Assessing the Economic Impacts of Flood Risks

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Content

1 Description work package

1.1 Problem definition, aim and central research questions

How do flood risks impact behavior of firms and households and regional economic development? This work package focuses on the assessment of indirect economic effects of floods. Indirect effects represent long-term damage to firm supply chains, migration of households and firms, real estate prices and labour markets. Computable General Equilibrium (CGE) models can be used to capture the effects of business interruption. However, the equilibrium approach typical of CGE-models needs elaboration in order to be able to handle important discontinuities related to flooding events. After a flooding event the economic system will be characterized by uncertainty, disruption and disequilibrium. Impact on real estate value, changing behavior of investors and public recovery plans may structurally impact sectoral and regional development paths.

To capture characteristics related to the recovery and performance of the flooded area, the RAEM-E3 model will be employed, providing a strong regional focus and a market imperfections approach based on New Economic Geography. The results are applicable for vital policy issues like spatial planning, flood protection and insurance.

The RAEM-E3 model will be expanded and complemented by a multi-agent modelling approach that can capture several characteristics not available in traditional models. Multi-agent models provide a powerful tool for addressing behavior of adaptive economic agents characterized by learning, increasing returns and path dependence and their impact on the economic system. It is these types of characteristics and adaptive dynamics that are considered of paramount importance in improving our understanding of economic adaptation and mitigation strategies to climate change risks.

Central research questions of this WP are:

- What are the impacts of flood event and flood risk on behavior of firms and households?
- How do regional economies recover from flood events?
- What is the role of governmental policy in the economic recovery of a flooded region?
- What are the economic modelling instruments which can help policymakers and researchers to project and make scenarios for the future development of the flooded region as well as to choose the most optimal policy to promote its recovery?

1.2 Interdisciplinarity and coherence between the projects

Work on this work package consists of three interlinked parts. The first part is dedicated to better understanding of economic effects of floods at the regional level and their modelling within the CGE modelling framework. The focus of this part is on the dynamics of economic recovery and further development of the flooded region. The second part contains a study of the changes in behavior of households and firms as a reaction to flood events and flood risk. This adaptive behavior will be implemented within a multi-agent modelling approach. The third part links the previous two methodological approaches and findings together within the framework of integrated CGE and multi-agent modelling approaches. On the basis of the developed methodology an extended version of the RAEM-E3 model will be constructed for the Netherlands. The model will be further used in order to assess various governmental policy scenarios related to flooding events.

The combination of two different methodological approaches allows on the one hand for accounting for changes in behavior of households and firms, which cannot be explained by classical micro-economic models with perfect information and full rationality assumptions. On the other hand it preserves the useful features of having a structural economic model which can be used for policy and scenario analysis.

The proposed approach combines classical micro-economic theory with behavioral economics and quantitative simulation approach.

1.3 Stakeholders

Relevant stakeholders include policymakers in all bodies of government concerned with water safety investment, insurance and spatial planning. Known interested stakeholders are PBL, hotspot Veenweidegebieden, hotspot Haaglanden and hotspot Waddenzee. Other organizations include, furthermore, Rijkswaterstaat, which is responsible for water defense maintenance. However, this WP is relevant to lower bodies of government dealing with water management as well, notably water boards, provinces and communities. Water boards will have to meet requirements for the safety of dikes and other water defense works based on flood probabilities by 2015 and hence are in the process of assessing various solutions for increasing water safety/ Of special interest are relevant cities with low elevation and high population density. In this respect, Amsterdam and Rotterdam have been included by the OECD in its top ten of urban agglomerations prone to flood risk according to assets exposed.

Relevant private parties include (re)insurance companies such as AON, Munich Re, Swiss Re, SCOR; since the new Water Law stresses citizens" own responsibilities for their own water safety, yet flood risk is currently not an insurable risk in the Netherlands. This is predominantly due to the particular elevation levels in the country and lack of information on eventual flood damage and flood probability. See also the project document on an elaboration of the stakeholder interaction.

2 Project 2.1 Development of methodological framework for integration of Computable General Equilibrium and multi-agent modeling approaches for flood risks

Project leader: dr ir M. Kok

2.1 Problem definition, aim and central research questions

How do flood risks impact behavior of firms and households and regional economic development? Indirect effects represent long-term damage to firm supply chains, migration of households and firms, real estate prices and labour markets. After a flooding event the economic system will be characterized by uncertainty, disruption and disequilibrium. Impact on real estate value, changing behavior of investors and public recovery plans may structurally impact sectoral and regional development paths.

