5: "[LORD,] who laid the foundations of the earth, that it should never be removed."
  - Ecclesiastes 1.5: "The sun also ariseth, and the sun goeth down, and hasteneth to his place where he arose."
- Consistency with observable data:
  - If the Earth actually spun on an axis, why didn't objects fly off the spinning Earth?
  - If the Earth was in motion around the sun, why didn't it leave behind the birds flying in the air?

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Historical example

- Nicolaus Copernicus: 1473-1543
  - Ptolemaic model is too complicated
- Galileo Galilei: 1564-1642
  - Instead of studying stars only with his telescope, Galilei models the mechanics of the planets with the help of a pendulum and inclined planes.
  - The laws of motion in Galilei's lab fit the Copernican Model, but not Ptolemaic system
  - → Galilei as the founder of modern physics

Historical example

Heliocentric model:

- Consistency with observable data (both in- and outside the lab)
- Simplicity

- We find a simple theory that explains behaviour on the inclined plane.
- This theory can be tested extensively in the lab.
- Finally, this theory can be used to explain movements of the planets.

→ Galilei (and Isaac Newton, 1643-1727) as founding father of modern natural sciences.

Historical example

Samuelson and Nordhaus (1985) Principles of Economics, p. 8:

"...One possible way of figuring out economic laws ... is by controlled experiments ... Economists [unfortunately] ... cannot perform the controlled experiments of chemists or biologists because they cannot easily control other important factors. Like astronomers or meteorologists, they generally must be content largely to observe."

Historical example

Blanchard (1997) Macroeconomics:

"...When an engineer wants to find out how the temperature affects material's conductivity, she builds an experiment in which she changes the temperature, makes sure that everything else remains the same, and looks at the change in conductivity. But macroeconomists who want to find out, for example, how changes in the money supply affect aggregate activity cannot perform such controlled experiments; they cannot make the world stop while they ask the central bank to change the money supply"

Historical example

Misunderstanding:

- Physicists do not really move planets in their experiments
- Economic experimenters do not really have to change ...
    - Central bank policy
    - Labour market policy
    - Foreign trade policy ...

  to find out how these policies work...
- Both build a model in a laboratory situation.

Trust

- Model of a bridge in an engineer's lab $\rightarrow$ real bridge!
- Model of the labour market in an economist's lab $\rightarrow$ real labour market?

$\rightarrow$ In both cases model and reality differ. If something works in the lab, it need not work in real life. If something fails in the lab, it might also fail in real life

Historical example

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Historical example

Anyway...

Winners of the Nobel prize who study economic behavioural rationality:

- 1988: Maurice Allais
- 1994: Reinhard Selten
- 1998: Amartya Sen
- 2000: Daniel L. Mc.Fadden
- 2001: George A. Akerlof
- 2002: Daniel Kahneman and Vernon L. Smith
- 2004: Edward C. Prescott
- 2005: Robert J. Aumann and Thomas C. Schelling
- 2009: Elinor Ostrom
- 2012: Alvin E. Roth

Historical example

Experiment: Call Market

Instructions:

- Go to http://veconlab.econ.virginia.edu
- 'Login as Participant'
- select 'Initial Login for All Programs'
- enter session name: tbkc2
- enter your name and password 1234
- follow instructions on the screen.

Historical example

You are **buyer** $\boxed{4}$: At the beginning of the game you do not own any objects. During the game you can buy objects. Objects that you own at the end of the game have a value according to the following table

	Value	Price	Profit
1.	300		
2.	250		
others	0		

You are **seller** $\boxed{4}$. At the beginning of the game you own two objects. During the game you can sell these objects. Objects that you own at the end of the game have a value according to the following table

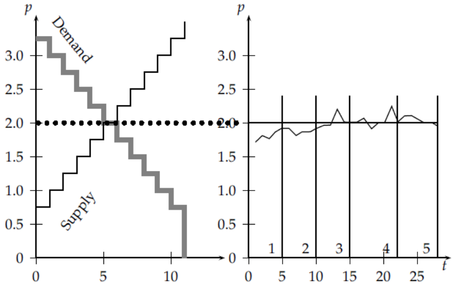
	Value	Price	Profit
1.	150		
2.	100		
others	0		

