Integrating economic activity and water quality: Consequences of the EU Water Framework Directive for the Netherlands using a dynamic AGE approach

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ABSTRACT

There is a need to gain more insight into the consequences of the implementation of the Water Framework Directive (WFD) on the national economy. To fulfill this need, an integrated model framework has been developed which provides insight in the consequences of implementation of the WFD on the national economy as well as on water quality.

The integrated framework consists of a link between the economic model DEAN-W and the national substance flow model WFD Explorer. With DEAN-W the direct and indirect economic consequences of several policy alternatives are evaluated. Then, using WFD Explorer the effects of the sectoral emission reductions on water quality in the main water bodies in the Netherlands are calculated.

The simulations show that a 20% of emission reductions can be achieved through adjustments in the economy that are virtually costless from a macro-economic perspective. Unfortunately, when such a policy is implemented unilaterally, i.e. when foreign inflow of water pollution at the border is not decreased, the policy does not affect water quality in a significantly positive way either: for many waterbodies, concentrations remain at an unacceptably high level.

To reach a substantial improvement in water quality, it is necessary to reduce domestic emissions by at least 50%. This however results in a decline of the national income for 2015 with roughly ¾ percent. It should be noted that for certain substances the inflow from abroad (especially via the Rhine) will need to be reduced as well to be able to reach the water quality goals: for some substances, even a zero-emission unilateral policy will not improve water quality sufficiently in all waterbodies.

While further improvements of the integrated framework are certainly possible and desirable, the current analysis provides a good insight in the effects of the WFD on both the economy as well as water quality, and highlights the international dependence of Dutch water quality on foreign policies.

Keyword: Water quality, general equilibrium modelling, integrated modelling
JEL classification: C68, O52, Q25, Q28

1. INTRODUCTION

The consequences of the implementation of the EU Water Framework Directive (WFD) on the national economy and on water quality of the main water bodies are likely to be substantial, especially in a country such as the Netherlands, which is largely a delta area where several European rivers flow into the sea. The WFD is one of the first European directive that explicitly mentions cost-effectiveness as a tool for evaluation of the policies implemented.

For the Netherlands, there is no comprehensive hydro-economic model to calculate the economic consequences of the WFD (see Reinhard and Linderhof, 2006). Brouwer *et al.* (2007) have made a first attempt to estimate the economic consequences of the implementation of the WFD using a static AGE model that includes water related emissions for the different economic sectors. The disadvantage of the static AGE model is that it ignores the long-run impacts that are particularly interesting in the case of analyzing the impact of the implementation of the WFD in 2015. Therefore, we construct and apply an integrated water and economy model, that links economic activities to emissions of pollutants to water and to water quality of the main water bodies in the Netherlands Thus, we will be able to analyse the economic effects of measures to improve the water quality and subsequently the ecological quality of rivers, regional and local waters.

As the water quality requirements of the WFD are yet unknown, it is impossible to calculate the exact consequences of the implementation of the WFD. We therefore simulate the consequences for different emission reduction scenarios with varying degrees of strictness of domestic policies and changes in the water quality of the inflow from abroad. We then project the impacts of these policies on water quality in the main water bodies.

Section 2 describes the general features of the integrated model; Section 3 deals with the calibration of the model, and Section 4 presents the results of the calculations; Section 5 concludes.

2. MODEL DESCRIPTION

2.1 DESCRIPTION OF THE ECONOMIC MODULE

For the economic module, we use a forward-looking neo-classical growth model, DEAN-W. This model type has the advantage that the specification is fully dynamic: the agents take not only the current state of the economy, but also future situations into account when making decisions that affect current and future welfare. This intertemporal aspect lacks in recursive-dynamic models. Moreover, the transition path from the original balanced growth path to a new growth path is more flexible and realistic in a model with an endogenous savings rate (Barro and Sala-i-Martin, 1995). The model builds on the DEAN model as presented in Dellink (2005) and Dellink and Van Ierland (2005) and is adapted to study water quality issues; the main features of the model will be discussed briefly below.

Consumption of different goods and environmental services are combined in a nested CES utility function. Each level of consumption requires some combination of pollution permits and abatement, as will be explained in more detail below. Non-unitary income elasticities are specified using the Linear Expenditure System approach. The private households have income from the sale of their endowments of capital goods and labour, reduced with lumpsum transfers to the government. The government has three sources of income: sale of the pollution permits, the lumpsum transfer from the private households and tax revenues. The lumpsum transfers are endogenously adjusted to ensure budget balance for the government.

Effective labour supply grows with an exogenous rate as a combination of demographic developments and increases in labour productivity. Capital formation is based on an exogenous interest rate and endogenous capital stock. To account for capital stocks after the model's time horizon, a transversality condition is included. Producer behaviour is specified through a nested CES production function for domestic supply and through a zero-profit condition.

World market prices are exogenously given (in foreign currency), and the international market is big enough to satisfy demand for imports and absorb supply of exports at these international prices. Under these conditions, all international trade links with other countries can be aggregated into one additional sector in the model, 'Rest of the World' (RoW). The demand by this sector represents exports and the supply is imports; the budget deficit is exogenously given and the endogenous exchange rate ensures that equilibrium is attained. The reactions on the markets to changes in domestic prices are specified by the Armington approach by assuming that domestic and foreign goods are imperfect substitutes. The market balance conditions for produced goods, domestic demand, the capital and labour market close the model.

2.2 EMISSIONS AND ABATEMENT IN THE ECONOMIC MODULE

Production and consumption processes lead to pollution (emissions). Allowances to emit polluting substances to the environment are linked to production output and consumption. The government sets the environmental policy targets exogenously by issuing a restricted number of pollution permits[1] and redistributing the proceeds to the private households in a lumpsum manner. In this way, a market for pollution permits is created, where prices are determined endogenously by equating demand and supply. Polluters have the choice between paying for their pollution permits or increasing their expenditures on pollution abatement. This choice is endogenous in the model, and the polluters will always choose the cheaper of the two. A third possibility for producers and consumers is to reduce their production and consumption of pollution intensive goods, respectively. This becomes a sensible option when both the marginal abatement cost and the price of the permits are higher than the value added foregone in reducing production or utility foregone in reducing consumption. In the benchmark projection, the government distributes exactly the number of permits that allows the producers and consumers to maintain their original behaviour.

A key feature of the model is that the expenditures on abatement are explicitly specified to capture as much information as possible about the technical measures underlying the abatement options. The supply of ‘abatement goods’ is modelled through a separate producer whose production inputs represent the cost components of the underlying technical measures. For each environmental theme, abatement cost curves are constructed, using detailed technical data. This procedure involves making an inventory of all known options available to reduce pollution, including end-of-pipe measures and process-integrated measures. A constant elasticity of substitution function is estimated and governs how much additional abatement effort is needed to reduce pollution by one additional unit; the function thus reflects marginal abatement costs (*cf.* Dellink, 2005).

The existing technical potential to reduce pollution through abatement activities, *i.e.* without economic restructuring, provides an absolute upper bound on technical abatement in the

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[1] Practical considerations may lead to a different choice of policy instrument in reality. Nonetheless, the approach taken here can serve as a reference point for evaluating other policy instruments.

model. This is a clear difference with the traditional quadratic abatement cost curves, where no true upper bound on abatement activities exists. The empirical importance of an absolute limit on environmental technology has been emphasised by Hueting (1996).

Autonomous pollution efficiency improvements result in a relative decoupling of economic growth and pollution. The development of abatement possibilities and abatement costs over time are captured via specific parameters that govern the changes in technical potential for pollution reduction over time, and efficiency improvements in the abatement sector. In the current specification of the model, these developments in the abatement possibilities and costs, *i.e.* innovation of new abatement measures, are driven by exogenous parameters. Nonetheless, the model does contain endogenous diffusion of existing abatement technology.

