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Optimal Local Adaptation Measures under Climate Uncertainties

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Abstract

Progresses in the assessment of economic damage from climate change have been substantial. However, the involved level of aggregation and the scale of analysis have largely missed the local level. Hence, the economic appraisal of local adaptation options remains limited to only few examples. This contrasts with the widespread recognition that climate change impacts will be felt more acutely at the local level. In this study, we explore the potential and limitations of a first-of-its-kind **dynamic stochastic optimization model** of the natural and economic system for the **appraisal of adaptation measures at the local scale under uncertain evolution of climate impacts**. We show that the approach of dynamic programming is promising at the local scale and suggests that flexible adaptation measures are economically often more optimal than their rigid counterparts.

Case study - The Alpine Valley of Grimsel (Central Switzerland)

The valley is an example of what alpine areas will be increasingly confronted with under impacts of climate change (including slow onset events such as glacier and permafrost changes).

Increasing threats from debris flows and floods, but evolution of the intensity and frequency of these events is highly uncertain

A number of adaptation options have been considered so far for this area including building a dam, close the main access road and relocate inhabitants.

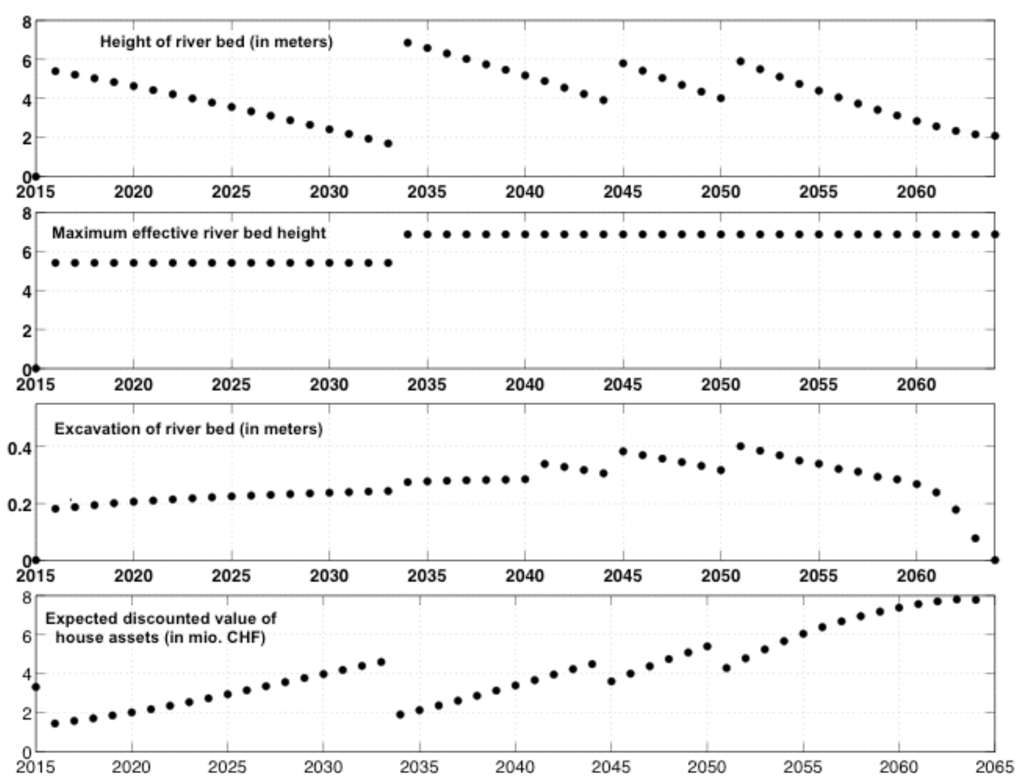
The stochastic hazard management problem

- The decision maker takes into account the stochastic occurrence of floods and debris flows which can destroy surrounding residential areas (here house assets).
- The objective of the decision maker is to maximize the expected discounted remaining value of house assets at a chosen the terminal year.
- The decision maker can decide at each time period to apply the (exit) control options of building a dam or relocation of inhabitants.
- In addition, we study under which condition excavating the riverbed might become a viable (preventing) adaptation option.