Historical example

The theory behind this experiment

Market equilibrium with perfect competition

- Edward H. Chamberlin (1948), “An experimental imperfect market”, Journal of Political Economy, 56, p. 95-108.
  46 **decentralised** markets
- Vernon Smith (1962) Journal of Political Economy
  Centralised market, open order book



Historical example

Recap of the classroom experiment

- external validity
- internal validity
  - participants (recruiting, selection)
  - instructions (was the experiment clear to all)
  - running the experiment
  - simple experimental structure
  - "neutral" instructions
  - incentives (salient, monotonic, dominant / hypothetical)
  - anonymity
  - deception / honesty

Historical example

Behavioural/experimental econ → new discipline, since ca. 1950

- How empirical are other sciences?
- Let us compare different ways to test theories.

Testing theories

- Physics: **law of free fall**: $s = 1/2g \cdot t^2$
- Economics: **1st welfare theorem**: Each Walrasian equilibrium is weakly Pareto efficient.

	Physics	**Economics**
abstract concepts	electric/magnetic field, light waves, quarks, ...	preferences, utility functions, equilibria, ...
method	unity of theory and experiment	???
measurement	sharp	noisy → econometrics

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Theories and data?

Field: (OECD, federal bureau of census, . . .)

few independent observations (1 country = 1 observation?)
endogeneous policy
uncontrolled parameters
field experiments are rare

Theory:

many models
conjectures
predictions
policy recommendations

Laboratory:

many observations
long time-series
flexibel modelling
controlled parameters
what-if experiments
replication
but it is not the field

Definition: Theory

Theory

$$\underbrace{\underbrace{\boxed{\begin{array}{l}\text{assumptions}\\ \text{axioms}\\ \text{definitions}\end{array}}}_{\text{Model}} \to \boxed{\begin{array}{l}\text{conclusions}\\ \text{rules of inference}\end{array}}}_{\text{Theory}} \to \boxed{\text{interpretation}}$$

Desirable properties of theories:

1. **Internally correct** (tautology, no mistakes in derivations)
2. **Testable**, informative (we can map elements of the theory to observables in the field)
3. **Simple**, parsimonious (allows understanding the complexity of the field)
4. **Robust** (holds, even if assumptions are not fulfilled)

? **Accurate** (captures a relevant element of the real world (or is this the ratio between "robust" and "simple"?))

Definition: Theory

1. Internal correctness:
   - can we falsify a theory? – no, unless the author made a mistake in his or her derivations.
2. Testability:
   - what does it mean that a theory is “testable in real life”?
   - do we have to duplicate a theory in “real life”? → no: why duplicate a tautology
   - does this mean that a theory needs no relation to “real life”?
3. Simplicity:
   - Why do we want theories to be simple?

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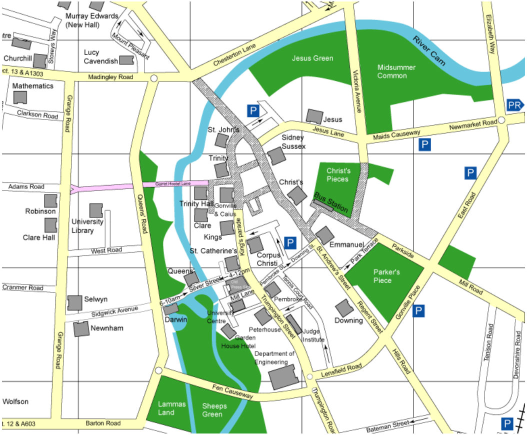
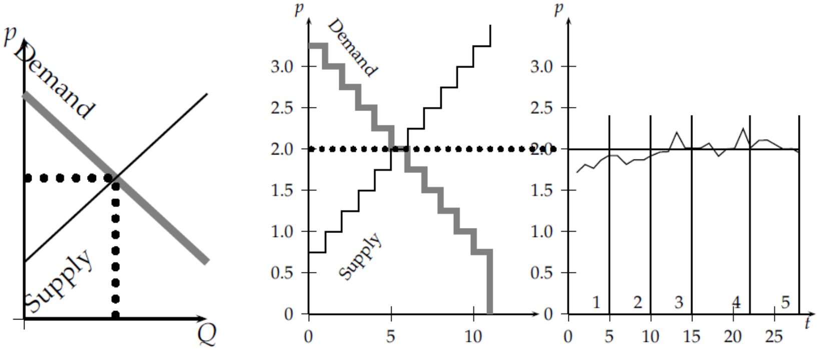
Definition: Theory

