

## Lecture 2: The Toolkit

Econ 490: Compensation in Organizations

Jacob Kohlhepp

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Discussion: Lazear (2000)

## What Should You Know Already?

- ▶ Single variable derivatives.
- ▶ Inequalities.
- ▶ Very basic probability.

# What Will I Teach You Today?

- ▶ The concept of risk aversion and a useful formula.
- ▶ A decision problem.
- ▶ Simple game theory, static.
- ▶ Simple game theory, dynamic.

## Caveats

- ▶ I will try to cover just what is needed for the class.
- ▶ I will not cover Nash equilibrium in depth.
- ▶ I will not cover risk aversion in depth.
- ▶ If you want to go beyond this or want more practice, see my notes and practice problems from an old course: <https://github.com/jakekohlhepp/Econ101>.

# Table of Contents

Risk Aversion

Decision Problem

Game Theory

## Compensation as Lotteries

- ▶ Your performance in a job is often effort + noise/luck/chance/circumstance
- ▶ Effort is in your control, but the rest is random.
- ▶ If you get paid based on performance, your compensation is a lottery!

## A Survey

Suppose a company offered you three compensation schemes:

- a.  $X_a$ : \$100,000 with probability 50%, \$0 with probability 50%.
- b.  $X_b$ : \$49,000 with probability 100%
- c.  $X_c$ : \$200,000 with probability 24%, \$0 with probability 76%.

Which would you choose? (will tally on board)

## Risk Attitudes

- ▶ Before looking at the results, notice some facts:
  - ▶ b has lower average than a:  $E[X_a] = 50 > 49 = E[X_b]$ .
  - ▶ But a has higher variance than b:  $Var(X_a) = 2500 > 0 = Var(X_b)$ .
  - ▶ So if you dislike variance or uncertainty, you will prefer a.
  - ▶  $E[X_c] = 48 < 49 < 50$ : in terms of expected money, c is worse than both a and b.
  - ▶ However, the variance of c is higher:  $Var(X_c) \approx 7296 > 2500 > 0$ .
  - ▶ You will only choose c if you like uncertainty/risk.
- ▶ A rough interpretation of the results:
  - ▶ If you chose b you are *risk averse*: you dislike uncertainty/risk, and are willing to pay to reduce it
  - ▶ If you chose a you are either *risk neutral*
  - ▶ If you chose c you are *risk loving*
- ▶ We will assume people are risk averse or risk neutral.

# Expected Utility Theory

- ▶ We analyze uncertainty using **Expected Utility Theory**.
- ▶ This theorem justifies the tools we will use in this class:

## Theorem 1

*Under a set of axioms (which you do not need to know), we can represent an individual's preferences over lotteries using an **expected utility function**  $u$  where  $E[u(X_a)] \geq E[u(X_b)]$  means that lottery  $a$  is preferred to lottery  $b$ .*

## Risk Attitudes As Functions

A person with expected utility function  $u$  is...

- ▶ **risk averse** if  $u$  is concave.
- ▶ **risk neutral** if  $u$  is linear.
- ▶ **risk loving** if  $u$  is convex.

## Certainty Equivalent

- We often want to rank lotteries/gambles. The following concept is useful for ranking lotteries:

### Definition 2

The amount of money for sure a decision maker is willing to pay for lottery  $a$  is the **certainty equivalent** ( $d_a$ ). Mathematically:

$$u(d_a) = E[u(X_a)]$$

- Given a lottery that gives me  $d$  dollars for sure and  $X_a$ , it is the value of  $d$  where I am indifferent.

# Certainty Equivalent

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- ▶ Given a lottery that gives me  $d$  dollars for sure and  $X_a$ , it is the value of  $d$  where I am indifferent.
- ▶ Gut check: What is the certainty equivalent of a lottery with  $E[X_a] = 10$  when the decision maker is risk neutral?

## Certainty Equivalent

- We often want to rank lotteries/gambles. The following concept is useful for ranking lotteries:

### Definition 3

The amount of money for sure a decision maker is willing to pay for lottery  $a$  is the **certainty equivalent** ( $d_a$ ). Mathematically:

$$u(d_a) = E[u(X_a)]$$

- Given the choice between  $d$  dollars for sure or  $X_a$ , it is the value of  $d$  where I am indifferent.

# Certainty Equivalent

- We often want to rank lotteries/gambles. The following concept is useful for ranking lotteries:

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- Given the choice between  $d$  dollars for sure or  $X_a$ , it is the value of  $d$  where I am indifferent.
- Gut check: What is the certainty equivalent of a lottery with  $E[X_a] = 10$  when the decision maker is risk neutral?

## Exponential Utility

- We will use the exponential utility function in this class:

$$u(x) = \frac{1 - e^{-rx}}{r}$$

- $r$  captures risk aversion:
  - When  $r > 0$  the decision maker is risk averse
  - When  $r < 0$  they are risk loving.
- What happens when  $r \rightarrow 0$ ? Using L'Hopital's rule:

$$\lim_{r \rightarrow 0} \frac{1 - e^{-rx}}{r} = x$$

So we have risk neutrality!

## Exponential Utility

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$$u(x) = \frac{1 - e^{-rx}}{r}$$

### Theorem 4

When a person has risk preference given by an exponential utility function  $u(x) = \frac{1 - e^{-rx}}{r}$ , the certainty equivalent of a normal lottery with mean  $\mu$  and variance  $\sigma^2$  is given by:

$$d = \mu - r \frac{\sigma^2}{2}$$

- In this class, you can apply this formula directly.
- Talk to me if you are interested in the derivation!

