Evaluation of flood damage and flood risk

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Structure of the lecture

1. Evaluation – an economic perspective
2. Weighting land use and flood protection
3. Calculation of flood damage potential
4. Vulnerability analysis
5. Calculating and assessing flood risk
6. Consequences and problems of flood risk management
7. Outlook: Research challenges of flood risk management
1. Evaluation – an economic perspective

- What is value?
- What is the economic value of goods?
- Which significance do prices have?
- What about the value of non-market good (health, environment)?
- How to consider economic value over a period of time?
The economic value of goods

Three components of economic value:

1. Costs
2. Producer surplus
3. Consumer surplus

Market price P* is efficient: At this point nobody can be made better off without making somebody else worse off!
The economic value of goods

Welfare effects of measures are determined by changes in producer and consumer surplus:

Producer surplus change: \(-c + e\)

Consumer surplus change: \(-d - e\)

Welfare effect: \(-c - d\)

Example: state-regulated production of a good \((P_s; Q_s)\)
The economic value of goods

What about the economic value of a natural good?

Valuation approach: trying to construct the demand curve (asking people for their willingness to pay)

Example: natural floodplain

Valuation problem: there is no market, at least no production!

Price (P), costs, willingness to pay

Output (Q) ha of floodplain
Value and time

If goods are evaluated over time, several aspects need to be considered:

- Inflation: calculating Euro values for a base year

- Market developments: estimating market price developments (very tricky task – often not done)

- Time preference (people prefer present values): discounting future values (opposite of paying interest)
2. Weighting land use and flood protection

Philosophies of evaluating flood protection measures are changing over time:

Past / today: Design-Standard Approach
Comparing costs of measures to ensure a standard

Today / future: Risk management
Comparing costs of measures to benefits of measures
Benefits and costs of flood protection measures

**Costs of flood protection**
- direct costs of measures
- reduced welfare due to changed land use
- reduced non-market consumer surplus due to changes in reduced land use or due to realisation of measure

**Benefits of flood protection**
- reduction of flood damage
- increased welfare due to changed land use
- increased non-market consumer surplus due to changes in land use or due to realisation of measure

**Design-Standard Approach:**
measures to achieve same standard for all regions

**Risk Management:**
consider efficiency in the choice of measures
Advantage of the wider risk management perspective

Fictitious example: increasing natural floodplains by relocating levees

**Costs of flood protection**

- direct costs of measures: **relocating levees**
  - 200 Mio € (total)

- reduced welfare due to changed land use: **Profit loss agriculture**
  - 3 Mio € (yearly)

- reduced non-market consumer surplus: **none**
  - ---

**Benefits of flood protection**

- reduction of expected flood damage:
  - 10 Mio € (yearly)

- increased welfare due to changed land use:
  - **Profit gains from pasture farming**
  - 1 Mio € (yearly)

- increased non-market consumer surplus due to:
  - **increased recreational value of floodplains**
  - 0.5 Mio € (yearly)

Is this flood protection measure advantageous?
And under which conditions?
5 Minutes: discuss and calculate with your neighbour!!

Risk Management:
Weighting benefits and costs for a given time period!
3. Calculation of flood damage potential

Crucial definitions:

**flood damage ex post**: damage figures calculated after a flood event

**expected flood damage**: flood damage figures estimated before a flood event in the context of flood risk management

**flood damage potential**: maximum possible damage in a flood prone area

caution needed:

flood damage potential is sometime also used as a synonym for expected flood damage
Categories of flood damage

Current focus of flood damage evaluation

- **Physical water contact**
  - Direct
    - Tangible: buildings, infrastructure, crop, cattle, capital goods, consumer goods, ...
    - Intangible: life, health, environment, unique goods, art and cultural goods, ...
  - Indirect
    - Tangible: production losses (in and outside inundation area)
    - Intangible: market disturbances, loss of time, ...

- **No physical water contact**
  - Tangible: reduced competitiveness, migration, increased vulnerability of economic actors, ...
  - Intangible: ...