Maps are simple and inaccurate models. The map of Cambridge is simple and inaccurate. Due to its simplicity it is more useful than a 1:1 map.



Definition: Theory

Market equilibrium with perfect competition.
Assumptions of this theory?
→ efficient allocation, trade at equilibrium prices, equilibrium quantity



Definition: Theory

3. Simplicity (cont'd):
   - Should a theory be close to the real life?

   → No: too difficult to analyse, we have real life already
   - Example: London stock exchange – we can duplicate this, but why?
   - Theories simplify → to reveal structure.
   - E.g., only one asset, only 2 traders...

Definition: Theory

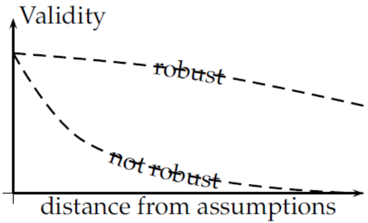
4. Robustness:

- In real life the **assumptions** of the theory of perfect competition **never hold**. Is this theory therefore useless?

→ No – at least not if it is "robust"

- Wouldn't it be better to study real markets from real life?

→ No – in real life we do not know demand and supply



Sources of data

Cost and quality of data

	cost of obtaining data	quality of data
field	often already there	has often been produced for non-scientific purposes. quality is often doubtful
lab	has to be produced	produced by the researcher who is responsible for its quality

Control

	uncontrolled process	controlled experiment
field	inflation, unemployment	experiment with job training programs (LaLonde, 1986)
lab	Penicillin (Alexander Fleming, 1928)	asset market in the lab (V. Smith, 1962)

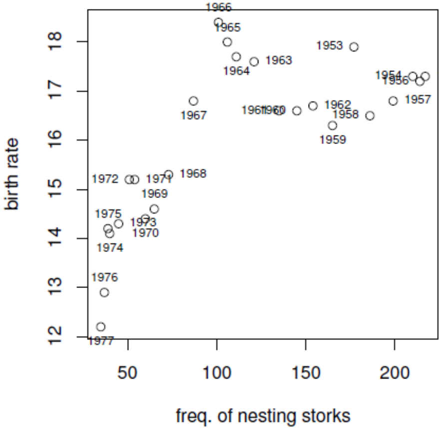
Sources of data

Why do we want experimental control?

Examples for problems that arise due to lack of control

- Storks in Denmark → birth rate (or industrialisation?)
- Sales of christmas trees → christmas
- Higher crop yields under trees: bird droppings as fertilizer, shade-luminists versus aviophiles (Leamer, 1983, "Let's take the Con out of Econometrics", AER 73, p. 31-43).

Sources of data



Sources of data

Can one do experiments in the field?

- Loss of control
  - no lab
- Gain of control
  - more time for decisions
  - control for age, profession, sex (heterogeneous groups of participants)

Sources of data

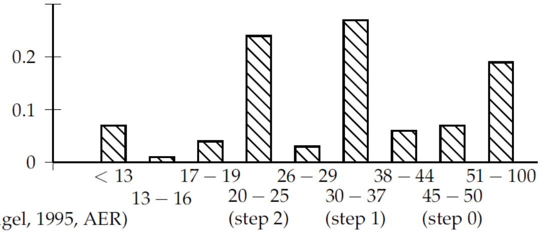
Implementation of experiments (formats)

- Where:
  - Classroom / Laboratory / Field
- How:
  - Paper & Pencil, Computerised Experiments
- Decisions:
  - Direct response method (choices are made for a given situation and role)
  - Strategy method (choices are made for all situations of a given role)
  - Strategy vector method (choices are made for all situations of all roles)

Using experiments

Example: Guessing game

- Several people try to guess what 2/3 of the average of their guesses will be
- numbers are restricted to the real numbers in [0,100]
- the winner is the one closest to 2/3 the average.



