General equilibrium simulations of floods

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Sinergia-CCAdapt Workshop

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Structure of the presentation

- Context
- Models
- 4 steps towards modelling the economic costs of floods with adaptation
- Special emphasis on adaptation under uncertainty with bounded rationality
- Research in Gunter Stephan's group
- Expected results

General equilibrium simulations of floods
- Contract with FOEN for 2014-2016
- Based on existing literature and research, including our own previous projects on CC impacts and adaptation
- Gaps in the literature identified, in particular the lack of monetary assessment of impacts
- Enhance integrative CGE modelling framework (GEMINI-E3) and perform simulations
- In depth analysis of costs of floods with adaptation in this Sinergia project
Economic modelling

The two models

- “Theory with numbers” ("toy model")
  - close to theoretical models, with stylized data
  - high flexibility

- GENESwIS
  - fully dynamic CGE calibrated to Swiss input output table
  - open economy (CH) including taxes and GHG emissions
  - simulates interaction of inter-temporally optimizing agents (firms, households) and government
  - flexible prices and quantities
  - substitutability of consumption goods & inputs to production governed by nested CES utility and production functions
GENESwIS: sectoral production (NCES)
The simulation approach

Four steps

1. Improve knowledge about flood damages
2. Introduce floods into the simulation models
3. Incorporate adaptation measures into the models
4. Try alternative decision-making rules for adaptation
Four steps

Step 1

1. Improve knowledge about flood damages
   - use inputs from "impacts" group
   - select historical flood events
   - assess related damages (WSL database)
   - learn about possible adaptation measures
   - develop dynamic damage projection methods for the selected types of events
   - project damage costs until 2100
Identify typical flood events
Floods selected for economic simulations

<table>
<thead>
<tr>
<th>Priority</th>
<th>Year/ month</th>
<th>Most affected</th>
<th>Magnitude</th>
<th>Return period</th>
<th>CH impact Mio. CHF</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1999 May</td>
<td>Thur Aare Linthkanal Bodensee</td>
<td>1129 m³/s 613 m³/s</td>
<td>&gt; 150</td>
<td>751</td>
<td>Extensive damage, different from 2005 in terms of process and affected region.</td>
</tr>
<tr>
<td>2.</td>
<td>2000 Oct</td>
<td>Lago Maggiore</td>
<td>BU, UR</td>
<td>&gt; 150</td>
<td>3109</td>
<td>A lake case; differs from other floods w.r.t. adaptation measures and spatial development.</td>
</tr>
<tr>
<td>1.</td>
<td>2005 Aug</td>
<td>Aare Reuss</td>
<td>605 m³/s 523 m³/s</td>
<td>&gt; 150 30</td>
<td>722</td>
<td>The largest historical event in terms of damages.</td>
</tr>
<tr>
<td>2.</td>
<td>2007 Aug</td>
<td>Birse Aare</td>
<td>383 m³/s 524 m³/s</td>
<td>&gt; 150 62</td>
<td>118</td>
<td>Processes similar to 2005. How has adaptive behaviour reduced costs relative to 2005?</td>
</tr>
<tr>
<td>2.</td>
<td>2011 Oct</td>
<td>Kander Lötschental</td>
<td>65 m³/s 120 m³/s</td>
<td>&gt;100 30-100</td>
<td>777</td>
<td>This particular process may increase in frequency due to climate change.</td>
</tr>
</tbody>
</table>
Step 2

2. Introduce floods into the simulation models
   - unanticipated stochastic shocks
   - destruction of capital (more/less vulnerable locations)
   - direct impact on welfare (e.g. non-market damages)
   - toy model:
     Poisson flood event distribution & log-normal distributed damage scale
Four steps

Step 2

- Perfect foresight, but not concerning the timing and magnitude of flood events
- The model needs to be re-initialized after each unanticipated flood
- Evaluating individual flood scenarios as well as Monte Carlo simulations
3. Incorporate adaptation measures in the model

- **types of measures**
  - (infra-)structural, e.g. protection capital, alarm systems
  - spatial planning, e.g. building in less vulnerable locations
  - environmental information

- **private and public adaptation**
  - private: structure of the economy adapts to shocks
  - public: investment into adaptation capital & spatial planning