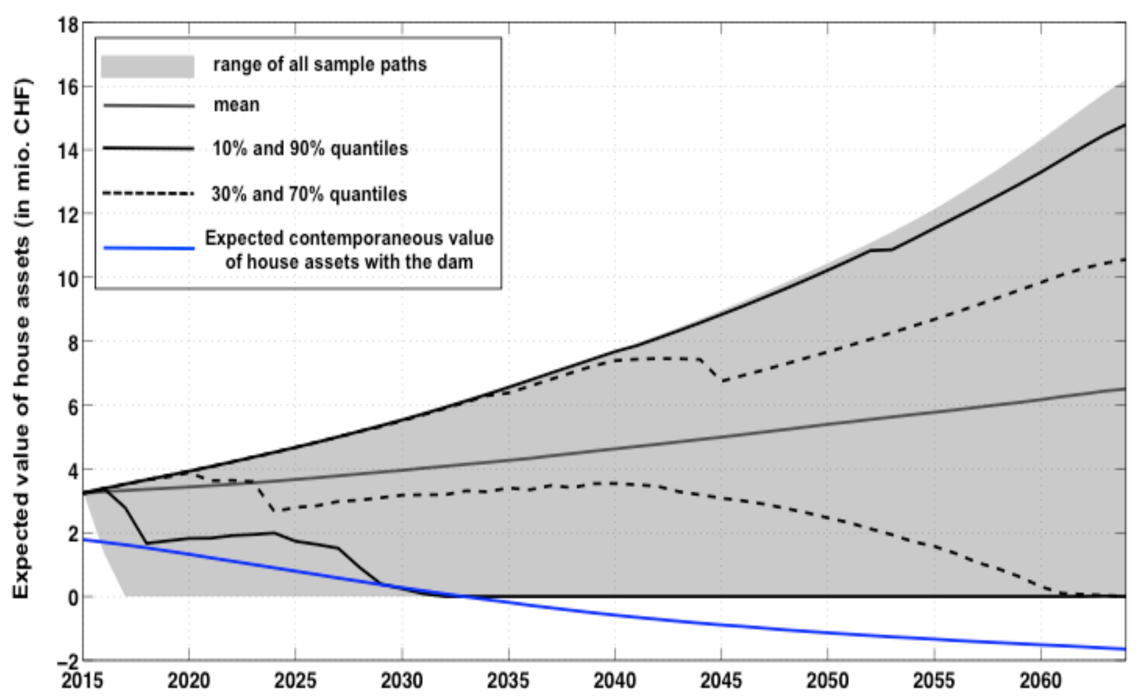
The dynamic programming solution method

- The model objective is to maximize the expected discounted remaining value of house assets at terminal year (we choose a 50 year horizon, 2015-2065).
- We define three categories of debris flows and 2 category of floods (under three different climate scenarios).
- Because of the continuous state and control variables, the model must be solved with dynamic programming.
- We start by the terminal period and proceed recursively backwards.