(Nagel, 1995, AER)

Using experiments

Was the winning strategy 'rational'?

- theory: players play the equilibrium which can be found by recursively eliminating dominated strategies in this game
- test this theory

$\rightarrow$ should we actually test theories?

- what did physicists do before?

External validity

Can we generalise from our experiments? Does our experiment reflect the essential aspects of the situation in the field? – students who play for small amounts of money in the lab ↔ traders at stock exchange

- Induction
  - theory has the same problem, sometimes even worse:
  - why should any theory hold in the field?
- If a theory (which claims to be general) holds in the lab, that is already a good sign
- If a theory does not even hold in the lab (where we can control most assumptions), why should the theory then hold in the field?
- If somebody comes with a second theory to explain why the lab experiment has different properties than the field, then we can test this with another experiment.

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External validity

Cleave, Nikiforakis, Slonim (2010): Is There Selection Bias in Laboratory Experiments?

- Classroom experiment with 1173 students
- Elicit risk preferences and behaviour in trust game for <u>all</u> students
- Ask students whether they want to participate in experiments
- Invite <u>those</u> students to the lab
- Compare behaviour of participants in the lab with those in the classroom experiment

→ no bias

Internal validity

We want to find out: is there a "treatment effect" in our experiment? – does the treatment variable affect the dependent variable?

- no systematic error
- precision

$$
\begin{aligned}
\text{observation} = {} & \text{treatment effect} \\
& + \text{treatment error} \\
& + \text{unit effect} \\
& + \text{measurement error}
\end{aligned}
$$

Practical advice

1. Simple experimental structure
2. Simple instructions
3. "Neutral" instructions (Strategies A+B) e.g. Liberman, V., Samuels, S.M. & Ross, L. (2004): Prisoners' dilemma game as "Wall Street Game" / "Community Game"
   Engelmann, Ortmann (2009): Gift exchange: "neutral" / "employer / worker"
4. Anonymity
5. Honesty, no deception

Practical advice

6. Incentives
   - Monotonic
   - Salient (in contrast to questionnaires, hypothetical questions)
   - Dominant
7. Script
   - Welcoming the subjects
   - Assigning to seats
   - Assigning to roles in the experiment
   - Presentation of instructions by outside
   - Dealing with questions

Practical advice

Real effort experiments

- Nut-cracking (Fahr, Irlenbusch, EL, 2000)
- Dragging a computerised ball across the screen
- Adding numbers
- Counting letters
- Solving sudokos
- Counting coins (Bortolotti, S., Devetag, G., Ortmann, A., 2009)
- Stuffing envelopes (Konow, AER, 2000)
- Constructing words (like in Scrabble)

Practical advice

Direct / indirect control

- Direct control of observable parameters: e.g. 2×2 design (not changing two parameters at the same time)
- Indirect control of unobservable parameters: randomise (allocate participants randomly to treatments)
- E.g. buyers and sellers in a market experiment: do not allocate roles depending on arrival time.

Practical advice

Factorial design

- Full factorial
  E.g. $2 \times 2 \times 2$ factorial design (3 factors are varied)
  Generally, with k factors $\rightarrow$ at least 2^k treatments.
- Fractional factorial
  Neglects interactions among factors
  Ronald Fisher (1926): "No aphorism is more frequently repeated in connection with field trials, than that we must ask Nature few questions, or, ideally, one question, at a time. The writer is convinced that this view is wholly mistaken. Nature, he suggests, will best respond to a logical and carefully thought out questionnaire"

Practical advice

Within-subject design / accross subject design

- shoe-leather test (left/right different leather),
- not trivial if sequence effect is possible
- Within subject: ABA treatment, sequence effects, BAB treatment is necessary
- Accross subjects: more noise