Economic damage categories

- **Monetary**
  - Tangible: buildings, infrastructure, crop, cattle, capital goods, consumer goods, ...
  - Intangible: life, health, environment, unique goods, art and cultural goods, ...

- **Non-monetary**
  - Tangible: production losses (in and outside inundation area)
  - Intangible: market disturbances, loss of time, ...

- **Net**
  - Tangible: reduced competitiveness, migration, increased vulnerability of economic actors, ...
  - Intangible: ...

**e.g.**
- buildings
- infrastructure
- crop, cattle
- capital goods
- consumer goods
- ...

- life
- health
- environment
- unique goods
- art and cultural goods
- ...

- production losses (in and outside inundation area)
- market disturbances
- loss of time
- ...

- reduced competitiveness
- migration
- increased vulnerability of economic actors
- ...
Flood damage evaluation: a matter of scale!

Accuracy

Costs per area

scale of study site
local
regional
(inter-)national

macro scale
meso scale
micro scale

Source: Meyer 2001, S. 30; Reese 2003, S. 54
## Scale level and accuracy of evaluation

### Example for a meso type evaluation

<table>
<thead>
<tr>
<th>Scale level</th>
<th>Data needs</th>
<th>Size of study region</th>
<th>Planning level</th>
<th>Accuracy</th>
<th>Expenditure per area</th>
</tr>
</thead>
<tbody>
<tr>
<td>macro</td>
<td>low: average values per district</td>
<td>(inter-) national</td>
<td>(inter-) national flood protection policy</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>meso</td>
<td>middle: land use specific values</td>
<td>regional</td>
<td>flood protection strategies</td>
<td>middle</td>
<td>middle</td>
</tr>
<tr>
<td>micro</td>
<td>high: damage data per object type</td>
<td>lokal</td>
<td>local flood protection measures</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>
Example: Damage potential für Jade-Weser Estuary

Research project KRIM
(Climate change and preventive risk and coast management at the German coast)

- Damage potential for a study area of regional dimension

Source: Meyer 2005
Applied method

- classical meso scale approach:

I. Quantifying values on district level
II. Spatial damage modeling for land use units
III. Integration of geomarketing data

Source: Meyer 2005
I. Quantifying values on district level

value categories

inhabitants
Assets:
residential assets
household goods
cars
capital assets
inventory stocks
livestock
public open space
streets
railways
value added
ground value

Source: mostly official statistics
same reference year
Time values
## Results for Bremerhaven

<table>
<thead>
<tr>
<th>value categories</th>
<th>value (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>inhabitants</td>
<td>122741</td>
</tr>
<tr>
<td>Assets:</td>
<td>Mio. Euro</td>
</tr>
<tr>
<td>residential assets</td>
<td>4277</td>
</tr>
<tr>
<td>household goods</td>
<td>1710</td>
</tr>
<tr>
<td>cars</td>
<td>454</td>
</tr>
<tr>
<td>capital assets</td>
<td>4358</td>
</tr>
<tr>
<td>inventory stocks</td>
<td>494</td>
</tr>
<tr>
<td>livestock</td>
<td>0.3</td>
</tr>
<tr>
<td>public open space</td>
<td>33</td>
</tr>
<tr>
<td>streets</td>
<td>338</td>
</tr>
<tr>
<td>railways</td>
<td>12</td>
</tr>
<tr>
<td>value added</td>
<td>3144</td>
</tr>
<tr>
<td>ground value</td>
<td>3269</td>
</tr>
</tbody>
</table>

Source: Meyer 2005
II. Spatial modelling of damages for land use units

Source: Meyer 2005
Example: inhabitants

Source: Meyer 2005
Example: monetary assets per m²

Vermögenswerte in EUR / qm

- 0
- 0 - 5
- 5 - 50
- 50 - 100
- 100 - 250
- 250 - 500
- 500 - 750
- >750
- keine Daten

