Optimal timing, cost benefit analysis, stochastic analysis, real options, deep uncertainty and climate change

Ekko van Ierland                                  Wageningen University
with contributions of Thomas van der Pol
Introduction

1. Risk and uncertainty
2. Economic decision making: deterministic; probabilities; stochastic; deep uncertainty
3. Level 2: probabilities are not known
4. Real option theory: irreversibilities, uncertainty and learning
5. Deep uncertainty
6. Conclusions
1. Types of uncertainty

• No uncertainty: deterministic setting
• Type 1: probabilities known
• Type 2: probabilities basically unknown
• Type 3: fundamental or deep uncertainty
2. Economic decision making

- Maximize net benefits to society
- For mitigation: Maximize utility, i.e. minimize the Net present value of mitigation costs and damage costs
- For adaptation: Minimize the net present value of adaptation costs and damage costs

- In the end we will do some mitigation and we will have to do some adaptation. The less mitigation, the more adaptation.
- Mitigation requires international efforts; if these fail, we have to do a lot of adaptation;
- The more we adapt, the less is the incentive to mitigate!
2a Deterministic setting

• Standard Cost benefit analysis

• NPV = sum of discounted benefits-costs =
  \[= \sum ((B(t) - C(t)) / (1+r)^t)\]

Simple calculations; simple results..., but most cases involve uncertainty in one way or another
Reasons for discounting

In favour

• Time preference
• We will be richer in the future
• Capital productivity: put your money in the bank and it will grow!? 100 now is 110 tomorrow: 110 tomorrow is 100 now
• Opportunity cost of money

Not in favour

• It reduces the economic value of future costs and benefits
• This implies that the welfare of future generations is valued less than that of current generations
• It may lead to climate catastrophe, because we compare today's costs of mitigation to highly discounted damages in the future
Discount rate and discount factor
Projects A and B

<table>
<thead>
<tr>
<th>Project A</th>
<th>Project B</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=1</td>
<td>T=1</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>T=2</td>
<td>T=2</td>
</tr>
<tr>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>T=3</td>
<td>T=3</td>
</tr>
<tr>
<td>500</td>
<td>300</td>
</tr>
</tbody>
</table>

Which project would you prefer?
Mitigation of climate change

Today
- Cost of mitigation: more expensive energy systems
- Cost of energy conservation

In the future
- Damages of climate change
- Forest fires
- Melting of artic ice
- Permafrost release of methane
- Extreme sea level rise

Long delays; once the system has changed it is almost irreversible; it takes centuries to go back to old situation
Stern Review: do not discount because future generations will be faced with disaster if we do!
2b Probabilistic setting

<table>
<thead>
<tr>
<th>Project A</th>
<th>Project B</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Calculate expected value \( E = \sum p_i \cdot B_i \)

Which project would you prefer?
Risk attitudes

- Risk neutral: maximize expected value
- Risk averse: avoid low pay off!
- Risk lover: enjoy the kick of gambling: choose the alternative with the most extreme range of outcomes! That is fun!!
Stochastic dynamic programming

• If we have a clearly defined stochastic process, for instance rainfall, we can apply stochastic dynamic programming and identify the best strategy to cope with weather extremes.

• Given the characteristics of the stochastic event we calculate the best strategy that maximizes the PV of the net benefits; it tells us what retention, storage and pump capacity is needed and what should be the size of the sewage system to handle water.
3 Let’s shift to level 2

Probabilities are not known

We have scenarios: possible future developments, but we do not know how likely they are..... “They are equally likely”
Probability of sea level rise by the year 2100

• KNMI scenarios

• 35 cm
• 85 cm

• Otherwise not so much information:
• Deltacommissie: “extreem” 110+ 20cm
• What should a policy maker do who needs to plan the new sluices at IJmuiden???
• Risk of overinvesting; or doing too little ...
What about obtaining best probabilities that we can produce??

• Expert judgment on the probability distribution for sea level rise?

• If that could be obtained, we could make rational choices about our adaptive policies, by balancing marginal cost of dike heightening with the expected benefits of avoiding flood damage
4. Real options and learning

- Over time we will learn about sea level rise
  a) We will have better models ...
  b) We will also be able to observe sea level rise in the coming decades

- Does this imply that we better wait with investing?

- Or should we act now?
Research questions

• What is an economically efficient dike height?
  – ...Under an uncertain rate for the structural increase of the water level
  – ...and provided that we may learn about this rate?
Optimal dike height

Original base case (no learning, no uncertainty) for different structural increases of the water level. Known moment of learning.
Results

- The total value of (perfect) information is in the order of 1-2% of total expected costs.
- The original base case solution does not remain periodic under a probabilistic rate for the structural increase of the water level.
- Uncertainty in isolation increases dike heightening effort.
- In contrast, a non-zero probability of future learning tends to reduce dike heightening.
Deep uncertainty

• Need to study
• Need to reflect on implications
• If costs of avoiding the risk is zero, then quickly take measures! (Ozone layer!?)
• Take actions to delay; search for a hedging strategy that allows you to act appropriately if necessary, but avoid excessive costs
• Monitor and invest in analysis of early warning signals
• Be risk averse and avoid approaching areas of catastrophic risk ... But this may be expensive in terms of welfare ......
Rand corporation

Robust decision making

Complex systems:
analyze all possible developments in the system and
analyze which strategy is robust: i.e. it will perform
well under a very wide range of possible states of the
world

Do not go for the optimal result
But go for robustness
Conclusions 1 of 3

• If probabilities of states of the world are known we can use various optimizations procedures for mitigation and adaptation policies

• If probabilities are not known, we can use scenario analysis, but in the end we need to choose a scenario if we implement policies. Which one to choose? ..
Conclusions 2 of 3

- We will probably learn about climate change. This provides an incentive to wait with policies, but we cannot wait too long given the risks at stake ... Search for safe landing corridor!
- For adaptation: be prepared, because the climate is changing and more heavy precipitation is already arriving ...
- For sea level rise: continue to observe, and for the moment formulate the best pdf that is possible to base decisions on... for 2030, 2050 ..2100
Conclusion 3 of 3

• For a setting of deep uncertainty, we need to obtain better information
• We should keep our options open and avoid excessive risks (e.g. slow down of Atlantic Gulf stream)
• In the long run a fundamentally changed climate with all its consequences cannot easily be compensated with money: It is better to protect future generations and focus on mitigation!