Practical advice

Terms

- Experiment: several treatments, several sessions
- Treatment: Experiment + specific parameters
- Session: Experiment at a given date with a given group of participants
- Round: short (repeating) part of a session

date	participants	monetary policy
09.05.1997	12	dynamic, constant, dynamic
15.05.1997	6	constant, dynamic, constant
12.12.1997	17	dynamic, constant, dynamic
⋮	⋮	⋮

Practical advice

A first step:

1. choose any question from economics that you want to answer in an experiment (the question should be one sentence with a question mark at the end)
2. what do you know about possible answers to this question?
3. what possibilities do you see to find answers to this questions. Consider experimental and other methods.
4. what are the advantages and disadvantages of experiments?
5. could this experiment yield results that are surprising?
6. how would you conduct the experiment? Describe the essential details of the design.
7. is your design the simplest possible design?

Purpose of behavioural studies:

1. Testing theories
2. Developing theories
3. Theory-free what-if studies (wind-channel experiments)

1. Testing theories

Wind-channel experiment: is useful in the following situation:

- theory is not informative
- theory is too complicated
- unclear which theory to apply

Theory-testing experiment: is useful if we are (or fear to be) in the following situation:

- theory is not accurate (mechanism)
- theory is not precise (prediction)

Allais Paradox (systematic deviation from theory)

	probability	prize
A	0.25	3000
B	0.2	4000

	probability	prize
A'	1	3000
B'	0.8	4000

$\rightarrow$ people prefer B $\succ$ A, but A' $\succ$ B'.

2. Developing theories

Bargaining games

The ultimatum bargaining game.

- Player 1: suggestion how to divide a “pie”
- Player 2: may accept or refuse
- subgame perfect solution:

$\rightarrow$ player 1 keeps (almost) the complete pie.

Güth, Schmidtberger, Schwarz (1982)

- offer $> 30\%$
- 20% of all offers are rejected

$\rightarrow$ not subgame perfect

2. Developing theories

Interpretation:

- altruism of the proposer
- inequality aversion of the responder
- players do not understand the game, play a different (repeated game) with punishment
- $(\frac{1}{2}, \frac{1}{2})$ is just a focal point

Aggregating microanomalies

- In the lab we find behavioural anomalies on the micro level
- Q: Do these "microanomalies" cause behavioural anomalies on the macro level?

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3. What if experiments, policy recommendation

Wind-channel experiments

Kagel and Roth (2000): What makes a successful clearinghouse?

- Examples of clearinghouses:
  - New York City school match
  - U.S. National Resident Matching Program

→ Each doctor (hospital) submits a rank-order list of hospitals (doctors). Computer algorithm generates an assignment

- Q: Do markets unravel if clearinghouses do not produce stable matchings?

→ Yes – participants prefer equilibrium inducing mechanisms. (Lab setting allows them to "hold fixed" the environment)

Summary

- Testing **robustness** of economic theories
- developing new economic theories
- theory-free what-if studies

Limitations:

- Control (in the lab we make assumptions, too. Perhaps fewer than in the field, but we always test "observation + assumption").
- Generality (we only test finitely many parameters)
- Parameters (not all parameters can be induced in an easy way)

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2. Bargaining
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The ultimatum bargaining game

Experiment: Bargaining games

Instructions:

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- 'Login as Participant'
- select 'Initial Login for All Programs'
- enter session name: tbkc3
- enter your name and password 1234
- follow instructions on the screen.

The ultimatum bargaining game

(most simple form of bargaining)

- Proposer: proposes a division of a “pie”.
- Responder: accepts or refuses.
  In case of refusal, both players receive nothing.

Interpretation: monopolist offers a good at a fixed price.

- subgame perfect solution:

$\rightarrow$ player 1 keeps (almost) the entire pie.

The ultimatum bargaining game

Güth, Schmidtberger, Schwarz (1982)

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$\rightarrow$ not subgame perfect

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The ultimatum bargaining game

Players do not understand the game: Binmore, Shaked, Sutton (AER, 1985)

- Subjects did not understand the GSS game. They played $(\frac{1}{2}, \frac{1}{2})$ just because it is a focal division.

  Thus, they have to learn the game. Subjects first play a training game, then play another game.

