# Decision Making

BUS 735: Business Decision Making and Research

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## 1.1 Goals and Agenda

**Goals and Agenda**

| Learning Objective | Active Learning Activity |
|---|---|
| Learn how to make decisions with uncertainty, without using probabilities. | Lecture / Example problems. |
| Practice what we learn. | In-class exercise. |
| Learn how to make decisions with uncertainty, using probabilities. | Lecture / Example problems. |
| Practice what we learn. | In-class exercise. |

# 2 Decision Making Without Probabilities

**Decision Making Without Probabilities**

- Suppose you have to decide on one of three choices for your business:

  1. Expand facilities.
  2. Renovate existing facilities.
  3. Do nothing.

- Each have costs (known) and benefits (unknown).

- Suppose profits depend on economic conditions:

| Decision | Good Economic Conditions | Bad Economic Conditions |
|---|---|---|
| Expand | $150,000 | -$10,000 |
| Renovate | $90,000 | $10,000 |
| Do nothing | $70,000 | $40,000 |

## 2.1 Maximax Decision

**Maximax Decision**

- Problem: probabilities of having good economic conditions or bad economic conditions are unknown.

- Maximax Decision:

  - Compute the best (maximum) outcome for each choice (very optimistic).
  - Choose the maximum of the best outcomes.
  - Choosing options given best-case scenarios.

| Decision | Good Economic Conditions | Bad Economic Conditions | Maximum |
|----------|--------------------------|-------------------------|---------|
| Expand | $150,000 | -$10,000 | $150,000 |
| Renovate | $90,000 | $10,000 | $90,000 |
| Do nothing | $70,000 | $40,000 | $70,000 |

- Maximum of maximums = $150,000. Choice = Expand!

## 2.2 Maximin Decision

**Maximin Decision**

- Maximin Decision:

  - Compute the worst (minimum) outcome for each choice (very pessimistic).
  - Choose the maximum of the worst outcomes.
  - Choosing options given worst-case scenarios.

| Decision | Good Economic Conditions | Bad Economic Conditions | Minimum |
|----------|--------------------------|-------------------------|---------|
| Expand | $150,000 | -$10,000 | -$10,000 |
| Renovate | $90,000 | $10,000 | $10,000 |
| Do nothing | $70,000 | $40,000 | $40,000 |

- Maximum of minimums = $40,000. Choice = Do Nothing!

## 2.3 Minimax Regret Decision

**Minimax Regret Decision**

- **Regret** is the difference between the payoff of a given decision and the best decision under a given scenario.

- Example: Suppose you chose to *do nothing* and there ended up being good economic conditions.

  - Best decision given good economic condition is to *expand*. Profit = $150,000.
  - Profit from *doing nothing* given good economic condition is $70,000.
  - Regret = $150,000 - $70,000 = $80,000.

- Minimax Regret Decision:

  - Compute regrets for every cell in table..
  - Find the maximum regret for each decision.
  - Choose the minimum of these maximum regret values.

**Minimax Regret Decision**

- Payouts Table:

| Decision | Good Economic Conditions | Bad Economic Conditions |
|---|---|---|
| Expand | $150,000 | -$10,000 |
| Renovate | $90,000 | $10,000 |
| Do nothing | $70,000 | $40,000 |

- Regrets Table:

| Decision | Good Economic Conditions | Bad Economic Conditions | Maximum |
|---|---|---|---|
| Expand | $0 | $50,000 | $50,000 |
| Renovate | $60,000 | $30,000 | $60,000 |
| Do nothing | $80,000 | $0 | $80,000 |

- Minimum of maximum regrets = $50,000. Choice = Expand!

## 2.4 Maximum-Weighted Decisions

**Equally Likely Decision**

- Suppose (for no reason whatsoever) that each outcome is equally likely.

- Compute weighted average of each decision (with equal weights).

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- P(Good Economic Conditions) = P(Bad Economic Conditions) = 0.5.

- Equal Likelihood Table:

| Decision | Good Economic Conditions | Bad Economic Conditions | "Expected" Value |
|---|---|---|---|
| Expand | $150,00 | -$10,000 | $70,000 |
| Renovate | $90,000 | $10,000 | $50,000 |
| Do nothing | $70,000 | $40,000 | $55,000 |

- Maximum "expected" value = $70,000. Decision = Expand!

## Hurwicz Decision

- Take a weighted average again, but choose an arbitrary weight for the best-case value.

- Coefficient of optimism, given by $\alpha$, is a measure of the decision makers optimism.

- Best-case weight = $\alpha$, worst-case weight = $(1 - \alpha)$.

