Economic modeling and assessment of the impacts of climate change and adaptation strategies on freshwater resources

Work package leader: prof.dr. R. Brouwer (VU-IVM)

Content

1 Description work package

1.1 Problem definition, aim and central research questions

Climate change has important implications for the stock and flows of freshwater resources in the Netherlands. A significant share of the Dutch economy depends on the availability of these freshwater resources. Besides the direct economic interests in the availability of freshwater resources, also less tangible public goods can be identified that depend on these freshwater resources. Previous studies examining the allocation of limited freshwater resources under scarcity conditions, such as the „Droogtestudie", can be characterized as partial, single sector oriented, driven by hydrological models, and focusing primarily on the direct financial implications of water use restrictions. There is a need for a more integrated, multiple-sector, dynamic hydro-economic model. Such a model is not available in the Netherlands. This model should include sufficient economic rigor and regional detail to assess the wider direct and indirect economic impacts of implementation of national water policy as laid down in, for example, the National Water Plan and institutionalized water allocation decision rules under scarcity conditions. The main objective of this work package is to develop such an integrated hydro-economic model. This model will support policy and decision-making towards economically efficient water allocation across different water users and river basins whilst accounting for the shadow prices of scarce freshwater resources. This also provides the basis for the design of possible future water markets. The model will be developed in such a way that it can relatively easily be extended to include substance balances, links with surrounding river basin countries, and so-called non-market benefits of freshwater use.

Central research questions of this WP are:

- How efficient are current freshwater resources allocation decision rules across sectors and regions in the Netherlands from an economic point of view?
- What are the economic implications of future climate change scenarios on the freshwater resources allocation across sectors and regions in the Netherlands?
- How can economic efficiency of freshwater resources allocation be improved across sectors and regions in the Netherlands given future climate change through cost-effective adaptation strategies?
- What role is there for economic markets to improve freshwater resource allocation efficiency across sectors and regions in the Netherlands given future climate change?
- How to design efficient economic markets to improve freshwater resource allocation efficiency across sectors and regions in the Netherlands given future climate change?

1.2 Interdisciplinarity and coherence between the projects

Work in this workpackage consists of one project only. The work is highly interdisciplinary. The modelling of the economic impacts of climate change adaptation strategies on freshwater resources is directly linked to existing hydrological (water balance) models and water distribution models. Climate change scenarios have to be translated in terms of their impacts on water balances and distribution patterns (involving both meteorological and hydrological knowledge and information), which are intrinsically linked to water dependent socio-economic activities (involving both technical (e.g. agronomic) and economic knowledge and information). The economics of water use conflicts and cost-efficient solutions, including water markets, is driven by behavioral economic principles. Micro-economic principles are incorporated into macro-economic models of the Dutch water economy, while the assessment of the potential role of water markets is assessed based on institutional economics.

1.3 Stakeholders

Relevant stakeholders include policymakers in all national and regional government bodies concerned with freshwater allocation and security. Identified interested stakeholders include DG Water of the Ministry of Transport, Public Works and Water Management, Waterdienst Rijkswaterstaat, PBL, and regional water boards (e.g. Dommel and Regge and Dinkel). This WP is also relevant for the agricultural sector (Ministry of Agriculture, Nature and Food Quality) for irrigation water, the energy sector for cooling water, the food and paper industry for their use of food and paper processing water, and the recreation and tourism sector given the possible health risks associated with low water flow levels and bathing water quality. Most importantly at national level collaboration will be sought with the DG Water led Program Team „Zoetwater", including the organization of common stakeholder workshops. Where possible, a link will be established with the stakeholders consulted and involved in the Droogtestudie Nederland and follow-up studies, such as the „Landelijke Verkenning Zoetwatervoorziening".see also the project document on stakeholder interaction and related workshops.

2 Project 5.1 Economic modeling and assessment of the impacts of climate change and adaptation strategies on freshwater resources

Project leader: prof.dr. R. Brouwer (VU-IVM) in collaboration with J. Kind (Deltares)

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2.2 Approach and methodology

Water is more and more considered an economic good due to competing water use resulting in resource scarcity (e.g. Young, 2005). Policy demand for information about the economic value of water and the wider economic consequences of water management has increased correspondingly. The complexity of interactions between water and the economy can be captured through mathematical models linking relevant hydrological and biogeochemical structures and processes to economic „laws" of supply and demand underlying the provision of scarce water services. Historically, these models have been developed by hydrologists and civil engineers, focusing on single and multiple objective decision-making and trade-offs (e.g. Braat and Lierop, 1987; Andreu et al., 1996; Rosegrant et al., 2000; Cai et al., 2003). These models often include a detailed hydrological module to control for the hydro-geological heterogeneity in a basin area. In the case of agriculture, water demand and supply functions are for example based on an agronomic model, such as a crop yield function, which depends on factors like soil, crop acreage, rainfall, crop evapo-transpiration and irrigation system characteristics. Economic behavior is usually included through a profit maximization objective function, where fixed and variable production costs are subtracted from the yield benefits subject to the natural resource constraints such as land and water availability. The latter is obviously dependent on the hydro-geological conditions involved, including water supply and water quality constraints.