The ultimatum bargaining game

The training game: A two stage game:

- 1st move: Player 1 decides how to divide a given amount of money.
- 2nd move: Player 2 is informed about player 1's move and accepts or refuses.
  - If player 2 accepts, the game ends and players will be paid following the proposal of player 1.
  - If player 2 refuses, there will be a second stage (3rd and 4th move):
- 3rd move: Player 2 decides how to divide 25% of the initial amount.
- 4th move: Player 1 is informed about player 2's move and accepts or refuses.
  - If player 1 accepts, the game ends and players will be rewarded following the proposal of player 2.
  - If player 1 refuses, both players receive nothing.

The ultimatum bargaining game

The subgame perfect solution of the training game:

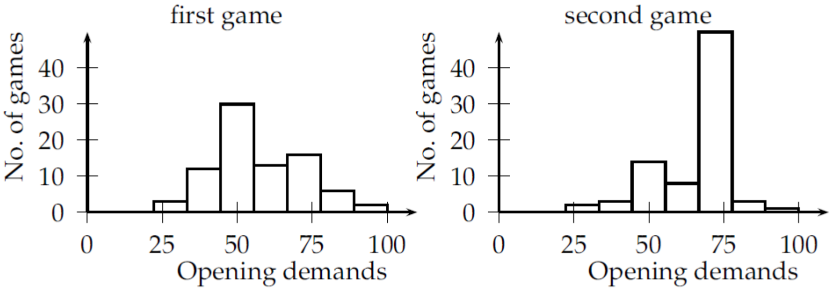
- Player 1 offers 25% in the first stage, and player 2 accepts all offers that are equal or better than 25% for player 2.

  Should we enter the second stage, then player 2 offers 0% for player 1 and player 1 accepts all offers.

The ultimatum bargaining game

The second game

Now those subjects that were in position of player 2 during the training play are in the position of player 1:



The ultimatum bargaining game

Interpretation

- In the training game, the average first round offer was 43%.
- In the second game, the average first round offer was 33%.

→ Players have learned the subgame perfect solution

The ultimatum bargaining game

Altruism vs. inequality aversion, Forsythe, Horowitz, Savin, Sefton (1994)

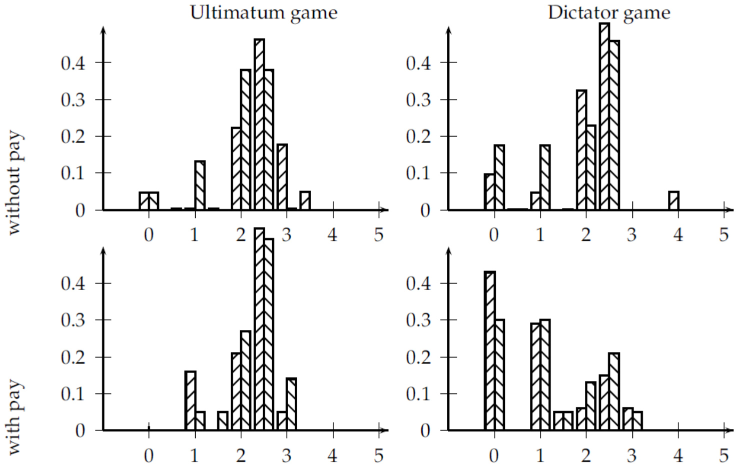
Dictator game: Player 2 may never reject the proposal of player 1.

- Subjects pretend to be generous, as long as they do not have to pay for it (they may wish to please the experimenter).
- As soon as they play for real stakes, subjects are substantially less generous in the dictatorship game.
- in the double blind treatment subjects stop almost completely being generous

→ Player 1s are not fair, but try to avoid punishments.