# Table of Contents

Risk Aversion

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## Making a Decision

- ▶ Suppose there is a single person ( $A$ ) making a decision.
- ▶  $A$  takes an action which we will call  $e$ .
- ▶  $e$  can be a **discrete action**:
  - ▶ accept or reject
  - ▶ work hard or slack off
- ▶  $e$  can be a **continuous action**:
  - ▶ exert  $e$  units of effort
  - ▶ drive  $e$  miles
- ▶ The utility or payoff of an action  $e$  is  $u(e)$

# Table of Contents

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## Game Theory in This Class

- ▶ Game theory lets us model strategic interaction.
- ▶ Therefore it is a tool, but not the point, of this class.
- ▶ I do not require you to learn the definitions of Nash equilibrium, best responses, etc.
- ▶ However, if you want to go to econ. grad school this can be useful.
- ▶ I do require you to make either mathematical and/or verbal arguments.
- ▶ For tests, I will only ask you to solve models we solved in class (sometimes with slight modifications).

## Competing for a Worker (Bertrand Game)

We will use the basic ideas of this game often:

- ▶ **Players.** Two identical firms, numbered  $i = 1, 2$ , and one worker.
- ▶ **Actions.** Firms choose wages *continuously*:  $0 \leq w_i < \infty$
- ▶ **Payoffs.**
  1. Worker payoff is the wage of the firm they choose.
  2. When firms set the same wage the worker chooses randomly.
  3. The firm which hires the worker gets productivity  $p$  and pays the wage.
  4. If a firm does not hire they get 0.

## Competing for a Worker: Solution

See the board (we will solve this almost entirely verbally)!

## The Company Call List (Tragedy of the Commons)

- ▶ **Players.** Two sales workers,  $i = 1, 2$ , share a common list of company sales contacts.
- ▶ **Actions.** Each chooses a number of people on the list to call,  $q_i$
- ▶ **Payoffs.**
  1. The cost to the worker of making a call on the list is 0.
  2. The amount of commission the worker makes per call is  $120 - q_1 - q_2$

## The Company Call List (Tragedy of the Commons) - Solution

See the board!

## Sequential Games

- ▶ We will consider several models in this class where a firm moves first (usually to set up a compensation plan)
- ▶ Then a worker reacts to this compensation plan.
- ▶ Unlike the last examples these are sequential games.
- ▶ Two key differences between static and dynamic:
  - ▶ In sequential games, future players take past player actions as fixed.
  - ▶ Earlier players anticipate future players will react to their current choices.
- ▶ To deal with this, we use subgame perfect Nash equilibrium.
- ▶ For this class, that just means we use backwards induction.

## The Pirate Riddle

There is a tricky riddle that we will use to illustrate backwards induction.

*Five pirates, numbered 1 through 5, must decide how to divide 100 gold coins. Their decision process is as follows. Starting with pirate 1, each pirate proposes a split consisting of a number of coins for each of the pirates on the ship. Then all pirates vote. If a strict majority approve, the allocation happens. If it does not the proposer is thrown off the ship and the remaining pirates repeat the process. Assume pirates value 2 coins more than 1, etc and that getting thrown off is worse than getting 0 coins. Assume pirates vote no when indifferent (they get a little bit of enjoyment from watching someone walk the plank). What is the maximum number of coins P1 can obtain and not get thrown off?*

## Pirate Riddle: Verbal Solution

- ▶ Start from the end of the game. If P5 gets to make a proposal, then they are the last pirate left. They propose 100 coins for themselves and get it!

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- ▶ Rolling back, P4 needs pirate 5's vote for a strict majority. There is no way to get it since P5 knows they get 100 coins if they throw off P4. Thus P4 can propose anything, and P5 always rejects.

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- ▶ Roll back. P3 needs 1 other vote to get a majority. The easiest person to convince is pirate 4, since pirate 4 gets thrown off if the game continues. To get P4's vote P3 can get away with giving P4 0 coins. P3 proposes 0 for all other pirates and 100 for themselves.

## Pirate Riddle: Verbal Solution

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- ▶ Rolling back, P4 needs pirate 5's vote for a strict majority. There is no way to get it since P5 knows they get 100 coins if they throw off P4. Thus P4 can propose anything, and P5 always rejects.
- ▶ Roll back. P3 needs 1 other vote to get a majority. The easiest person to convince is pirate 4, since pirate 4 gets thrown off if the game continues. To get P4's vote P3 can get away with giving P4 0 coins. P3 proposes 0 for all other pirates and 100 for themselves.
- ▶ Roll back. P2 needs to get two votes. All pirates except P3 get 0 coins if the game continues, so P2 proposes 1 coin to P1 and 1 coin to P4 and keeps 98.

## Pirate Riddle: Verbal Solution

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- ▶ Roll back. P2 needs to get two votes. All pirates except P3 get 0 coins if the game continues, so P2 proposes 1 coin to P1 and 1 coin to P4 and keeps 98.
- ▶ Roll back. P1 needs two other votes. P3 is the cheapest to convince. P1 and P4 are next cheapest, and P1 need only convince one. So P1 proposes 0 for P2 and P5, P3 1, and P4 2 and keeps 97!

## Pirate Riddle: Open Discussion

What can we learn from the pirate riddle? What is surprising about the outcome/solution?

## The Company Call List - Sequential Version

We now modify our static company call list game to be sequential.

- ▶ **Players.** Two sales workers,  $i = 1, 2$ , share a common list of company sales contacts.
- ▶ **Actions.** Each chooses a number of people on the list to call,  $q_i$
- ▶ **Timing.** Worker 1 calls first, then worker 2.
- ▶ **Payoffs.**
  1. The cost to the worker of making a call on the list is 0.
  2. The amount of commission the worker makes per call is  $120 - q_1 - q_2$

## The Company Call List - Sequential Version Solution

See the board!