2.3 LINKING THE ECONOMIC AND HYDROLOGICAL MODULES

The effects of the changes in economic activity as assessed with the economic module are entered into the hydrological module in two steps. First, the national results of changes in activity levels of the different economic sectors and the associated changes in emission levels of individual pollutants are regionalised using an existing system of regional water accounts. The regionalisation step is carried out using an available dataset, NAMWARiB (National Accounting Matrix Including Water Accounts for River Basins; see Brouwer et al., 2005 for details). Next, these regional effects are input into the hydrological module to assess the changes in water quality, measured in terms of concentrations and related to Maximum Tolerable Risk (MTR) of 154 water bodies in the Netherlands. Figure 1 shows the water bodies as identified in the model. As both modules and the NAMWARiB database all use the Emission Registration (Statistics Netherlands, 2007) as the basis, there are minimal adjustments required to achieve consistency.[2]

Unfortunately, some essential information cannot be entered in the hydrological module in this way. First, the regional estimates assume that pollution sources in different geographical locations all adopt the same percebntage emission reduction. Thus, the current framework does not allow an intensified policy in those regions where water quality is the worst. Secondly, annual averages are used, whereas in reality, water quality differs per season. Thirdly, there is insufficient information to assess the expected concentrations of pollutants entering the water bodies at the border. This information is essential, as the Netherlands is a

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[2] Unfortunately, the NAMWARiB database uses an older version of the Emission Registration information, and is not updated. This is accounted for by calculating regional shares from the database, and using the emission totals from the more recent information uused in the economic module.

downstream area with several international rivers, including the Rhine and Meuse. Therefore, in the numerical calculations, two different assumptions will be used with respect to concentrations at the border.

Figure 1:Water bodies identified in the hydrological module

3. CALIBRATION OF THE MODEL

3.1 CALIBRATION OF THE ECONOMIC MODULE

The base year data are derived from the most recent statistics for the year 2000 by Statistics Netherlands. With the most recent data that is available for economic activity and emissions the model parameters are calibrated. On the production side, 27 producers of private goods are identified; this allows for a moderate degree of detail on the side of economic and environmental diversity. A more disaggregated set-up was not feasible due to environmental data limitations. There are two consumer groups: private households and the government. Some characteristics of production in The Netherlands in 2000 are shown in Table 1. Total production value is given both in absolute amounts and as share of total production value in the economy. The column for total consumption shows absolute and relative consumption levels for private households and government together. The largest sectors in terms of production value, value added and consumption are Non-commercial services (21% of production value) and Commercial services (17% of production value).

Table 1. Sectoral economic data for The Netherlands, 2000
(in million Euro at 2000 prices).

		SBI-code	Production 2000		Consumption 2000	
Sector number & description[1]		(1993)[2]	mln Euro	(share)	mln Euro	(share)
1	Agriculture and fisheries	01 – 05	18,835	(2.9%)	2,332	(1.0%)
2	Extraction of oil and natural gas	11	10,240	(1.6%)	0	(0.0%)
3	Other mining and quarrying	10, 14	0,807	(0.1%)	26	(0.0%)
4	Food and food products industry	15, 16	35,026	(5.4%)	12,880	(5.5%)
5	Textiles, clothing and leather industry	17 – 19	3,331	(0.5%)	5,065	(2.2%)
6	Paper and –board industry	21	3,782	(0.6%)	650	(0.3%)
7	Printing industry	22	10,988	(1.7%)	3,262	(1.4%)
8	Oil refineries	23	15,992	(2.5%)	1,694	(0.7%)
9	Chemical industry	24	23,409	(3.6%)	2,745	(1.2%)
10	Rubber and plastics industry	25	5,227	(0.8%)	540	(0.2%)
11	Basic metals industry	27	4,896	(0.8%)	6	(0.0%)
12	Metal products industry	28	11,115	(1.7%)	490	(0.2%)
13	Machine industry	29 – 31	12,831	(2.0%)	224	(0.1%)
14	Electromechanical industry	32, 33	16,925	(2.6%)	3,683	(1.6%)
15	Transport equipment industry	34, 35	10,373	(1.6%)	4,040	(1.7%)
16	Other industries	20, 26, 36, 37	14,613	(2.3%)	6,193	(2.6%)
17	Energy distribution	40	12,651	(2.0%)	5,153	(2.2%)
18	Water distribution	41	1,456	(0.2%)	927	(0.4%)
19	Construction	45	46,515	(7.2%)	898	(0.4%)
20	Trade and related services	50 – 55	99,607	(15.4%)	13,440	(5.7%)
21	Transport by land	60	14,564	(2.3%)	3,563	(1.5%)
22	Transport by water	61	4,450	(0.7%)	219	(0.1%)
23	Transport by air	62	7,047	(1.1%)	1,035	(0.4%)
24	Transport services	63	11,038	(1.7%)	3,895	(1.7%)
25	Commercial services	64 – 74	134,062	(20.8%)	57,771	(24.6%)
26	Non-commercial services	75 – 95	104,677	(16.2%)	97,565	(41.5%)
27	Other goods and services	99	10,462	(1.6%)	6,904	(2.9%)

[1] Goods are represented by their production sector.

[2] See Statistics Netherlands (1996) for an explanation and official description of the sectors.

The values of the most important parameters are derived from trend analysis over the period 1990 – 2000; together with the data for the base year they govern the benchmark projection of the economy. For a detailed justification of the parameter values, see Dellink (2005). The growth rate of labour supply equals 2 percent; and a stable annual interest rate of 4% is used.[3] The steady-state relationship between investments and capital is used to calculate a depreciation rate of 3 percent. The values for the substitution elasticities and the nesting structure for the production functions, the utility function and the international trade functions are taken from Gerlagh *et al.* (2002) and represent adaptation possibilities for the medium term. The intertemporal elasticity of substitution has to be calibrated only for the private households; the value equals 0.5.

3.2 CALIBRATION OF ENVIRONMENTAL MODULE

Since the analysis of the WFD concerns only emissions to surface waters, emission data from Statistics Netherlands are used (Statistics Netherlands, 2007). [4] Emissions of euthrophying substances are concentrated to a large extent in the Agricultural sector and with Households. As shown in Table 2, these two sector both account for around 40 percent of all emissions. In addition, both sectors emit large quantities of toxic substances. The Chemical industry is also responsible for substantial emissions of eutrophying substances and the dispersion of toxic substances to water (see Section 3.3 for the definition of the individual substances of this theme).

One technical problem that has to be dealt with is the fact that the environmental services sector, which includes the waste water treatment plants amongst others and is part of the Non-commercial services, prevents substantial amounts of emissions, for instance due to household organic waste and manure that is incinerated or dumped. In the original data, this is represented as negative emissions. These negative emissions are larger than the positive emissions in the other parts of the Non-commercial services, and consequently the total sector Non-commercial services would have negative emission coefficients. This can lead to technical problems in the model if a system of pollution permits is introduced; therefore the negative net emissions in environmental services are re-attributed to the sectors in which these emissions have originated, such as the agricultural sector and the households.

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[3] This interest rate is 1 percent point lower than in Dellink (2005), to reflect recent developments.

[4] Please note that in the interim reports, total emissions as reported in Hofkes et al. (2004) were used.

Table 3.2: Sectoral emissions for Eutrophication and Dispersion to Water for The Netherlands, 2000.

		Eutrophication		Dispersion to Water	
Sector number & description		mln P-equivalents	(share)	bln AETP-equivalents	(share)
1	Agriculture and fisheries	11.79	(43.6%)	57.15	(27.5%)
2	Extraction of oil and natural gas	0.00	(0.0%)	0.01	(0.0%)
3	Other mining and quarrying	0.00	(0.0%)	0.03	(0.0%)
4	Food and food products industry	1.68	(6.2%)	6.49	(3.1%)
5	Textiles, clothing and leather industry	0.08	(0.3%)	2.94	(1.4%)
6	Paper and –board industry	0.09	(0.3%)	1.37	(0.7%)
7	Printing industry	0.00	(0.0%)	2.00	(1.0%)
8	Oil refineries	0.05	(0.2%)	1.83	(0.9%)
9	Chemical industry	1.82	(6.7%)	15.04	(7.2%)
10	Rubber and plastics industry	0.01	(0.0%)	0.73	(0.3%)
11	Basic metals industry	0.11	(0.4%)	5.02	(2.4%)
12	Metal products industry	0.02	(0.1%)	15.77	(7.6%)
13	Machine industry	0.00	(0.0%)	1.84	(0.9%)
14	Electromechanical industry	0.07	(0.2%)	4.36	(2.1%)
15	Transport equipment industry	0.01	(0.0%)	3.85	(1.9%)
16	Other industries	0.01	(0.0%)	4.10	(2.0%)
17	Energy distribution	0.00	(0.0%)	0.06	(0.0%)
18	Water distribution	0.01	(0.0%)	0.01	(0.0%)
19	Construction	0.00	(0.0%)	0.62	(0.3%)
20	Trade and related services	0.01	(0.0%)	1.37	(0.7%)
21	Transport by land	0.01	(0.0%)	1.99	(1.0%)
22	Transport by water	0.00	(0.0%)	3.41	(1.6%)
23	Transport by air	0.00	(0.0%)	0.03	(0.0%)
24	Transport services	0.00	(0.0%)	0.09	(0.0%)
25	Commercial services	0.00	(0.0%)	2.15	(1.0%)
26	Non-commercial services	0.01	(0.0%)	2.04	(1.0%)
27	Other goods and services	0.00	(0.0%)	0.38	(0.2%)
Private households		11.29	(41.7%)	72.85	(35.1%)
Total		27.07	(100%)	207.52	(100%)