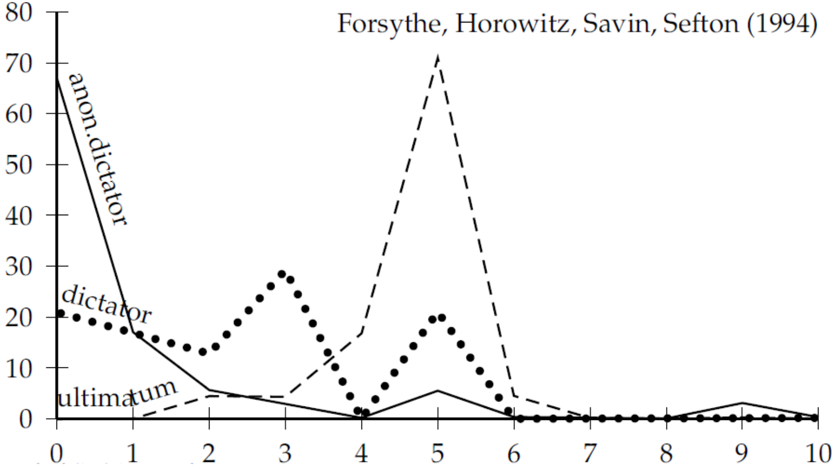
The ultimatum bargaining game

Ultimatum und Dictator Game – Offers of Player 1 (FHSS)



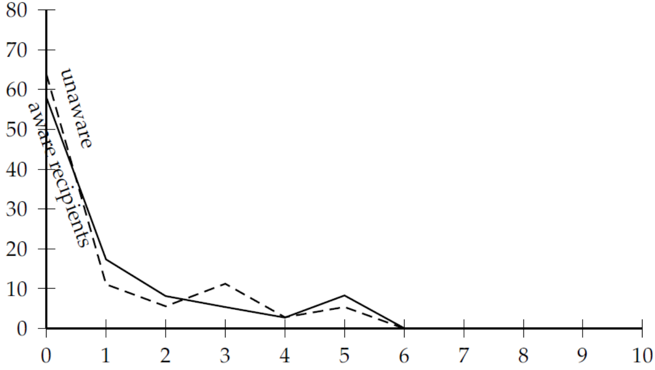
The ultimatum bargaining game

Ultimatum und Dictator Game II – Offers of Player 1 (FHSS)



The ultimatum bargaining game

Opponents' awareness of the rules of the game (Koch & Norman, 2005)



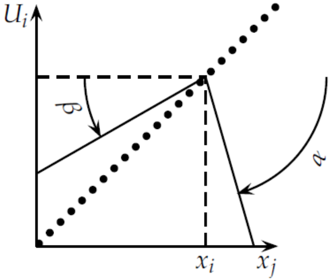
Nevertheless some players transfer money – why?

- they care about their own utility?
- they care about the other person's utility?

The ultimatum bargaining game

A model of fairness and inequality aversion (Fehr Schmidt)

$$U_i(x) = x_i - \alpha_i \cdot \max\{x_j - x_i, 0\} - \beta_i \cdot \max\{x_i - x_j, 0\},\ i \neq j$$



$\beta = 0$: Egoist, $\beta > 1$: strong inequality aversion.

The ultimatum bargaining game

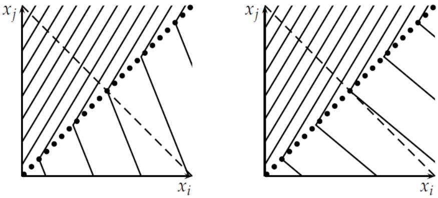
How can we represent a utility function in x_j, x_i?

$$
\begin{aligned}
x_j &> x_i \\
C &= x_i - \alpha_i(x_j - x_i) \\
C &= x_i - \alpha_i x_j + \alpha_i x_i \\
\alpha_i x_j &= x_i + \alpha_i x_i - C \\
x_j &= x_i \cdot \left(1 + \frac{1}{\alpha_i}\right) - \frac{C}{\alpha_i}
\end{aligned}
$$

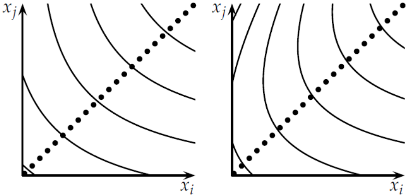
$$
\begin{aligned}
x_j &< x_i \\
C &= x_i - \beta_i(x_i - x_j) \\
C &= x_i - \beta_i x_i + \beta_i x_j \\
-\beta_i x_j &= x_i - \beta_i x_i - C \\
x_j &= x_i \cdot \left(1 - \frac{1}{\beta_i}\right) + \frac{C}{\beta_i}
\end{aligned}
$$

The ultimatum bargaining game

How can we represent a utility function in x_j, x_i?

