Bounded Rationality

Lecture 3

Full Rationality (contd.)
Limits of Rationality and Procedural Rationality
Behavioral Evidence

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Outline

1. Further Examples of “Substantive” Rationality in Economic Models
   - Overview
   - Competitive Industry
   - Cournot Oligopoly

2. Bounded Rationality: Inception

3. Behavioral Evidence
Rational Choice Models consist of two elements:

**Individual Rationality:** Economic agents make the best decision given their perceived opportunities.

**Mutual Consistency of Actions:** Individual actions are mutually consistent.

Rational Choice Model = optimization + equilibrium

Examples:
1. General Competitive Equilibrium
2. Nash Equilibrium
3. Monopoly
Full Rationality:

1. Individual Rationality
   - The rational agent knows the set of alternatives available and knows the consequences associated to each of these alternatives.
   - The rational agent has a (transitive and complete) preference ordering over the set of consequences and is able to determine his/her most preferred (best) alternative.

2. Mutual Consistency of Actions
   - In an economic system, the decision of one agent forms part of constraints upon others.
   - Mutual Consistency requires that the beliefs and actions of everybody are consistent (general equilibrium, Nash Equilibrium, rational expectations).
Example 4. Competitive industry with $n$ identical firms

Let inverse demand function $P(Q)$, cost function $c(q)$ and number of firms $n$ be given. ($q$ is output of a firm, $Q$ is total output.)

1. **Individual rationality**
   Any firm solves
   \[
   \max_q \{pq - c(q)\},
   \]
   derives $p = c'(q)$ and produces an output $q^* = g(p) = g(P(Q))$. 
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   Firm also should form expectations about total output $Q$ in the industry! E.g., $Q = n\bar{q}$, where $\bar{q}$ is an average firm’s choice.
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   Firm also should form expectations about total output $Q$ in the industry! E.g., $Q = n\bar{q}$, where $\bar{q}$ is an average firm’s choice.

2. **Mutual consistency of actions**
   
   In equilibrium firm’s expectations are rational (self-fulfilling)
   \[
   Q = nq^*,
   \]
   since all firms are identical.
Example 4. Competitive industry with $n$ identical firms.

Critical Evaluation
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Critical Evaluation

1. How plausible is an assumption that all firms have Rational Expectations?

2. And if some firm’s expectations are not rational, what happens then?

3. How shall we model “out-of-equilibrium” situation? (It involves specification of perception about perceptions, etc.)
Example 4. Competitive industry with \( n \) identical firms. Critical Evaluation

1. How plausible is an assumption that all firms have Rational Expectations?

2. And if some firm’s expectations are not rational, what happens then?

3. How shall we model “out-of-equilibrium” situation? (It involves specification of perception about perceptions, etc.)

4. Does the firm indeed have no incentives to deviate from equilibrium?
Rational Expectations

In order to explain fairly simple how expectations are formed, we advance the hypothesis that they are essentially the same as the prediction of the relevant economic theory. In particular, the hypothesis asserts that the economy generally does not waste information, and that expectations depend specifically on the structure of the entire system. (p.315)
Rational Expectations

In order to explain fairly simple how expectations are formed, we advance the hypothesis that they are essentially *the same as the prediction* of the relevant economic theory. In particular, the hypothesis asserts that the economy generally does not waste information, and that expectations depend specifically on the structure of the entire system. (p.315)

Thomas Sargent (1993) *Bounded Rationality in Macroeconomics*:
Rational expectations equilibrium [...] typically imputes to the people inside the model *more* knowledge about the system they are operating in than is available to the economist or econometrician who is using the model to try to understand their behavior. (p.21)
Example 5. Cournot oligopoly

Let inverse demand function $P(Q)$ ($Q$ is industry supply) and cost functions $C_i(q_i)$, satisfying the usual assumptions, be given.

1. **Individual rationality**

Each firm solves

$$q_i = R(Q^e_{-i}) = R(q_1^e + \cdots + q_{i-1}^e + q_{i+1}^e + \cdots + q_n^e)$$

$$= \arg \max_{q_i} \left\{ P(Q_{-i}^e + q_i) \cdot q_i - C_i(q_i) \right\} .$$
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   \]

2. **Mutual consistency of actions**

   \((q_1^*, q_2^*, \ldots, q_n^*)\) is a Nash-equilibrium such that

   \[
   q_i^* = R_i(Q_{-i}^*) \quad \text{for all } i.
   \]
Example 5. Cournot oligopoly: Critical Evaluation
Example 5. Cournot oligopoly: Critical Evaluation

1. Does the equilibrium exist?

2. What firms should know to compute the equilibrium?

3. Is the equilibrium unique?

4. What would you do at the duopolist’s place?
Example 5. Cournot oligopoly: Adjustment model

Duopoly:

Let inverse demand function $P(Q)$ ($Q$ is industry supply) and cost functions $C_1(q_1)$ and $C_2(q_2)$, satisfying the usual assumptions, be given.