- Suppose $\alpha = 0.2$ (very arbitrary).

| Decision | Good Economic Conditions | Bad Economic Conditions | "Expected" Value |
|---|---|---|---|
| Expand | $150,00 | -$10,000 | $22,000 |
| Renovate | $90,000 | $10,000 | $26,000 |
| Do nothing | $70,000 | $40,000 | $46,000 |

- Maximum "expected" value = $46,000. Decision = Do Nothing!

## Dependence on Optimism

- Coefficient of optimism can be very difficult to choose.

- Optimal choice might vary a lot depending on this parameter.

- For each pair of decisions, find the cut-off value of $\alpha$ that leads one to switch decisions.

## Summary of Results

| Criterion | Decision |
|---|---|
| Maximax | Expand |
| Maximin | Do nothing |
| Minimax Regret | Expand |
| Equal Likelihood | Expand |
| Hurwicz ($\alpha = 0.2$) | Do nothing |

- **Dominant decision:** when same choice is made for every criterion considered.

- **Dominated decision:** when choice is never made for every criterion considered.

# 3 Decision Making With Probabilities

## 3.1 Expected Values

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### Expected Values: Probabilities Known

- Suppose probabilities for good economic conditions and bad economic conditions are known.

- Suppose P(Good Economic Conditions) 0.6, P(Bad Economic Conditions)

= 0.4.

| Decision | Good Economic Conditions | Bad Economic Conditions | Expected Value |
|---|---|---|---|
| Expand | $150,00 | -$10,000 | $86,000 |
| Renovate | $90,000 | $10,000 | $58,000 |
| Do nothing | $70,000 | $40,000 | $58,000 |

- Maximum expected value = $86,000. Decision = Expand!

- A **risk neutral** decision maker should make this decision.

### Expected Opportunity Loss

- **Expected opportunity loss (EOL)** = expected value of regret for each decision.

- Regrets Table:

| Decision | Good Economic Conditions | Bad Economic Conditions | Expected Value |
|---|---|---|---|
| Expand | $0 | $50,000 | $20,000 |
| Renovate | $60,000 | $30,000 | $48,000 |
| Do nothing | $80,000 | $0 | $48,000 |

- Minimum expected regret = $20,000. Decision = Expand!

- Minimum expected loss decision *will always be equal to* maximum expected value decision.

**Expected Value of Perfect Information**

- Suppose you could purchase "perfect information" about what will happen. How much would you pay?

- If you were told good economic conditions:

    - Decision = Expand, Profit = $150,000.

- If you were told bad economic conditions:

    - Decision = Do nothing, Profit = $40,000.

- A priori expected profit (given you will make a perfect decision):

    - Expected Profit = (0.6)($150,000) + (0.4)($40,000) = $106,000.

- Expected profit from maximizing expected value = $86,000.

- EVPI = $106,000 - $86,000 = $20,000.

- Not coincidentally, EVPI = EOL.

## 3.2 Bayesian Analysis

**Bayesian Analysis**

- **Bayesian analysis:** decision making using additional information which alter conditional probabilities.

- Suppose P(good economic conditions), P(bad economic conditions) are simply based on past history.

- Suppose your the Minneapolis Federal Reserve Bank issues an economic report (which they do) that indicates whether they have a positive economic outlook or a negative economic outlook.

- This is useful information, but not *perfect information*.

- Define the following events:

    - P: positive economic report.
    - N: negative economic report.
    - g: Good economic conditions.
    - b: Bad economic conditions.

- Of course, $P(P) = 1 - P(N)$, $P(g) = 1 - P(b)$.

**Bayesian Analysis**

- Suppose generally, good economic conditions occur 60% of the time, and bad economic conditions occur 40% of the time.

- Suppose past experience indicates the Federal Reserve report accurately forecasts...

    - good economic conditions 80% of the time, and
    - bad economic conditions 90% of the time.

- Probabilities:

    - $P(P|g) = 0.8$, $P(N|g) = 0.2$.
    - $P(N|b) = 0.9$, $P(P|b) = 0.1$.
    - $P(g) = 0.6$, $P(b) = 0.4$.

**Bayesian Analysis**

Suppose a positive report came out. We want to know $P(g|P)$:

$$P(g|P) = \frac{P(g \cap P)}{P(P)} = \frac{P(P|g)P(g)}{P(P|g)P(g) + P(P|b)P(b)}$$

$$= \frac{(0.8)(0.6)}{(0.8)(0.6) + (0.1)(0.4)} = 0.923$$

**Compute Conditional Expected Values**

- Now use $P(g|P)$ and $P(b|P)$ to find decision that maximizes expected value. What is the expected value?

- What would your decision be if there was a negative report? What is the expected value?