The substances that cause Eutrophication are phosphorus (P) and nitrogen (N). They mainly stem from agricultural use of fertiliser and manure, but emissions of NH_3 and NO_x contribute as well. The substances can be aggregated into P-equivalents by dividing nitrogen emissions by 10, reflecting the lower environmental impact of N emissions. The measures to reduce

Eutrophication amount to a number of 40 options, many of which also contribute to abatement of acidifying emissions. The curve, together with the CES approximation, is given in Figure 2.[5]

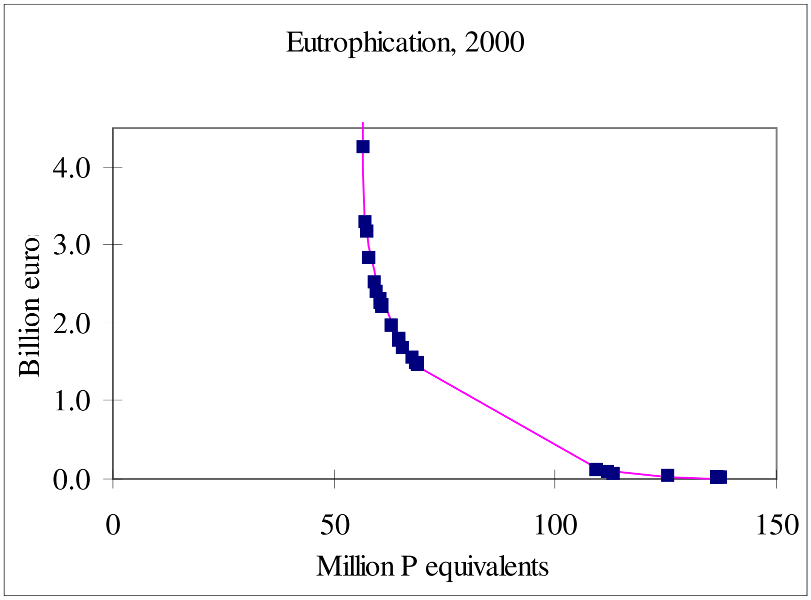

Figure 2: Abatement cost curve for eutrophication in 2000.

Reduction of Eutrophication concentrates in the sectors agriculture, industry and sewerage, resulting in a maximum reduction of emissions of just over 120 million P-equivalents, around 62 percent of total emissions. The most important measure consists of elimination of excess manure, which reduces over 65 million P equivalents at a yearly cost of about 1.3 billion euro. Due to lack of data this measure could not be subdivided into its components, which include also dephosphating and denitrifying of wastewater from industry and households. Further steps in reduction relate to additional measures in sewerage and water purification, and one of the measures at the very end of the curve is relocation of farms: a reduction of 0.14 million P equivalents at the cost of more than 100 million Euro yearly.

The environmental theme ‘dispersion of toxic substances to water’ consists of 8 heavy metals (mercury, cadmium, lead, zinc, copper, nickel, chromium, and arsenic) and the total of 9 Polycyclic Aromatic Hydrocarbons (PAHs). The substances can be aggregated to ‘(aquatic eco)toxicity equivalents’ using the Aquatic Eco-Toxicity Potentials (AETPs) as shown in Table 3. In our calculations, we use the equivalence factors suggested by Van der Woerd et al,

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[5] An update of these curves, using improved information on abatement measures for specific sectors, is envisaged as part of future research.

to ensure consistency between the abatement cost curve and the emission data. Note, however, that since then, new equivalence factors have been proposed in Huijbregts et al. (2000).

Van der Woerd et al. (2000) provide 127 independent options to reduce dispersion of toxic substances to water for 1995. With additional assumptions as described in Hofkes et al. (2004), we construct the abatement cost curve for 2000. The reduction potential is kept constant and proportionally with the level of emissions. The abatement costs are corrected for the changes in the consumer price index between 1995 and 2000.

Figure 3 shows the total amount of abatement costs and emission reduction potential for ‘dispersion of toxic substances to water’. Based on the information of individual measures, we approximate the cost abatement curve in a CES structure that will be used in the model calculations.[6]

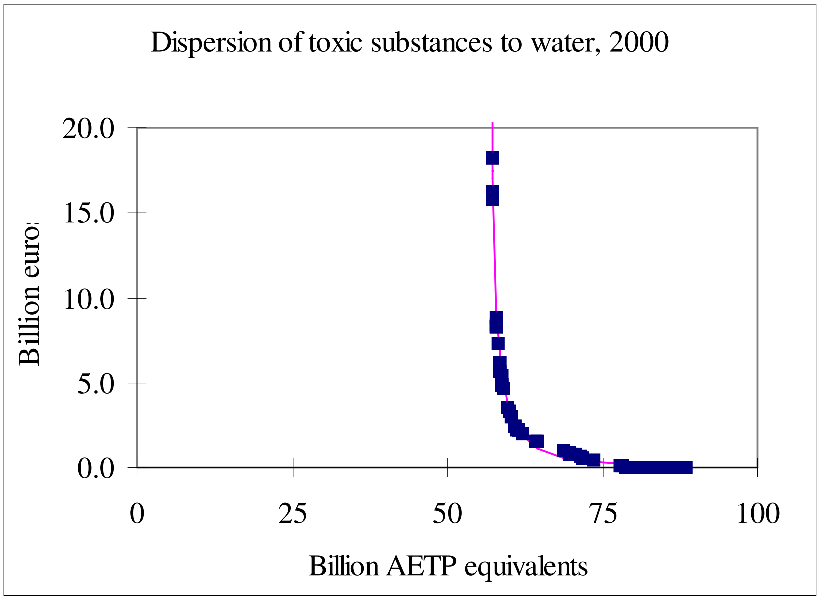

Figure 3. Abatement cost curve for dispersion of toxic substances to water in 2000.

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[6] An update of these curves, using improved information on abatement measures for specific sectors, is envisaged as part of future research.

Table 3: Equivalences among substances in the environmental theme 'Dispersion of toxic substances to water'.

Dispersion of toxic substances to water	
1 million AETP equivalents =	
3.6 kg	mercury
3.4 kg	cadmium
666.7 kg	lead
55.6 kg	zinc
3.2 kg	copper
0.3 kg	nickel
217.4 kg	chromium
6.3 kg	arsenic
13.0 kg	PAHs

Source: Van der Woerd et al. (2000).

The pollution-abatement-substitution (PAS) elasticities, benchmark price of the emission permits and technical potential for pollution reduction are directly derived from the abatement cost curves (Dellink, 2005). The growth rate of the technical potential for pollution reduction is based on a comparison of the abatement cost curves for 1990 and 2000, using Hofkes *et al.* (2002) and Brouwer et al. (2007). The autonomous pollution efficiency improvements are calibrated for each environmental theme separately using the realised development of emission levels between 1995 and 2000; the *ad-hoc* assumption is made that these effects of current policies will fade over time, leading to a stabilisation of benchmark emissions in the long run.[7] The autonomous abatement efficiency improvement is calibrated to 0.5 percent per year throughout the model horizon.

3.3 CALIBRATION OF THE HYDROLOGICAL MODULE

Figure 4 shows how the expected water quality in the different water bodies are when no additional policies are implemented. These are calibrated using the regionalised emission data from the economic module (see also Section 2) and the assumption that concentrations at the border are equal to the observed concentrations in the year 2000. To ease the interpretation of the results, water quality is expressed in terms of concentrations (blue and green are blow

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[7] Pollution efficiency improvements reflect the impacts of other environmental policies, such as the European Nitrate Directive (91/676/EC), Urban Waste Water Treatment Directive (91/271/EC) amongst others.

MTR, yellow, orange and red above). Unfortunately, it was not possible to assess water quality for all pollutants in the hydrological module; thus, results can only be presented for the eutrophying substances (nitrogen, N, and phosphor, P) and for the heavy metals cadmium (Cd), copper (Cu), nickel (Ni) and zinc (Zn).

For cadmium and zinc, concentrations are above MTRs for a few water bodies (colours yellow, orange and red), whereas the situation is more problematic for copper, nickel, nitrogen and, to some extent phosphor. An important observation is that poor water qualities tend to exist especially in the Rhine area, where the inflow from abroad is of relatively poor quality. This is also clear from Figure 5.