Central research questions of the PhD trajectory are:

1. What are the impacts of flood event and flood risk on (adaptive) behavior of firms and households?
2. How do regions recover from flood events?
3. What is the role of governmental policy in an economic recovery of the flooded region?
4. What are the economic modeling instruments, which can help policy makers and researchers to predict the future development of the flooded region as well as to choose the most optimal policy to promote its recovery?

2.2 Approach and methodology

The approach will be to combine the computable general equilibrium (CGE) modeling approach typical of the RAEM-E3 model with multi agent (MAS) modeling approaches to arrive at an integral model framework for post-flood behavior of economic agents. Integrating CGE and MAS models could benefit both sides. CGE models are dominating economic policy modeling. They can depict detailed economic data and trace indirect effects through all economic sectors. Yet they would benefit from true micro foundations that can better address underlying causes for economic change. MAS could benefit from having real world macro-data imposed on them.

Three steps will be taken to arrive at the desired modeling framework. The first step is dedicated to better understanding of economic effects of floods at the regional level and their modeling within the CGE modeling framework. The focus of this part is on the dynamics of economic recovery and further development of the flooded region. The second entails a study of the changes in behavior of households and firms as a reaction to flood event and flood risk. This adaptive behavior will be implemented within a multi-agent modeling approach. The third step links the previous two methodological approaches and finding together within the framework of integrated CGE and multi-agent modeling approach. On the basis of the developed methodology an extended version of the RAEM-E3 model for the Netherlands will be constructed. The model will be used in order to assess various governmental policy scenarios related to flooding events.

CGE models deal with national economies, but there are also regional models as well as multi-regional and multi-country ones. A CGE model depicts the economy as a web of interrelated activities by four types of agents: producers, households, government, and the rest of the world. All markets are assumed to be in equilibrium, that is, quantity supplied equals quantity demanded (this constitutes "general equilibrium"). CGE models abstract from the process by which general equilibrium comes about. Dynamics can enter these models from various sources. Many models have producers with durable capital stocks that are updated each period through depreciation and investment. Some models assume forward-looking agents that hold expectations over future variable values and optimize over time. Exogenous population growth or exogenous shifts of the production function, meant to reflect technical progress, can also bring dynamics to the model.

RAEM-E3 is a spatial dynamic CGE model for the Netherlands comprising 40 regions and 15 economic sectors, identifying product, labour and housing markets per region and the respective ways in which these markets function. Its theoretical structure follows the New Economic Geography (NEG) school (Fujita, Krugman and Venables, 1999). RAEM-E3 model calculates indirect effects of economic shocks resulting from floods: loss of capital, loss of land use, loss of housing stock, and loss of labour force. RAEM-E3 uses results from direct flood damage models to estimate indirect and total flood damage. The indirect effects stem from supply and demand for products outside the inundated area, loss of transport connections, energy, water and communication networks, and feedback effects on labour and housing markets.

Multi-agent modeling has its origins in artificial intelligence, in particular in the study of complex adaptive systems (Holland and Miller, 1991). In multi-agent modeling, economic "agents" are heterogeneous, goal-oriented and adaptive. Adaptivity refers to the ability of the agents to learn which actions to take in order to better obtain their goals over time (Weidlich and Veit, 2008). "Adaptation" is therefore a central element of multi-agent modeling and evolutionary economics (Van den Bergh, Hofkes and Oosterhuis, 2006). Applications of multi-agent modeling are emerging (e.g. in diffusion of green products (Janssen and Jager, 2002), in electricity market models (Weidlich and Veit, 2008), and in (renewable) energy investment (Safarzynska, 2009)). In the proposed research project, a review of learning algorithms in the literature will be carried out; the most suitable ones for modeling agent behavior with respect to flooding events and risk will be selected and tested in small proto-type simulation models. Special attention will be paid to validation and verification procedures.

In the final stage of the project, the RAEM-E3 model will be expanded by an endogenous “learning” module for specified (groups) of agents, derived from or based on the models developed in stage 2. The full model will be used in order to assess various governmental policy scenarios related to flooding events. In integrating CGE and MAS approaches we want to follow a non-instrumental integration, That is both modelling approaches determine, or influence, important parts of one another. The MAS takes over determining some of the variables that would otherwise be computed in the CGE, and the CGE does the same for the MAS. The major challenge of this approach is the meaning of time in both modelling frameworks.