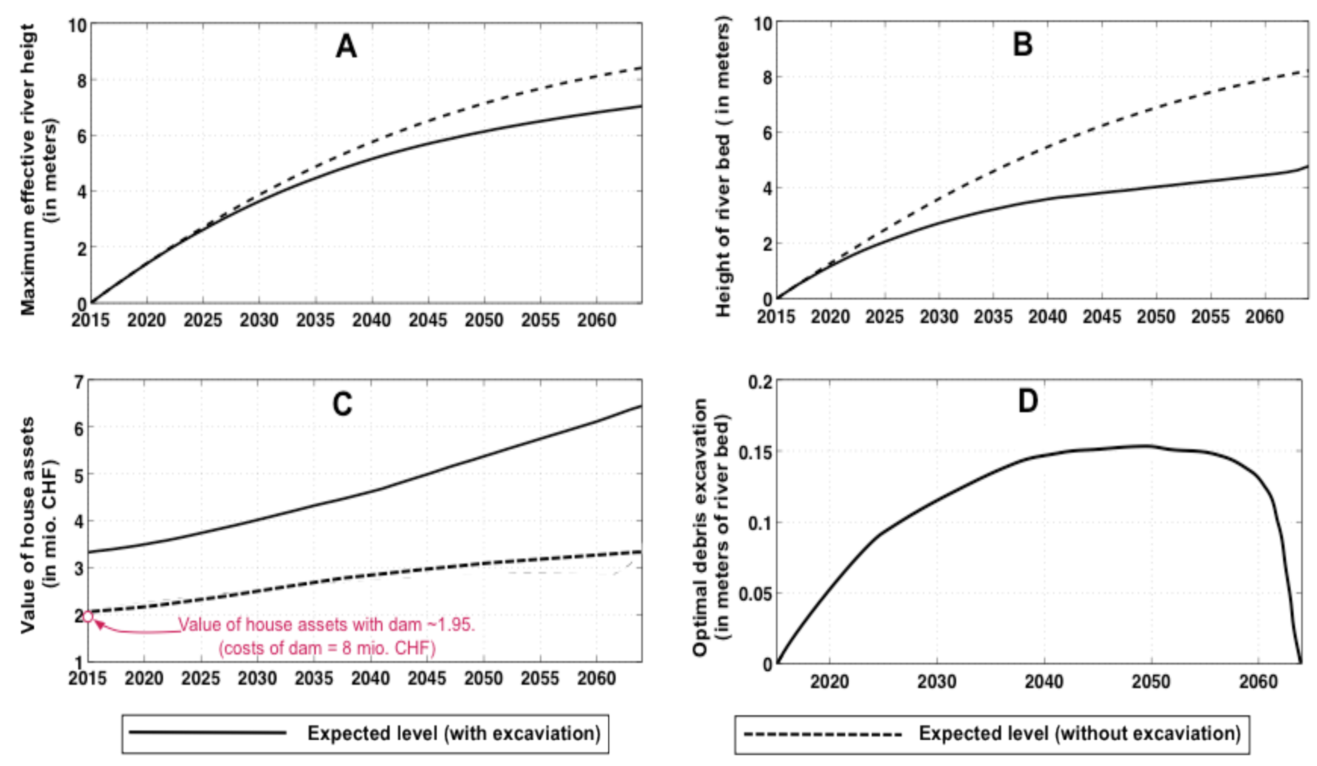
Results



One stochastic sample path of the model with two big debris flow events (2016 and 2034) and two small events (2045 and 2051) → **Due to simulated riverbed excavation the high-intensity debris flow event in 2034 does not impact house assets to a full extent.**



Statistic of 100'000 stochastic sample paths. The gray-shaded area shows the possible range of expected values from all simulations → **The expected value of house assets at the terminal period increases to. 6.5 millions CHF. In 30% of the cases all house assets will be destroyed.**



Panels A and B show that the option of excavation leads to an optimal reduction of the maximum effective river bed → **Excavation leads to a significant increase in the expected value of house assets and it's optimal around 2.2 metres/decade.**

- We observe that excavation is very effective in dampening the increase in the maximum effective river bed height.
- Excavation sets a buffer against further flood and debris flow events.
- Excavation leads to a significant increase in the expected value of house assets even after the costs of excavation are accounted for.
- Even without the option of excavation, building a dam is not optimal.
- The option of relocation is never optimal (not shown here).

While specific results from this study cannot be directly transferred to other local adaptation cases, we have achieved some advance in adaptation research by:

I. Integrating physically more realistic impact models in economic optimization studies.
II. Developing a model which is effective at a local scale where adaptation typically is implemented.
III. Extending the research to include identification of optimal adaptation decisions under uncertainties.

Conclusions

There is an important potential of our approach to support adaptation decision-making, even though the local scale is not the typical 'working domain' of these models. Results indicate that excavation of the river bed is a preferable adaptation option based on our assumption and modelling in comparison to building a dam or relocation of local settlements. This conclusion provides a new perspective to what has so far been sketched and evaluated by local authorities. Furthermore, it confirms that flexible and no/low regret adaptation measures are more optimal under uncertainties than hard adaptation solutions (e.g. building a dam).

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