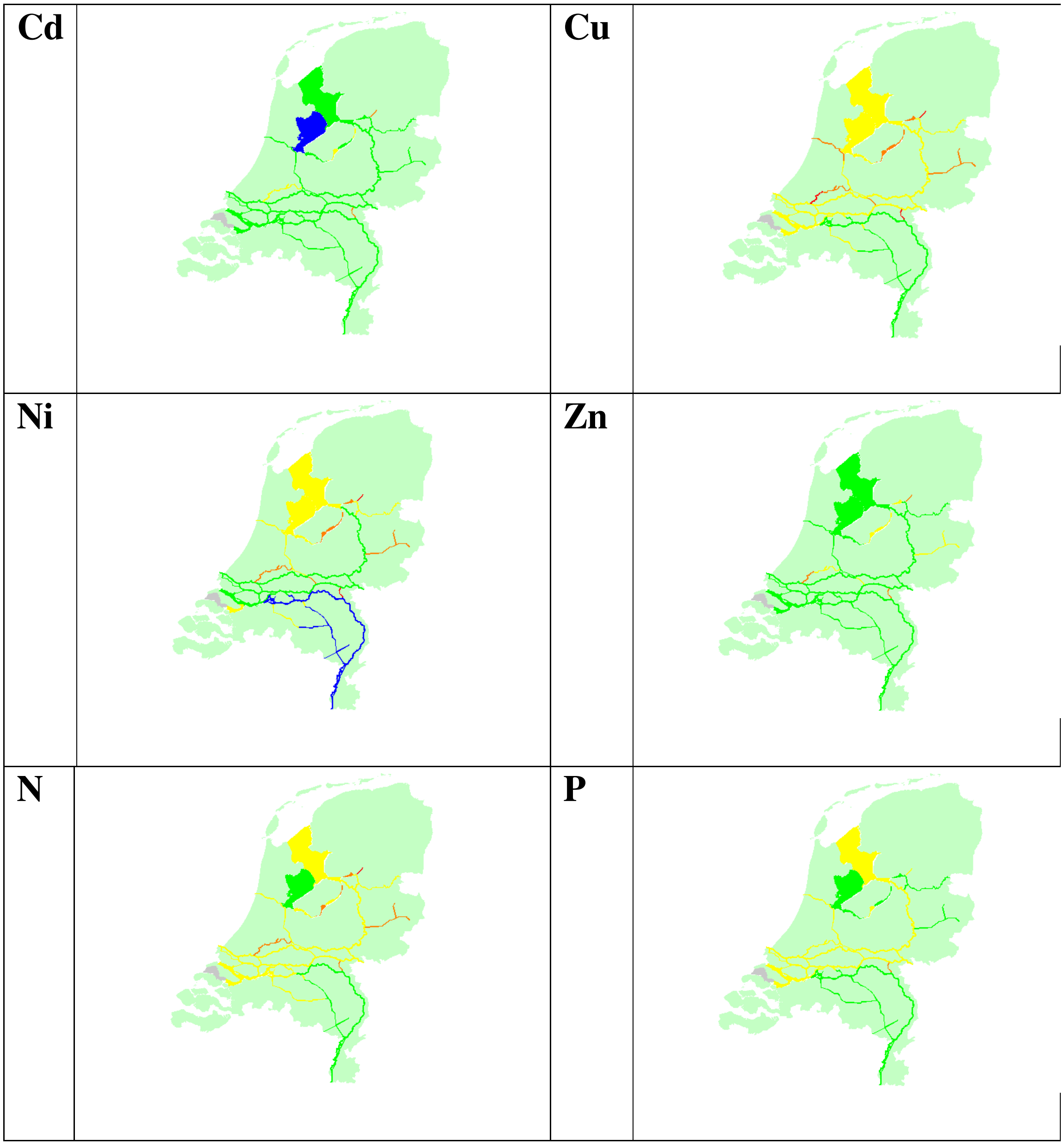
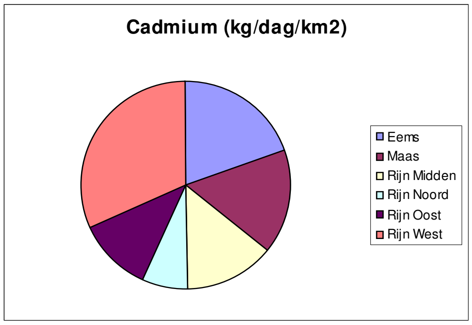
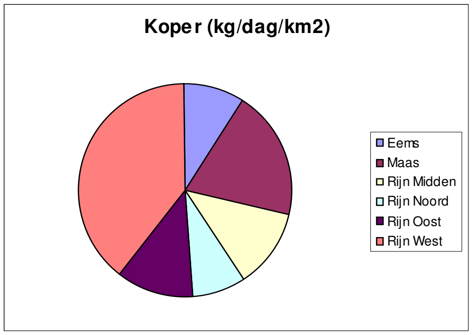
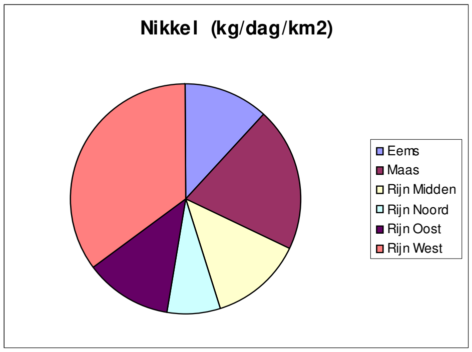


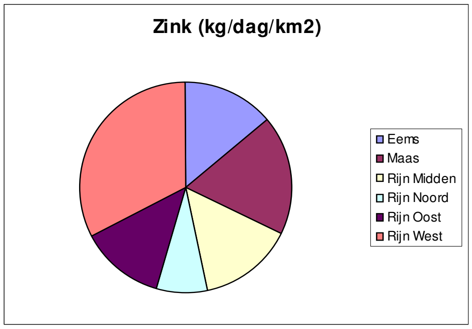
Figure 4. Expected water quality in 2015

Emissions by area:

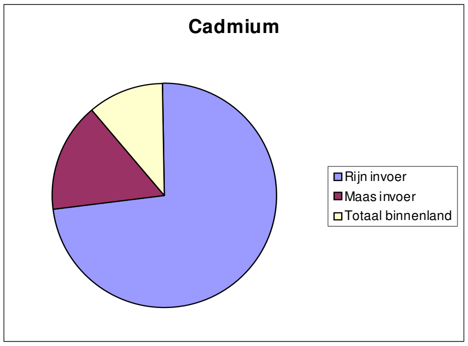


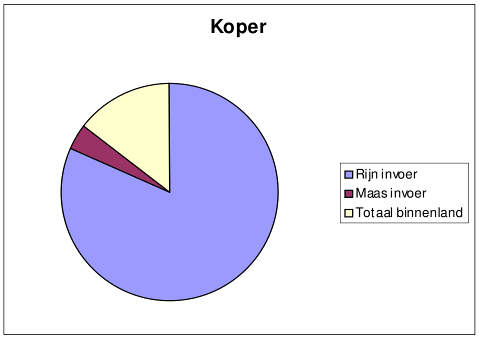


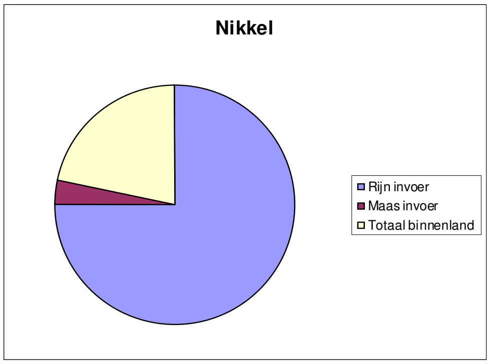


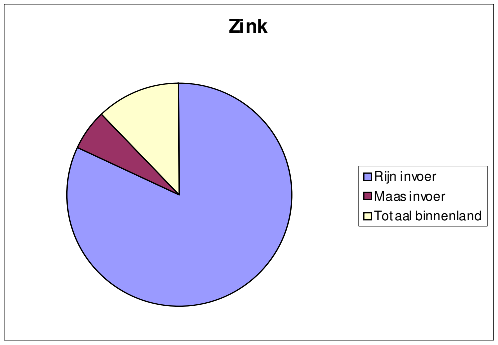


Emissions by source:









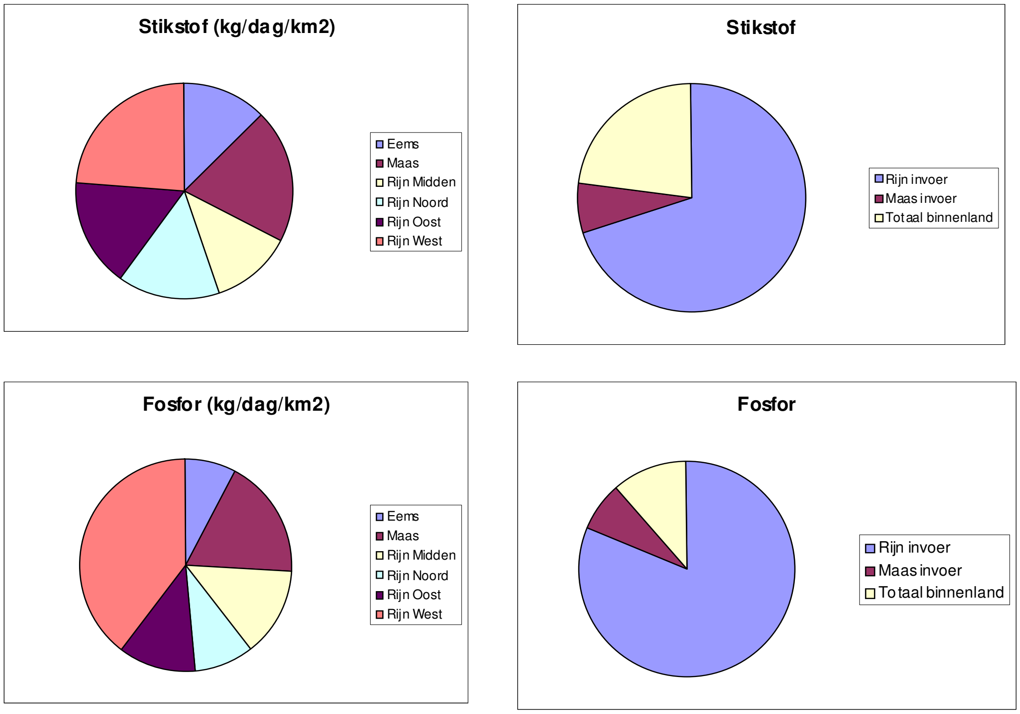


Figure 5. Sources of emissions in hydrological module

4. RESULTS

4.1 BENCHMARK PROJECTION AND POLICY SCENARIOS

In the benchmark projection, the economy is assumed to be on a balanced growth path. Economic activity increases with 2 percent per year, whereas the growth rates for emissions are determined by the combination of the economic growth rate, and the assumed autonomous pollution efficiency improvements.

The water quality requirements of the WFD are yet unknown, which makes it impossible to calculate the exact consequences of the implementation of the WFD. Furthermore, the dynamic AGE model requires standards for emissions for the environmental themes rather than water quality standards, and the water quality requirements have to be translated into emission standards for water related substances. Therefore, we simulate the economic consequences for different emission reduction scenarios ranging from 20 to 50 percent emission reduction from 2015 onwards with respect to emission levels in 2000. The implementation of the WFD will be executed gradually (see Van der Veeren, 2005; Brouwer, 2005) and we assume that the implementation will start effectively in 2008. In addition, we compare these to results for scenarios with a derogation of the target until 2027 (see Van der Veeren, 2005, for a discussion of the appropriate emission reduction scenarios). Given the assumed autonomous emission reduction over time in the DEAN-W model, the required 50 percent emission reduction in 2015 is roughly equivalent to a 50 percent emission reduction compared to the benchmark. A derogated target of 50% reduction implies a 20% reduction of emissions in 2015 compared to the benchmark.

Table 4. Overview of scenario assumptions

Scenario	**Percentage domestic emission reduction**	**Water quality at the border**
Base	none	Current concentrations
Lenient unilateral policy	20 %	Current concentrations
Strict unilateral policy	50 %	Current concentrations
Lenient multilateral policy	20 %	MTR
Strict multilateral policy	50 %	MTR
Derogated strict policy	50% by 2027	Current concentrations

Developments of emissions and emission targets for the different scenarios are given in Figures 6 and 7 for Eutrophication and Dispersion of heavy metals to water, respectively.

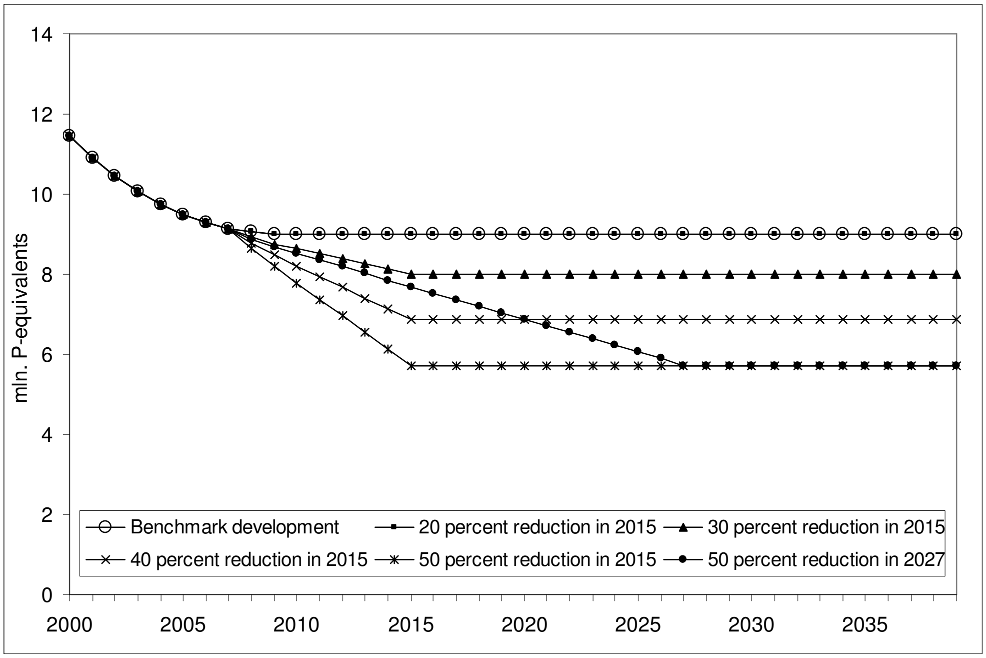


Figure 6. Development of emissions of eutrophying substances over time in different scenarios.

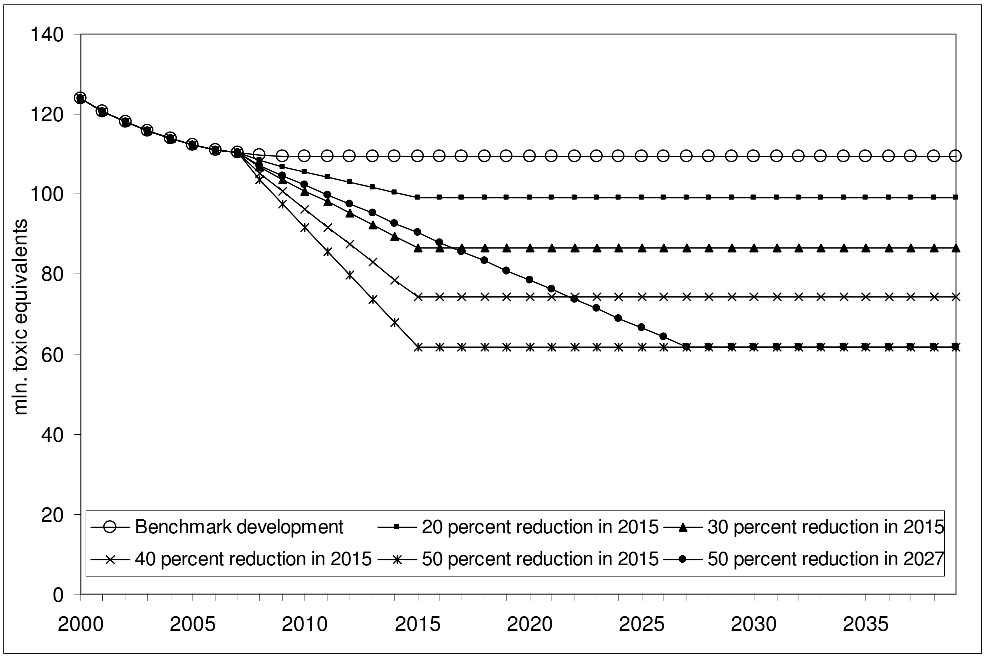


Figure 7. Development of emissions of dispersion of toxic substances to water over time in different scenarios.