2.3 Scientific deliverables and results

Deliverables

- PhD- thesis consisting of the following scientific articles:
  - **D1**: Journal publication 1: methodology for integrating CGE and MAS approaches
  - **D2**: Journal publication 2: results of several case studies of the regional effects of floods based on the historical data
  - **D3**: Journal publication 3: description of the extended RAEM-E3 with MAS component and its first application
  - **D4**: Journal publication 4: results of extended policy analysis which identify the most relevant options for improving the recovery process of the flooded area
- Conferences/Meetings
  1. EAERE with the presentation of methodology for integrating CGE and MAS approaches
  2. ERSA conference with the presentation of extended RAEM-E3 with MAS component
  3. European Transport Conference with presentation of the effects of interruption of transport infrastructure due to flooding
- Database of extended RAEM-E3 model
- Implemented code of extended RAEM-E3 model
- Full mathematical description of the model
- Non-technical description of the model aimed at policy makers and general public

2.4 Integration of general research questions with hotspot-specific questions

The central research questions deal explicitly with questions posed by the Climate Knowledge Facility on the assessment of indirect economic effects of floods, enhancing effective application of modeling tools for monitoring and evaluation. The required applicability of existing models to indirect damage will be examined. The spatial economic division in 40 NUTS3-regions allows for detailed estimation and visualization, both for scenario impact and policy assessment. The focus on temporal differences in flood effects allows for visualization of effects over time (HSOV). Moreover, indirect economic effects are of crucial importance to safety related investment options, questions on which are posed by the hotspots (notably HSZW). Explicit attention is given to the opportunities for a focus on policy options after a flood, instead of the conventional focus on ex ante policy (HSRR). Options for a rather offensive water safety (HSWZ) can also be assessed for flood risk effects. The current modeling setup for RAEM-E3 is based on the Dutch national standard for CBA requirements, offering full applicability as a decision support tool for CBA based assessments (Climate Knowledge Facility).

2.5 Societal deliverables and results

Deliverables:

- **D5:** Literature review of the problem of dynamic effects of flooding
- **D6**: Non-technical presentation of the extended RAEM-E3 with MAS component
- **D7**: Non-technical presentation of the extended policy analysis

The vast experience with indirect effects and flood scenarios guarantees immediate applicable model output. Moreover, model extension results can be expected within 1,5 years. As well, vast experience in economic trade-offs and disequilibrium economics as well as the availability of various existing models guarantees successful combination of the CGE and multi agent modeling approaches. Application extends to spatial planning in densely populated areas, environmental planning of water safety and biodiversity, and water safety investment assessments. Moreover, the extended application of CGE modeling can satisfy a need for sophisticated asset value data by insurance companies. The insurability of water safety in the Netherlands is a current debate due to the implementation of the new Water Law.

Integrating and communicating the results of the modeling exercise to access all relevant stakeholders (in the technical, economic, and decision making research, policy and business sectors), central for successful modeling and implementation. To achieve optimal stakeholder involvement, 4 workshops will be organized to gather feedback on the project results in various stages. The goal of these workshops is achieving optimal practical assessment of data and modeling results in the involved research, policy making and business sectors. Frequently the practice of flooding treatment appears fragmented into technical, economic, and policy assessments. It is crucial to overcome this fragmentation and involve all those involved to achieve maximum integration and implementation. This is done by checking data on availability for business (insurance) purposes, comparing to domestic and foreign flooding modeling practice, regional practice and central decision making.

Contributing stakeholders will include at least reinsurance company AON Benfield and AON Risk Management (contact: Mr Marcel Hansen), for checks and feedback on data and modeling results availability for insurance purposes. A second stakeholder is MIT/USGS (contact: Dr Herman A Karl and Prof Dr Kenneth Strzepek) to compare data and modeling results with practice in other countries (US). Adaptability of data and modeling results to current practice (i.e. concerning the Dutch damage model HIS-SSM) involves flooding experts at Deltares (contact: Mr Jarl Kind), and flood damage modeling experts of the Rijkswaterstaat public infrastructure agency Waterdienst. Policy relevance of the data and modeling results is checked via input by hotspot Haaglanden representatives, ministry of Housing, Spatial Planning and the Environment policy makers, ministry of Economic Affairs policy makers, and ministry of Finance policy makers. Workshop 1, to be organized in September 2010, will deal with literature survey results and the related modeling requirements. This workshop centers around societal deliverable D5 and scientific deliverable D1. Workshop 2 will be organized in May 2011 and deal with modeling multi agent behavior as well as case studies around historical data. The workshop centers around scientific deliverable D2. Workshop 3 will be organized in September 2010 presenting first modeling results and centering around scientific deliverable D3. Workshop 4 will be organized in September 2013. During this workshop the final multi agent enhanced CGE model will be presented. This workshop centers around scientific deliverable D4 and societal deliverables D6 and D7.

All workshops will be facilitated by TNO and VU.

2.6 Most important references

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