The key to integrated hydro-economic modelling is that water systems perform economic functions, they can be used as a source and a sink for socio-economic activity, and hence have economic value. Usually after some degree of transformation, water can be used as a source for economic consumption like drinking and recreation, and in economic production as an input factor in crop and food production, energy, paper, or metal production. The interaction between the hydrological and economic realm works both ways: water is transformed for economic use and the impact of economic use on water availability and quality consequently has implications in both the short and long term for the transformation process to modify water for economic use. This interaction and feedback mechanism will be at the core of the model development as this is where most scientific innovation will be found. The reciprocal effect of changes in the water system on the economic system and vice versa the effect of changes in the economic system on the water system is one of the most important future challenges in integrated hydro-economic modelling (Brouwer and Hofkes, 2008). Economic adaptation processes are sometimes implicitly part of the holistic models developed for water scarcity problems. Hydrological conditions and constraints determine water demand in different sectors (e.g. agriculture), and sets of hydrological supply and economic demand equations are solved simultaneously through (non-)linear optimization procedures. An important difference of the methodological approach used here is that the work will start from the economy side, making as much as possible use of existing hydrological (water balance) models, and focusing primarily on water dependent economic activities and their interrelationships with the wider economic system. Special attention will be paid to water pricing. Most existing water pricing models lack inter-sectoral linkages. The effect of water pricing on the general price level in the economy, and corresponding adjustments in inter-sectoral supply and demand, fall outside the scope of the analysis. Here, we focus explicitly on the wider economic impacts of water markets and water pricing through the simultaneous modelling of demand and supply equations in the meso and macro-economic models.

In order to achieve the main work package objective and answer the central research questions, the following main steps are distinguished:

1. Critical review of existing economic water allocation models and further identification of key methodological issues
2. Development of a methodological framework to the economic modeling and assess the impacts of climate change and adaptation strategies on freshwater resources at national and regional level focusing on the identified key methodological issues
3. Economic model development, integration (linking the economic model to available appropriate hydrological (water balance) model(s)) and calibration (including identification and quantification of water dependent activities)
4. Model testing: estimation of the direct and indirect economic impacts of future freshwater constraints and possible alternative adaptation strategies under climate change at national and regional level
5. Design of economically efficient water markets to address future climate change and freshwater adaptation strategies at national and regional level linked to the integrated hydro-economic model
6. Reporting of the methodological framework, developed integrated hydro-economic model, including the role of water markets, and model estimation results (in PhD thesis and separate conference and journal papers).

2.3 Scientific deliverables and results

The main outcome from this work package is an integrated hydro-economic model that allows policy makers to calculate through the impacts of future climate change scenarios and adaptation strategies on both freshwater resources and the economy at national, sector and regional level. Special attention will be paid to the wider economic impacts of existing and possible future water resource allocation rules and models. The integrated hydro-economic model will be designed in such a way that it also permits the design of cost-efficient freshwater allocation strategies, including the use of water markets. The following scientific deliverables are foreseen:

- PhD thesis on the economic modeling and assessment of the impacts of climate change and adaptation strategies on freshwater resources in the Netherlands

- Conference paper and peer reviewed international journal paper focusing on the innovative methodological issues involved in developing an integrated hydro-economic model to address freshwater resource allocation issues under climate change at both national and regional level.

- Conference paper and peer reviewed international journal paper about the introduction and design of economically efficient water markets (linked to the integrated hydro-economic model) to address freshwater resource allocation issues under climate change at both national and regional level.

2.4 Integration of general research questions with hotspot-specific questions

Droughts are increasingly becoming a problem in the Netherlands. The extreme drought in 2003 is a good example when important decisions had to be made with respect to the allocation of the limited freshwater resources. Freshwater allocation in times of more extreme droughts are expected to affect many regions in the Netherlands. The provinces of South Holland and Utrecht have indicated to struggle with solving these future freshwater resource allocation questions. Which adaptation strategies can they use which also take into account economic efficiency considerations. The work in this WP could add to answering such questions both at national, sector and regional level.

2.5 Societal deliverables and results

The most important societal outcome and deliverable is the opening up of the political and social discussion in the Netherlands, especially since 2003, how to ensure water security whilst taking into account important socio- economic interests. This includes market-based interests such as agricultural yield losses, but also non-market based interests related to recreational activities such as swimming. Bathing water quality was significantly impaired during the extreme 2003 drought. Extremely high surface water temperatures were recorded in 2003 and river flows were at a historical low, resulting in algal blooms and botulism, the death of fish, shellfish and birds, and the closure of bathing locations along the coast and inland for public health reasons. The Government issued a „code red‟ for surface water intake in order to safeguard national electricity production. The extreme weather conditions and the effects on economic activities (shipping, irrigation, electricity production), wildlife (birds and fish) and people (recreational bathing in open waters, water use in and around people‟s homes) were in the news every day for months, hence public awareness of the extremity of the event was very high. The work in this WP will contribute to these important societal issues and the societal debate how to deal with such extreme events, which are expected to increase in frequency and severity in the future due to climate change. The integrated model will aid policy and decision-making by helping to decide on the economic efficiency of future climate change adaptation strategies, taking into account the above mentioned wide variety of societal concerns and interests. Intermediate and final work package results will be presented to and discussed with policymakers and other interested stakeholders during workshops. Three workshops are foreseen. These workshop will be organized where possible together with the DG Water led Program Team „Zoetwater‟. Besides regional and national water managers, specific water users such as the agricultural, energy and recreation sector (the most important stakeholders are identified in Appendix 1 of WP5 under the heading „Stakeholders‟.) will be invited to participate in these stakeholder workshops to (1) help formulate relevant policy and research questions, (2) provide existing knowledge and information about current and expected future water demand, (3) inspect and validate (intermediate) results and outcomes, (4) help formulate climate-proof future water use management scenarios based on the research outcomes, and (5) disseminate research findings and link these findings back to practical day-to-day water use management practice. The first workshop will take place at the beginning of the project to present the set-up and design of the research, aiming to inform and consult policymakers and other stakeholders on the relevant issues involved. The second workshop will present intermediate results halfway through the project, allowing policymakers and other relevant stakeholders to provide feedback on these intermediate results, and the third workshop will present the final WP outcomes. The final WP results will also be written up for publication in a relevant Dutch water policy journal (e.g. H2O).

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