4.2 A LENIENT UNILATERAL POLICY

The main results of the policy where the emissions for Eutrophication and Dispersion simultaneously have to be reduced by 20 percent with respect to the emission level of 2000, and no foreign reductions are assumed, are represented in Table 5. Given the reduction in emissions between 2000 and 2015 as a result of existing policies (see Section 4.1), the target for Eutrophication is not strictly binding: benchmark emissions are below the target. Thus, no additional efforts are required for this theme (see the emission reduction in percentage change compared to the benchmark projection), when the required emission reduction is limited to 20% below 2000 levels. For Dispersion to Water, the target is binding: from 2015 onwards, emissions will have to be reduced almost 10 percent below benchmark projection levels. As marginal abatement costs for small amounts of reduction are relatively cheap, these emission reductions can completely be achieved through the implementation of low-cost technical measures. The macroeconomic results suggest that these adjustments in the economy are virtually costless. This does not mean that there are no substantial differences in terms of volume changes between the production of economic sectors. While there is hardly any change for the Service sectors, Agriculture suffers a 1.5% loss of production volume.

Table5: Main results for the Lenient unilateral policy scenario

	2010	2015	2020	2030
Macroeconomic results (%-change in volumes compared to benchmark projection)				
GDP	0.0	0.0	0.0	0.0
NNI	0.0	0.0	0.0	0.0
Total private consumption	0.0	0.0	0.0	0.0
Total production	0.0	0.0	0.0	0.0
Capital investment	0.0	0.0	0.0	0.0
Sectoral results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	-0.1	-0.1	-0.1	-0.1
Private consumption Industry	0.0	0.0	0.0	0.0
Private consumption Services	0.0	0.0	0.0	0.0
Sectoral production Agriculture	-1.4	-1.5	-1.5	-1.5
Sectoral production Industry	-0.1	-0.1	-0.1	-0.1
Sectoral production Services	0.0	0.0	0.0	0.0
Sectoral production Abatement services	24.9	28.0	28.0	28.0
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Eutrophication	0.0	0.0	0.0	0.0
Emissions Dispersion to Water	-3.6	-9.5	-9.5	-9.5
Prices of main variables (constant 2000 prices)				
Wage rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Exchange rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Price of abatement services (bm. index = 1)	1.0	0.9	0.9	0.9
Price Eutrophication permits (bm. index = 1)	1.5	1.7	1.9	2.3
Price Dispersion permits (bm. index = 1)	1.5	2.1	2.3	2.8

The prices of emission permits for Eutrophication and Dispersion to Water both increase over time, but remain at a low level. Though the required percentage reduction in emissions remains constant from 2015 onwards, the permit price increases over time reflecting the autonomous efficiency improvements in the benchmark[8], that induce compensating price increases; this effect carries over from the benchmark to the counterfactual simulations.

Note, however, that there is still uncertainty whether the scenario of 20 percent emission reduction compared to the emission in the year 2000 is sufficient to meet the water quality targets of the WFD in 2015.

Figure 8 shows the implications of these policies on water quality. The reduction of emissions is visible for some water bodies when comparing the concentrations with the business-as-usual concentrations (Figure 4), but in most cases, the improvements in water quality is

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[8] These efficiency improvements imply that the volume of inputs of emission permits in the benchmark reduces over time; this is compensated by a simultaneous increase in benchmark prices, such that the value of these inputs is in line with the common growth rate of the benchmark projection, i.e. the value share of all inputs remains constant in the benchmark projection.

insufficient to induce a significant change in water quality. Hence, it can be concluded rthat the lenient domestic policy is not stringent enough to meet the requirements of the Water Framework Directive in 2015.

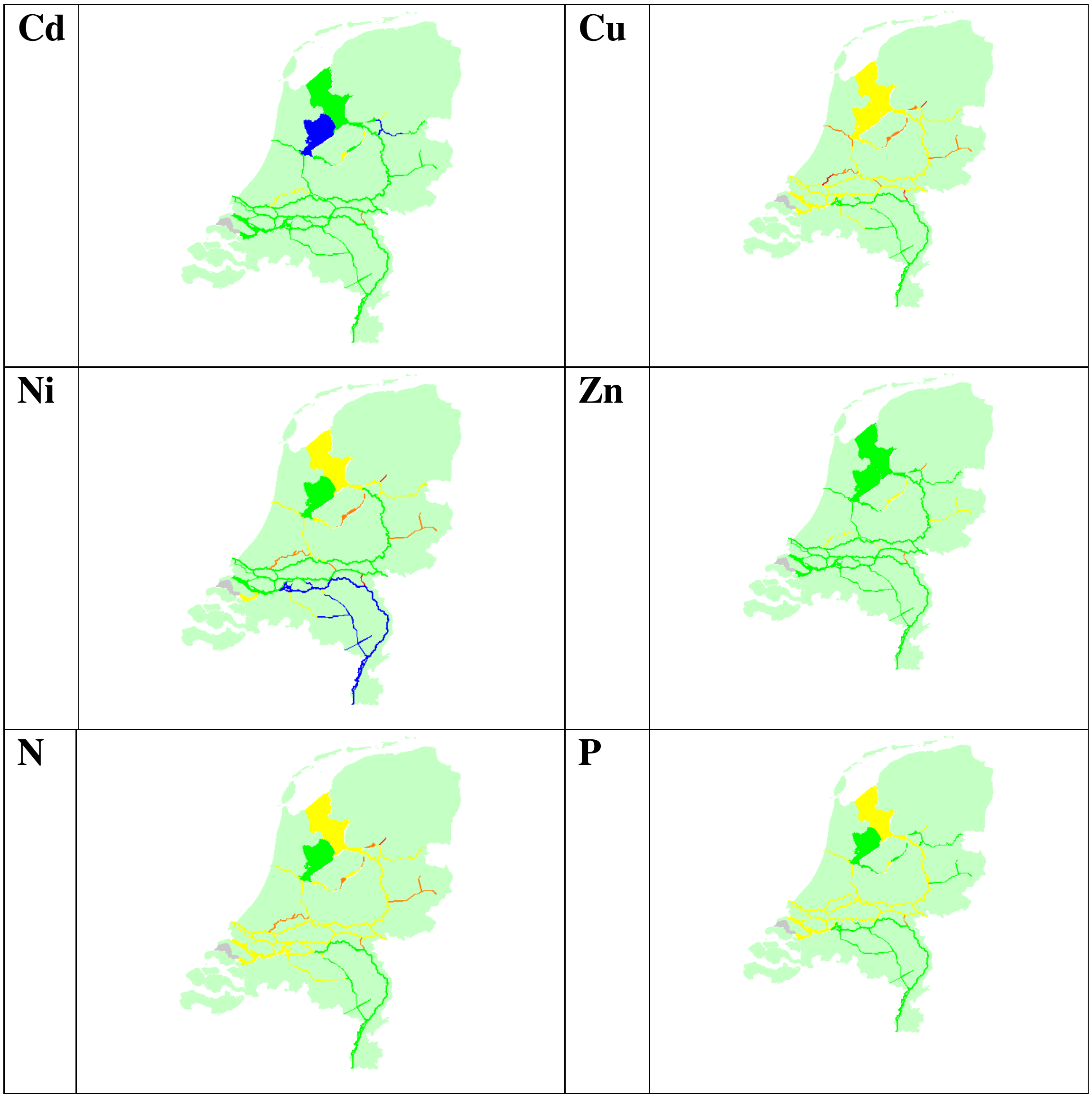

Figure8. Water quality results for the Lenient unilateral policy scenario

4.3 A STRICT UNILATERAL POLICY

Table 6 shows the main results for the more stringent policy where emission reductions of 50 percent (compared to emission levels in 2000) are required. As the stringency of the policy increases, the impacts become visible at the macro-economic level: GDP and NNI levels are decreasing. In the short run, the economic growth rate is reduced to below the benchmark level of 2 percent, the effect is strongest in 2015, where the growth rate equals 1.6 percent. But after 2015 the adjustment process stabilizes and the growth rate returns to 2 percent annually. The level of GDP and NNI is, however, permanently lower. For both themes, the more stringent target is binding, and from 2015 onwards emissions have to be reduced below benchmark projection levels by 36 and 43 percent, respectively. This stimulates production in the Abatement services sector. Note that most of the results for the years 2020 and 2030 are similar to the results for the year 2015 due to the fact that DEAN-W assumes a balanced growth path. As a consequence, the emissions stabilize after the WFD target is reached in 2015.