Source: Meyer 2005
III. Integration of geo-marketing data

here: considering data on purchasing power in small districts of Bremerhaven

Source: Meyer 2005
Damage potential for monetary assets

... under consideration of purchasing power

Vermögenswerte in EUR / qm

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Lightest</td>
</tr>
<tr>
<td>0 - 5</td>
<td>Light</td>
</tr>
<tr>
<td>5 - 50</td>
<td>Light</td>
</tr>
<tr>
<td>50 - 100</td>
<td>Light</td>
</tr>
<tr>
<td>100 - 250</td>
<td>Medium</td>
</tr>
<tr>
<td>250 - 500</td>
<td>Medium</td>
</tr>
<tr>
<td>500 - 750</td>
<td>Medium</td>
</tr>
<tr>
<td>&gt;750</td>
<td>Dark</td>
</tr>
<tr>
<td>keine Daten</td>
<td>No color</td>
</tr>
</tbody>
</table>

Source: Meyer 2005
Comparison: Damage modelling with and without geo-marketing data

change in results

Differenz Vermögenswerte
in EUR / qm
(Methodik I - Methodik II)

- < -500
- -500 - -250
- -250 - -100
- -100 - -50
- -50 - -5
- -5 - 5
- 5 - 50
- 50 - 100
- 100 - 250
- 250 - 500
- > 500

keine Daten
Gemeindegrenzen

Improved estimation of spatial value distributions within cities!

Source: Meyer 2005
Categories of flood damage

What about intangible damages?

- buildings
- infrastructure
- crop, cattle
- capital goods
- consumer goods
- ...

- life
- health
- environment
- unique goods
- art and cultural goods
- ...

- production losses (in and outside inundation area)
- market disturbances
- loss of time
- ...

- reduced competitiveness
- migration
- increased vulnerability of economic actors
- ...

E.g.:

- tangible
- intangible
- tangible
- intangible

physical water contact
monetary

indirect

non-monetary
Example: evaluation of ecosystem functions

Different Economists tried to quantify the value of floodplain ecosystem function:

**Gren et al (1995):** ecosystem services of Danube floodplain (indirect methods: relating to existing markets)
- provision of timber and clean water: 110 € / year and ha
- sink services for nutrients: 212€ / year and ha
- recreational functions: 180€ / year and ha

**Meyerhoff (2001):** willingness to pay to protect island Sylt (direct method: creating hypothetical markets)
- use and non-use values of consumers: 325 € /year

Such studies can be used to quantify an intangible good like the environment and to attach monetary values to ecosystems!
4. Vulnerability analysis

a) Diversity of vulnerability definitions

International Strategy for Disaster Reduction (ISDR) (2004):
 "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.”

ITC (2004):
 "The degree of loss resulting from the occurrence of a phenomenon.”

Sarewitz et al (2003):
 "Inherent characteristics of a system that create the potential for harm but are independent of the probability of any particular hazard or extreme event”

Green (2004):
 "The potential for a receptor to be harmed.”
a) Diversity of vulnerability definitions

Klijn (2004):
"Susceptibility * value"

Jones and Boer (2003):
"The amount of potential damage caused to a system by a particular-related event or hazard."

IPCC (2001):
"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate vulnerability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."
4. Vulnerability analysis

b) Elements of a vulnerability analysis

**Exposure indicators**
- proximity to river/coast
- elevation of area
- frequency of floods

**Elements at risk**
- persons, firms
- buildings
- production
- ecological populations
- etc.

**Flood characteristics**
- duration
- velocity
- inundation area and depth
- etc.

**Susceptibility indicators**
- susceptibility in a narrow sense
- susceptibility incl. social capabilities:
  - preparedness
  - coping
  - recovery

**Ecologic units, systems**
- resilience indicators

**Exposure characteristics**

**Severity of inundation**

**Affected units and their value (damage potential)**

**Flood vulnerability analysis**

**Expected damage**

**Source**: Messner/Meyer 2005
c) Our definition of vulnerability

“Vulnerability can be defined by the characteristics of a system that describe its potential to be harmed.

