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General equilibrium modelling of the direct and indirect economic impacts of water quality improvements in the Netherlands at national and river basin scale

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ABSTRACT

The main objective of the study presented in this paper is to estimate the direct and indirect economic impacts of water quality policy scenarios in the Netherlands focusing on the reduction of emission levels of nutrients and a number of eco-toxicological substances. For this purpose, an Applied General Equilibrium (AGE) model consisting of 27 production sectors is extended to water through the inclusion of substitution elasticities between labour, capital and emissions to water in the sectors' production functions. The macro-economic costs of a 10, 20 and 50% reduction of the emission levels in the year 2000 of ten priority substances in the EU Water Framework Directive vary between 0.2 and 9.4% of Net National Income (NNI). A large share of the total economic costs are borne by important sources of pollution like commercial shipping, the chemical and metal industry. However, important spin-off effects due to adaptation take place in the tertiary service sector. Besides the estimation of the economy-wide impacts of water quality improvements, the novelty of the study presented here is found in the downscaling of national and sector results to river basin level and the estimation of shadow prices for water-polluting substances through the introduction of an emission permits market.

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1. Introduction

Integrated river basin models aim to evaluate and predict the impacts of policy interventions on both economic and water systems, based on the idea that aquatic ecosystems perform valuable functions in economic consumption and production processes. Water is used as an input factor (source) in economic production processes (e.g. food processing, electricity production etc.) and at the same time also as a sink for the unwanted by-products of economic production processes (e.g. emission of pollutants to water). In the Netherlands, there exist no comprehensive hydro-economic models to estimate and predict the economic consequences of water policy on both the water and economic system (see Reinhard and Linderhof, 2006; Brouwer et al., 2007 for recent overviews). Most water related models are hydrological models supplemented by a simple economic module. For instance, the impact of varying groundwater levels on agricultural production is estimated with the help of physical dose–effect relationships and subsequently multiplied by an average market price for agricultural output. Another example is the impact of surface water flow on commercial shipload. Changes in shiploads as a result of different flow levels are valued in economic terms with the help of an average market price per ton shipload. A more systematic and comprehensive economic assessment, accounting for the direct and indirect economic consequences of water policy, is often lacking. Integrated water quality models that link biogeochemical

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water and substance flow models to economic models are rare. Most of the time ad hoc analyses are carried out to assess, for instance, the cost and effectiveness of possible water quality measures to achieve certain water quality objectives (e.g. Lohani and Thanh, 1978; Beavis and Walker, 1979; Schleich et al., 1996; Gren et al., 1997; Van der Veeren, 1999; Yang and Weersink, 2004; Kramer et al., 2006; Bonham et al., 2006; Wang, 2006; Clasen et al., 2007). Costs are based on the direct financial engineering costs of a technical pollution abatement measure like wastewater treatment, while the environmental impact assessment is based on estimated dose–effect relationships or expert judgment of the emission reduction capacity of the specific technical measure. More comprehensive integrated modelling of the wider economic impacts of water pollution abatement is missing in the international literature, the recently published input–output model for the emission of nutrients in wastewater in the Chinese City of Chongqing in this journal (Okadera et al., 2006) being an exception. A few new examples are given in this special issue, but none of these examples are based on AGE models.[1]

Until now the existing models seemed to suffice to underpin water policy. However, the demand for integrated economic assessments increases, including the estimation of the indirect economic impacts of water policy. In the Netherlands this was explicitly acknowledged for the first time in the Fourth National Water Policy Document (Ministry of Transport, Public Works and Water Management, 1998). At European level, the Water Framework Directive (WFD) (2000/60/EC) adopted in 2000 is the first European directive to explicitly recognize the importance of the interdependency between aquatic ecosystems and their socio-economic values and advocates a more integrated river basin approach to water policy. Investments and water resource allocations in river basin management plans are guided by cost-effectiveness and cost recovery. An important challenge here is to collate and present data and information about the water system and the economy at the level of river basins. For the assessment of what the WFD refers to as ‘disproportionate costs’ in relation to the Directive's environmental objectives, the estimation of both the direct and indirect costs of policy measures is expected to be relevant, especially when the corresponding changes in water use and water prices are substantial.

In order to meet this growing demand for integrated water policy assessment tools and methods at the scale of river basins, an integrated water economics information system called the National Accounting Matrix including Water Accounts for River Basins (NAMWARiB) was developed in the Netherlands (Brouwer et al., 2005). NAMWARiB provides information about the interlinkages between the physical water system and the economy at national and river basin scale and is an extension of the National Accounting Matrix (NAM) with physical water and substance flow satellite accounts. Based on this information system, interactions between economic activities and the water system can be modelled in a systematic way to predict future changes in water and economic systems. As a first step, we use an existing static applied general equilibrium (AGE) model of the Dutch economy in the year 2000, and extend this to include the emission of a number of polluting substances to surface water, such as nutrients (N and P), heavy metals such as Arsenic (As), Chromium (Cr), Cadmium (Cd), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb), Zinc (Zn) and the chemical compound Polycyclic Aromatic Hydrocarbon (PAH). Information from NAMWARiB is used to disaggregate the macro-economic model results to river basin level. The direct and indirect economic consequences of a number of emission reduction scenarios are estimated with this model. The paper's main objective is to present the integrated hydro-economic model, the economic results of the emission reduction policy scenarios in the context of the WFD and the disaggregation procedure of the macro-economic results to river basin level.[2]

The paper is structured as follows. First, the AGE model is presented in Section 2. Section 3 provides information about the calibration procedure and the way emissions to surface water are integrated into the model, including investments in pollution abatement. Section 4 introduces the policy scenarios and discusses the model results at macro-economic level, sector level and river basin level. Finally, Section 5 concludes.

2. General model description

The integrated hydro-economic model is based on the static Applied General Equilibrium (AGE) model developed for the Dutch economy by Gerlagh et al. (2002). Gerlagh et al. introduced so-called ‘environmental themes’ such as global warming, ozone layer depletion, acidification, waste and eutrophication based on the National Accounting Matrix including Environmental Accounts (NAMEA) originally developed by Statistics Netherlands in the 1990s (e.g. De Haan et al., 1993). In this paper we apply a version of the model that includes two environmental themes: eutrophication and dispersion of toxic substances to surface water. The model maximizes net national income subject to environmental constraints and was originally calibrated for the year 1990, and updated for the year 2000 by Hofkes et al. (2004). A detailed description of the original model can be found in Gerlagh et al. (2002). Here we present a summary description of the model.

The model distinguishes twenty-seven production sectors, and identifies domestically produced goods by the sectors where these goods are produced. There are two primary production factors, labour and capital. The model distinguishes

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[1] A number of economic general equilibrium models exist, which have been applied to optimize water allocation across multiple water users, examples of which are provided in this special issue.

[2] It is important to point out that the WFD distinguishes between chemical and ecological objectives. In this paper, we focus on the chemical (emission-related) objectives only. Ecological measures to improve water quality include hydro-morphological changes such as floodplain restoration. In the Netherlands, these ecological measures are taken by the central government in close collaboration with regional water boards, and therefore — contrary to the implementation of pollution abatement technology in production processes — more difficult to link to specific economic sectors.

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