- time is discrete, $t = 1, 2, \ldots$
- firms start from initial point $(q_{1,0}, q_{2,0})$
- each period every firm chooses the best response to the previous period, i.e., $q_{i,t+1} = R_i(q_{-i,t})$
Example 5. Cournot oligopoly: Adjustment model

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This is the first historical example of procedural rationality (Cournot, 1838).
Adjustment process: Critical Evaluation

1. Does the adjustment process converge and where?
Adjustment process: Critical Evaluation

1. Does the adjustment process converge and where?
2. What if there are multiple equilibria?
3. Are there any “unexplored opportunities” under this adjustment process?
4. Are other adjustment processes possible?
5. ...
Experiment 5: The guessing game.

Game between $n$ players. Tournament structure where the winner wins a prize.
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Game between $n$ players. Tournament structure where the winner wins a prize.
Every participant writes down a number from the set
\[ S = \{0, 1, \ldots, 100\} . \]
Experiment 5: The guessing game.

Game between $n$ players. Tournament structure where the winner wins a prize. Every participant writes down a number from the set

$$S = \{0, 1, \ldots, 100\}.$$ 

Let $X_i$ be the number written down by participant $i$ and let

$$X = \frac{1}{n} \sum_{i=1}^{n} X_i,$$

be the average of these numbers. The participant whose guess $X_i$ is closest to

$$\frac{2}{3} \times X$$

wins the prize.
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The Nash equilibria are that everyone chooses 0 or that everyone chooses 1.
Outline

1. Further Examples of “Substantive” Rationality in Economic Models

2. Bounded Rationality: Inception
   - Substantive vs. Procedural Rationality
   - Herbert Simon

3. Behavioral Evidence
Procedural Rationality

Herbert Simon: *From Substantive to Procedural Rationality*, 1976

**Psychology** behavior is *procedurally rational* when it is the outcome of appropriate deliberation

**Economics** behavior is *substantively rational* when it is appropriate to the achievement of given goals within the limits imposed by given conditions and constraints
Limits of Rationality

Models of Rational Choice assume there are no limits on

- informational
- cognitive
- computational
capacities of individual agents.
Tic-Tac-Toe and Chess
Tic-Tac-Toe game
Tic-Tac-Toe and Chess

von Neumann – Morgenstern

*If the theory of chess (i.e., the complete tree of possible games) were really fully known, there would be nothing left to play.*
Tic-Tac-Toe and Chess

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The goal of a player can be described as

- find the best strategy (requires the game tree)
- at each step evaluate each of the next moves
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Under Full Rationality: there is no difference!
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Limits of rationality:
- informational (choosing a strategy from only few of them)
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- **cognitive** (choosing a move having only rough representation of consequences)
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Limits of rationality:

- **informational** (choosing a strategy from only few of them)
- **cognitive** (choosing a move having only rough representation of consequences)
- **computational** (at the end there is no uncertainty!)
Bounded Rationality

**Herbert Simon:** Models of Bounded Rationality deal with deviations from the rational choice paradigm, where *limits on individual rationality* are imposed. Limits on:

- informational
- cognitive
- computational capacities of individual agents.
Bounded Rationality

Herbert Simon: Models of Bounded Rationality deal with deviations from the rational choice paradigm, where limits on individual rationality are imposed. Limits on:

- informational
- cognitive
- computational capacities of individual agents.

Thomas Sargent: Models of Bounded Rationality deal mostly with informational limits and also with deviations from a mutual consistency of actions. Focus on adjustment processes leading (or not leading) to equilibrium.
Outline

1. Further Examples of “Substantive” Rationality in Economic Models
2. Bounded Rationality: Inception
3. Behavioral Evidence
   - Experimental evidence in favor of bounded rationality
Experiment 1: Guess the next realization

- Consider an (unfair) coin which turns up head ($H$) with probability $p \in (0, 1)$ and tails ($T$) with probability $1 - p$. 

Below 4 sequences are given. Each sequence consists of 10 independent flips with the same coin (and hence the same $p$). Different sequences are generated by different coins (and hence different $p$).