It can be expressed in terms of functional relationships between expected damages regarding all elements at risk and the susceptibility and exposure characteristics of the affected system, referring to the whole range of possible flood hazards.” (Messner, Meyer 2005)
Evaluation of direct flood damage

Source: Asselman/de Bruijn
From hydrological model to economic damage

Source: M. Beyene, PROAQUA Aachen
Damage potential for monetary assets

... under consideration of purchasing power

Source: Meyer 2005
Expected flood damage for a special event

Expected flood damage for this special event: 480 Mio. Euro

Source: Meyer 2005
5. Calculating and assessing flood risk

**Definition of Flood Risk:**
Flood risk is a function of probability, exposure and vulnerability. Often, in practice, exposure is incorporated in the assessment of consequences, therefore risk can be considered as having two components — the probability that an event will occur and the impact (or consequence) associated with that event.

Flood Risk = Expected damage * probability

€ / year = € of a specific event * (1/return period)
From hydrological model to flood risk

1a: Hydrology
1b: Water level [mNN]
1c: Damage calculation
2a: Hydraulics
2b: Water depth [m]
2c: Damage [€]

Source: Beyene, PROAQUA Aachen
Mapping results in flood risk maps

Flood risk map (Egli 2000)
### Analysis of aggregated flood risk of a region regarding to two protection measures

<table>
<thead>
<tr>
<th>Return period</th>
<th>Measure 1, total damage</th>
<th>Measure 1, flood risk</th>
<th>Measure 2, total damage</th>
<th>Measure 2, flood risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 yrs.</td>
<td>100 mio €</td>
<td></td>
<td>0 mio. €</td>
<td></td>
</tr>
<tr>
<td>50 yrs.</td>
<td>300 mio. €</td>
<td></td>
<td>200 mio. €</td>
<td></td>
</tr>
<tr>
<td>100 yrs.</td>
<td>400 mio. €</td>
<td></td>
<td>800 mio. €</td>
<td></td>
</tr>
<tr>
<td>500 yrs.</td>
<td>1000 mio. €</td>
<td></td>
<td>5000 mio. €</td>
<td></td>
</tr>
</tbody>
</table>

What are the implications of these flood risk data?
6. Consequences and problems of flood risk management

Consequences:

- introduction of economic (efficiency) considerations into flood policy (orientation for public spending)
- unequal treatment of regions with different flood risks
- unrealistic protection goals are revealed
- relying on methods to quantify damages
6. Consequences and problems of flood risk management

Problems:

- not all kinds of monetary damages can be calculated easily and at low cost

- consideration of non-monetary damages is still weak

- incomplete flood risk figures might give wrong signals for policy making

- national or state laws might prohibit unequal treatment (design standards granted by law)

- no harmonised evaluation methods at hand
7. Research challenges of flood risk management

a) also include other economic evaluation methods

- buildings
- infrastructure
- crop, cattle
- capital goods
- consumer goods
- ...  

- life
- health
- environment
- unique goods
- art and cultural goods
- ...  

- production losses (in and outside inundation area)
- market disturbances
- reduced competitiveness
- migration
- increased social vulnerability of actors
- ...  

- ...  

- reduced competitiveness
- opportunity cost method
- input-output modeling

But there are still open evaluation questions !!
b) develop methods to include non-monetary damages

eexample 1: social vulnerability

People/communities may be vulnerable in terms of:

- being more likely than others to be flooded
- being less likely to be aware of flood risk
- being less able to respond to the threat, and to recover afterwards

Source: Tapsell et al 2005
example 1: social vulnerability

Social vulnerability indicators:
- age (above 75)
- Ill-health
- financial hardship

Source: Tapsell et al 2005
Results for regions with different income positions

Maidenhead (near London)

Salford / Manchester

Social Vulnerability
- Missing value
- Very low
- Low
- Average
- High
- Very high

Results are very likely to be complementary to direct damages!

Flood protection based on pure economic damage data favours higher income households!

Source: Tapsell et al 2005
example 2: cultural vulnerability
example 3: ecological vulnerability

c) improve multicriteria methods of decision support

- Identification of vulnerability hot spots
- Choice of measures based on minimising selected vulnerability effects
d) further research needs

- better estimation of risk to loss of life
- harmonising evaluation methods: guidelines
- impact of risk perception on damage generation
- ...

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Thank you very much for your attention