Table 6. Main results for the strict unilateral policy scenario

	2010	2015	2020	2030
Macroeconomic results (%-change in volumes compared to benchmark projection)				
GDP	-0.2	-0.7	-0.8	-0.8
NNI	0.0	-0.8	-0.8	-0.8
Total private consumption	0.2	-0.1	-0.2	-0.2
Total production	-0.2	-1.4	-1.5	-1.5
Capital investment	-1.0	-0.7	-0.7	-0.7
Sectoral results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	0.0	-3.0	-3.0	-3.0
Private consumption Industry	0.1	-0.8	-0.8	-0.9
Private consumption Services	0.2	0.2	0.2	0.2
Sectoral production Agriculture	-2.0	-33.2	-33.2	-33.2
Sectoral production Industry	-0.5	-4.1	-4.1	-4.1
Sectoral production Services	0.0	1.4	1.3	1.3
Sectoral production Abatement services	38.1	93.7	93.7	93.6
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Eutrophication	-13.6	-36.4	-36.4	-36.4
Emissions Dispersion to Water	-16.3	-43.4	-43.4	-43.4
Prices of main variables (constant 2000 prices)				
Wage rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Exchange rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Price of abatement services (bm. index = 1)	1.0	0.9	0.9	0.9
Price Eutrophication permits (bm. index = 1)	1.3	1.6	1.6	1.6
Price Dispersion permits (bm. index = 1)	1.9	175.1	174.7	174.0

Not surprisingly, the Agricultural sector substantially reduces its production levels, as this sector is the largest emitter of eutrophying substances and one of the largest emitters of toxic substances. Production levels of the industrial sectors decrease by around 4 percent. Thus, a shift in production from agriculture and industry towards the emission extensive services sector is induced. Aggregate production levels are also negative affected, but the reduction in consumption is limited, mainly due to lower investments.

In the short run, consumers anticipate on the environmental policy by changing their savings/consumption decision. Households increase their consumption in the short run at the expense of savings, as this has a positive effect on welfare, while accepting a lower growth rate of the economy (as the lower savings translate into lower investments and consequently into a lower growth rate of capital) and thus lower consumption levels in the long run. This reduction in the growth rate of the economy is one part of the optimal mix of reactions to the stringent environmental policy, together with expenditures on abatement and a restructuring of the economy. As consumers optimize their intertemporal utility function, this mix is the cost-effective response to the new policy.

Figure 8 shows the development of the percentage change in GDP over time in the different scenarios. The figure reflects that limited emission reduction targets can be met at little or no macroeconomic costs, but the economic costs of the policy increases more than proportionately with the stringency of the policy. This is trivial: first, the cheapest options to reduce emissions are implemented, and further reductions will have to be realized through more costly adjustments. The costs of economic adjustments also increase more than proportionately with stringency, as consumers prefer to stay as close as possible to the original consumption bundle.

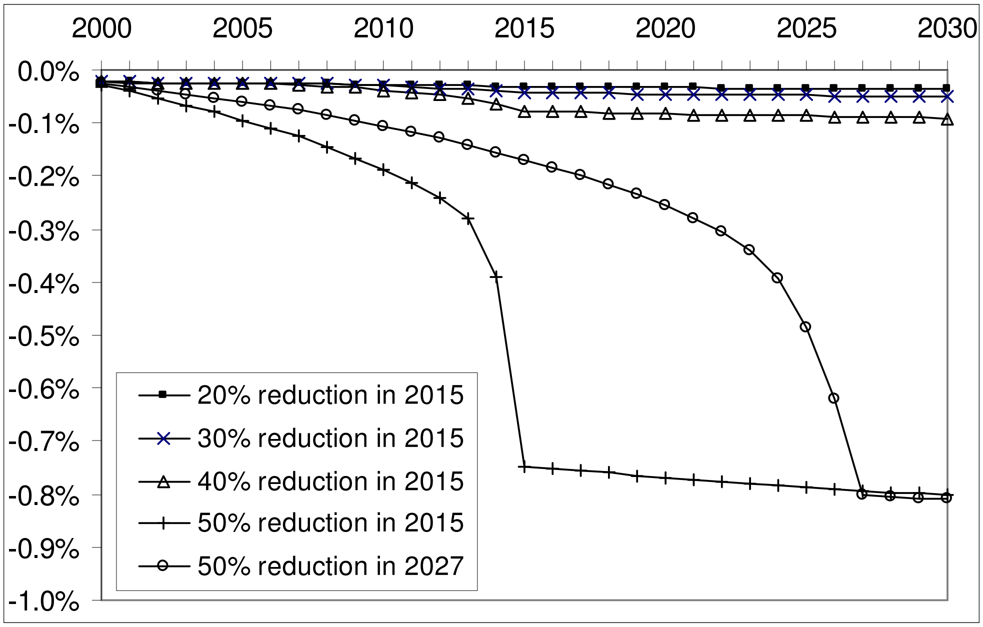

Figure 8. Percentage change in GDP – development over time

Figure 9 clearly shows the differences in impact of the environmental policy on production levels. As expected, the magnitudes of reduction of economic activity are larger when environmental policies are stricter. In addition, Figure 8 shows that the impacts increase more than proportional with the emission reduction scenarios ranging from 20 to 50 percent. The same picture emerges from Figure 9 for the individual industries. For most sectors the impacts for the 50 percent emission reduction scenario are more than proportionally larger than the impacts for the 20 percent scenario. Note that this holds for sectors that suffer from the stricter emission reduction scenarios as well as for those that benefit. The main reason for this disproportional impact of the emission reduction scenarios is the increasing marginal costs of pollution abatement and the increase in restructuring of the economy.