Sequence 1 (probability $p_1$):
T − H − H − T − H − T − H − T − T − T

Sequence 2 (probability $p_2$):
H − T − H − H − H − H − H − H − T − H

Sequence 3 (probability $p_3$):
T − T − H − H − T − T − H − H − H − H

Sequence 4 (probability $p_4$):
T − T − H − T − T − T − T − T − H − T
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  \[
  \]

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- Sequence 1 (probability $p_1$):

- Sequence 2 (probability $p_2$):

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- Sequence 4 (probability $p_4$):

- The optimal decision is $(T - T - T)$, $(H - H - H)$, $(H - H - H)$ and $(T - T - T)$, respectively.
Psychological Biases

Experiment 2. A bat and a ball cost $1.10 in total. The bat costs $1 more than the ball. How much does the ball cost?
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Experiment 3. Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student she was deeply concerned with issues of discrimination and social justice and also participated in antinuclear movements.
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What is the probability that:

1. Linda is a bank teller?
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What is the probability that:

2. Linda is a bank teller and active in the feminist movement?
Psychological Biases

Experiment 4.
Imagine that St.Petersburg is preparing for the outbreak of a disastrous flood, which is expected to kill 600 people. Two alternative programs to combat the disaster have been proposed. Assume that the exact scientific estimates of the consequences of the program are as follows:
Psychological Biases

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Imagine that St.Petersburg is preparing for the outbreak of a disastrous flood, which is expected to kill 600 people. Two alternative programs to combat the disaster have been proposed. Assume that the exact scientific estimates of the consequences of the program are as follows:

- If program A’ is adopted 400 people will die.
- If program B’ is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die.
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Imagine that St. Petersburg is preparing for the outbreak of a disastrous flood, which is expected to kill 600 people. Two alternative programs to combat the disaster have been proposed. Assume that the exact scientific estimates of the consequences of the program are as follows:

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- If program A is adopted 200 people will be saved.
- If program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved.
Psychological Biases

**Experiment 4.**
Imagine that St. Petersburg is preparing for the outbreak of a *disasterous flood*, which is expected to kill 600 people. Two alternative programs to combat the disaster have been proposed. Assume that the exact scientific estimates of the consequences of the program are as follows:

- If program A’ is adopted 400 people will die. [22%]
- If program B’ is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die. [78%]
- If program A is adopted 200 people will be saved. [72%]
- If program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved. [28%]
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You have written:

\[
\begin{array}{cccccccc}
1 & 33 & 18 & 0 & 85 & 3 & 14 & 17.5(???) & 0 & 17 \\
4 & 1 & 7 & 50 & 16 & 60 & 2 & 23 & 22 & 37 \\
26 & 5 & 60 & 75 & 17 & 10 & 10 & 6 & 25 & 11 & 1
\end{array}
\]
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1 33 18 0 85 3 14 17.5(???) 0 17
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with the average

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\frac{639}{30} = 21.3.
\]

and the two-thirds of the average

14.2

And the winner is:
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The guessing game is also called “beauty contest” game after the following passage from *General Theory* of J.M.Keynes:
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It is not a case of choosing those which, to the best of one’s judgment, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practise the fourth, fifth and higher degrees.”
Experiment 5: The guessing game.

(b) Target = 2/3 mean

Frequency (percent)

Number choices
Experiment 5: The guessing game.

(d) Target = 2/3 mean, game theorists and experimenters

![Bar chart showing frequency of number choices from 0 to 100.](chart.png)
Experiment 5: The guessing game.
“Experiment” 6. Index Mutual Funds


- experiment on real investment
- one-shot decision to allocate money between 4 investment index funds
- the expected return is the same, but the past performance reported in the prospects are different
- also different fees: the highest fees are for the funds with largest past return
Index Mutual Funds

Harvard staff

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<th>Fees treatment</th>
<th>Returns treatment</th>
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<td>Phoenix Insight (5.81%)</td>
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MBA students

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College students

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Why do we need to study Bounded Rationality?

1. The assumptions underlying the rational choice paradigm are too demanding.

   - Unbounded rationality requires too much from the cognitive abilities (information gathering and processing) of the human mind.
   - Rationality often depends on the “degree of rationality” of others (in models with heterogeneous agents).
   - Deliberation costs: it might be rational not to be rational.
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1. **The assumptions** underlying the rational choice paradigm are too demanding.
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   - Rationality often depends on the "**degree of rationality**" of others (in models with heterogeneous agents)
   - **Deliberation costs**: it might be rational not to be rational.

2. Behavioral deviations from the rational choice paradigm seems to be **systematic**.
   - Common sense and casual observation suggest that people tend to use simple (habitual) **rules of thumb / heuristics**
   - **Experimental evidence** (controlled environment).
Suggested reading


Tomorrow: Models of Individual learning

- Given their **perceived** set of alternatives and **perceived** consequences agents select the most preferred action...

- ...agents **observe** the outcome...
Tomorrow: Models of Individual learning

- Given their **perceived** set of alternatives and **perceived** consequences agents select the most preferred action...

- ...agents **observe** the outcome...

- ...agents use this **new information** and may change their action next time.
  - they **learn** about set of alternatives and consequences
  - they **learn** about the behavior of an opponent

In other words, **learning** means that economic decision makers have certain **beliefs** about their economic environment and **adapt** these beliefs as **new information** comes along.