- **costs and benefits of adaptation**
  - cost function: total costs and input shares
  - crude estimates of related damage reduction benefits
4. Try alternative decision-making rules for adaptation

- use insights from the "theory" and "policy" groups
- autonomous adaptation by optimising economic agents
  - depends on their anticipations
- proactive vs. reactive public adaptation according to decision rules
  - reference: optimal decision-making under uncertainty
  - descriptive: sub-optimal decision-making, e.g. heuristics
  - prescriptive: how to improve public decision-making on adaptation?
First results

Model and assumptions

- Simulations with toy model
- Two polar assumptions about private agents' anticipation relative to flood risks
  - 'perfect foresight': actors know when and what flood will occur -> optimal adaptation
  - 'hazard blindness': no anticipation that floods may occur and no learning from events -> no proactive adaptation
- No public adaptation yet
### First results

**Perfect foresight vs. hazard blindness** (10 runs)

<table>
<thead>
<tr>
<th>Perfect foresight</th>
<th>Hazard blindness</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph 1" /></td>
<td><img src="image2.png" alt="Graph 2" /></td>
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<tr>
<td><img src="image3.png" alt="Graph 3" /></td>
<td><img src="image4.png" alt="Graph 4" /></td>
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</tbody>
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**Capital stock**

**Investment**

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First results

Monte Carlo simulation (1000 runs)

(a) Capital stock

(b) Investment
Core of the research

- How to improve on sub-optimal decision-making for adaptation

Focus: decision-making under flood hazard uncertainty

- risks may be neglected before they materialize
- surprising extreme events are likely to induce additional adaptation
- agents may under- or overestimate damage increase through climate change
  - what is our own knowledge base in this respect?
  - how does a society learn?
  - how do scientists learn?
  - learning as part of the adaptation strategy?
Research in Gunter Stephan's group

Goals and means

- Quantitative assessment of flood damages with different adaptation options
- CGE model with a multi-region/multi-tier setting
- Main data and knowledge input:
  - Swiss input-output table (2008), data on sectoral output and employment at municipality level, and data on commuting (Swiss Statistics)
  - data on representative flood damages by municipality (WSL)
  - aqua-protect data on regional vulnerability ('impact' group)
  - financing strategies ('theory' group)
  - interaction between national and regional government ('policy' group)
Key modelling choices

- Dynamic Ramsey-type model with a time horizon of 2100 and 5-year periods
- Regional disaggregation by distinguishing land that is
  - more or less vulnerable to floods
  - an input factor for production or assimilated to households consumption
- Sectoral disaggregation: Sectors I, II and III have different production structures, especially with respect to land use
- Impacts of floods are described through damages to uncovered land and land covered with immobile capital and infrastructure
Key modelling choices - adaptation

- Damage functions are calibrated to WSL data
- Adaptation reduces lands' vulnerability to floods
- Only public adaptation is analysed:
  - land-use planning
  - establishment of protected areas
  - flood protection constructions
- Differentiation between local and national adaptation measures, i.e. provided either by the regional or the national government
- Analysis of different forms of adaptation funding
Expected results

- Advancements in CGE modelling of
  - flood risks
  - adaptation measures
  - decision-making for adaptation under uncertainty
  - decision-making for adaptation in a federal context

- Estimates of the cost of myopic policies under alternative flood scenarios and decision rules

- Finding realistic means to improve on the decision-making for flood adaptation
  - what are the most costly mistakes that we make?
  - what simple rules or spread of information could avoid these mistakes?

General equilibrium simulations of floods
Economic Models for the Numerical Analysis of Climate Change Impacts and Adaptation

Teams

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THANK YOU FOR YOUR ATTENTION
Modeling of flood adaptation

Interdisciplinary collaboration

Economic theory group
Uni. Basel

Quantitative assessment of different decision rules under a deterministic and a stochastic setting.

Theoretical basis for modeling adaptation measures under uncertainty.

CGE group
EPFL

Expected flood damages and cost-benefit of adaptation.

Cost efficient adaptation measures considering climate change.

Projections of floods as a function of uncertain climate change.

Climate policy group
Uni. Bern

Most relevant floods in terms of economic cost.

Hydrologic impact group
Uni. Bern

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