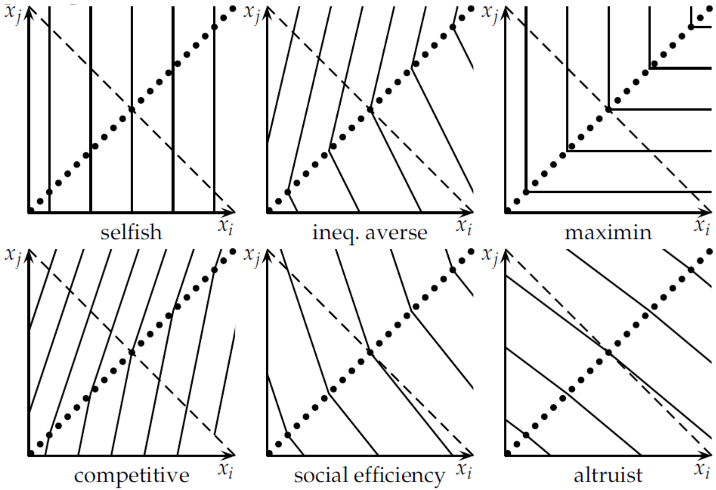


Of course, these indifference curves need not be straight lines:



The ultimatum bargaining game

Types of preferences (Bolton and Ockenfels, AER, 2002)

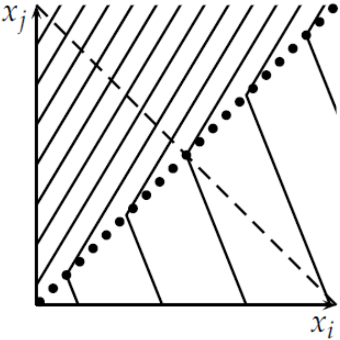


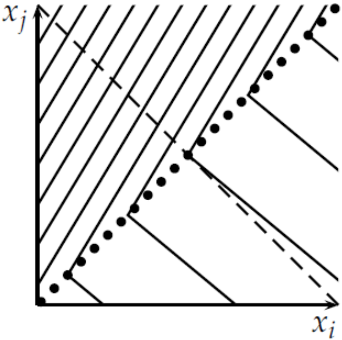
Outline

1. Introduction
   - Historical Example
   - Theories and data?
2. Bargaining
   - The ultimatum bargaining game
   - Modified Dictator game

Modified Dictator game

What does the dictator game tell us?





In the dictator game the dictator chooses (20,0) for $\beta < \frac{1}{2}$, and (10,10) for $\beta > \frac{1}{2}$. $\rightarrow$ How can we determine β with greater precision?

Modified Dictator game

A modified dictator game (Kahneman et. al (1986):
Dictators choose between (10,10) and (18,2). Extended version by Engelmann et. al (2006):

$$
\begin{array}{lll}
(20,0) \leftrightarrow (0,0) & (20,0) \leftrightarrow (7,7) & (20,0) \leftrightarrow (14,14) \\
(20,0) \leftrightarrow (1,1) & (20,0) \leftrightarrow (8,8) & (20,0) \leftrightarrow (15,15) \\
(20,0) \leftrightarrow (2,2) & (20,0) \leftrightarrow (9,9) & (20,0) \leftrightarrow (16,16) \\
(20,0) \leftrightarrow (3,3) & (20,0) \leftrightarrow (10,10) & (20,0) \leftrightarrow (17,17) \\
(20,0) \leftrightarrow (4,4) & (20,0) \leftrightarrow (11,11) & (20,0) \leftrightarrow (18,18) \\
(20,0) \leftrightarrow (5,5) & (20,0) \leftrightarrow (12,12) & (20,0) \leftrightarrow (19,19) \\
(20,0) \leftrightarrow (6,6) & (20,0) \leftrightarrow (13,13) & (20,0) \leftrightarrow (20,20)
\end{array}
$$