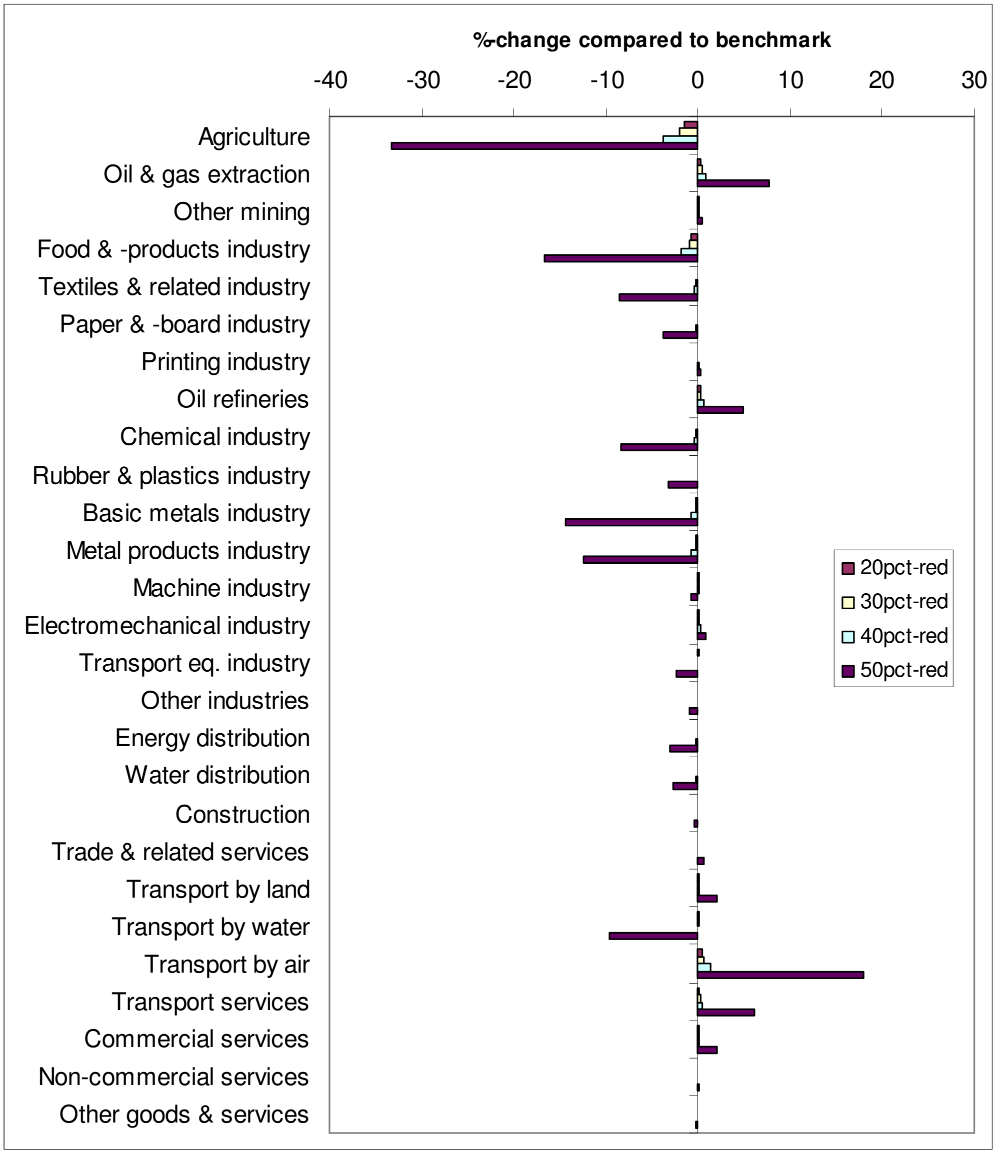

Figure 9. Percentage change in sectoral production levels in 2015

This also means that the sectors that can benefit from the new policy, including not only the Abatement sector, but also for example Transport by Air, are best served by a stringent policy (see Figure 9). The positive effect on Transport by Air can be explained by comparing the emission levels of the different transport modes in Table 2: there are no toxic emissions attributed to this sector, whereas the other transport modes have substantial emissions.[9] This illustrates that the economic impacts of environmental policy can best be regarded as a reallocation of available resources, rather than as a shrink of the economy. Thus, the sectoral impacts are much larger than the macroeconomic results suggest. Clearly, when these water policies are embedded in a wider range of environmental policies, the sectoral changes will be different, as different environmental themes have very different emission patterns over the sectors. Dellink (2005) investigates these interactions between different environmental problems in detail. Thus, the result that Agriculture will be most severely affected should be regarded in the context of a water policy only. Furthermore, a more detailed modeling of the agricultural subsectors may show substantial differences between the subsectors.

The DEAN-W model describes the costs of the policies primarily in terms of changes in GDP, NNI and sectoral changes in production and consumption levels. These sectoral and macro-economic changes are the combined effect of direct and indirect effects. In a CGE setting, the division between direct and indirect costs is less relevant than in partial analyses, where only certain costs can be assessed, while others are ignored. Nonetheless, our results can also be expressed in terms of direct and indirect costs by calculating sectors changes in generated value added; these value added changes add up to the change in national product. The direct sectoral costs include expenditures by the sector on abatement and on emission permits. The indirect costs (and benefits) include reduced tax payments (as by assumption the permit revenues are redistributed by lowering existing tax levels), changes in production structure and changes in production volume. Table 7 shows the decomposition of costs, where production sectors are aggregated into three broad categories. The column ‘Cons.’ encompasses costs to the private households and changes in value added generated through investments.

The total costs are evaluated at 3.7 billion Euro, or 0.7 percent of the GDP in the benchmark projection (cf. Table 6). The expenditures on emission permits and the associated tax reduction do not have any macro-economic impact: these are merely a financial redistribution

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[9] This is an artefact of the way Statistics Netherlands attributes emissions: only emissions of airplanes when landing and taking off are accounted for as Dutch emissions; in-flight emissions are not attributed to the Dutch economy.

from the polluting sectors to the government and from the government to the tax payers, respectively. For the government these scenarios are budget neutral. It is striking to see that at the macro-economic level the indirect costs are much larger than the direct costs. This can partially be explained by the concentration of emissions in relatively few number of sectors: rather than investing large amounts in abatement, it may be less costly to accept lower production levels in these few sectors, especially Agriculture, and reduce emissions in that way. It should be noted that the CGE framework assumes that production factors that become available by reducing production in one sector can be usefully employed in other sectors. Thus, the macro-economic costs comprise of the net effect of lower value added in the "dirty" sector plus higher value added in the other "cleaner" sectors. Again, this shows the importance of adopting a framework that can incorporate indirect effects in a consistent manner.

The sectoral direct costs reflect the shares of the different sectors in emissions (cf. Table 2): the higher the emissions, the more the sector needs to spend on abatement and buying permits. As Industry is a much larger sector than Agriculture, the largest absolute costs are borne by Industry; the relative burden on Agriculture is however much higher.

The sectoral indirect costs, without the tax reduction, are negative for Agriculture and Industry, and positive for Services. This reflects the natural tendency that the optimal reaction to changes in policy contain a mechanism of dampening extreme effects in order to smoothen the adjustments and minimize the impact of the policy on consumption patterns.[10] At the level of individual sectors, the effects are more pronounced. For instance, the Food and food-products industry is confronted with the decline in Agriculture and this causes substantial indirect costs in this industry (almost 1.5 billion Euro). Note that since the total indirect benefits for the industrial sector are 1.2 billion Euro, the sum of indirect benefits of the other industrial sub-sectors amount to 2.8 billion Euro). Substantial indirect costs are also borne by the Non-commercial services; the main reason for this is that substitution possibilities between production inputs are estimated to be much smaller than in other sectors, due to the specific nature of many of the services produced by this sector. Thus, this sector cannot respond as flexible to changes in relative prices as other sectors.

The total costs reported for consumers contains several effects. First, households have to invest in abatement and buy emission permits, as they are one of the major sources of

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[10] Note that in DEAN-W, initial consumption are assumed to be optimal and thus any forced change is considered to be detrimental to welfare.

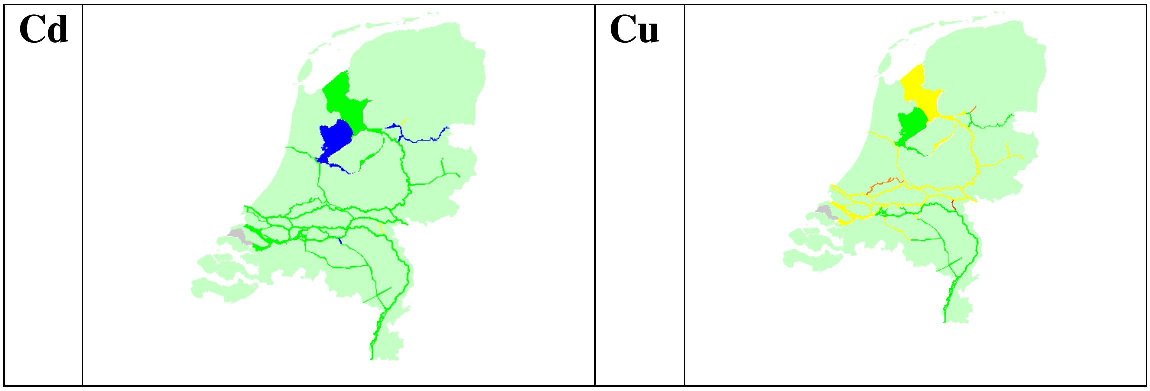
emissions for both environmental themes. Together, these account for 4.7 billion Euro. Secondly, households benefit from the lower taxes, especially from the lower VAT (more than 3 billion Euro), and adjusting consumption patterns as a response to changes in relative prices of consumer goods also increases their income with more than 3 billion Euro. In total, the private households have total net benefits of around 1.6 billion Euro. Thirdly, investment levels decrease, and hence the value added generated from investment decreases substantially; this amounts to indirect costs of almost 2.5 billion Euro. These effects counteract each other, and hence the total costs as reported in Table 7 are relatively low. Finally, the changes for the government comprise purely of a redistribution effect: the endogenous adjustment of existing tax levels ensures that provision of public goods remains constant throughout all simulations, and hence the different cost components exactly cancel each other out.

Table 7. Direct and indirect costs in 2015 (mln. Euro) for the Strict unilateral policy scenario

		Agric.	Industry	Services	Abat .	Invest.	Cons.	Gov't	Total
Abatement costs	Eutroph.	1	4	0			15	0	20
	Dispersion	40	80	15			100	0	235
Tradable emission permits	Eutroph.	35	16	0			51	-102	0
	Dispersion	2,390	3,802	703			4,558	-11,453	0
Tax reduction		-126	-1,667	-6,145		-2,216	-3,100	13,254	0
Other indirect costs		-243	-1,240	5,294	-152	4,686	-3,208	-1,699	3,438
Total costs		2,097	994	-132	-152	2,470	-1,585	0	3,692

Remark: A negative number means benefits, while a positive number means costs.

As in the previous scenario, these results can be translated into water quality graphs for the different pollutants; this is done in Figure 10. As expected, the strict policy induces more substantial improvements in water quality. For cadmium, nickel and zinc, the strict policy is sufficient, to assure a water quality in most or all water bodies that is below the MTR standard. For copper, nitrogen and phosphor concentrations remain above the target for several water bodies.



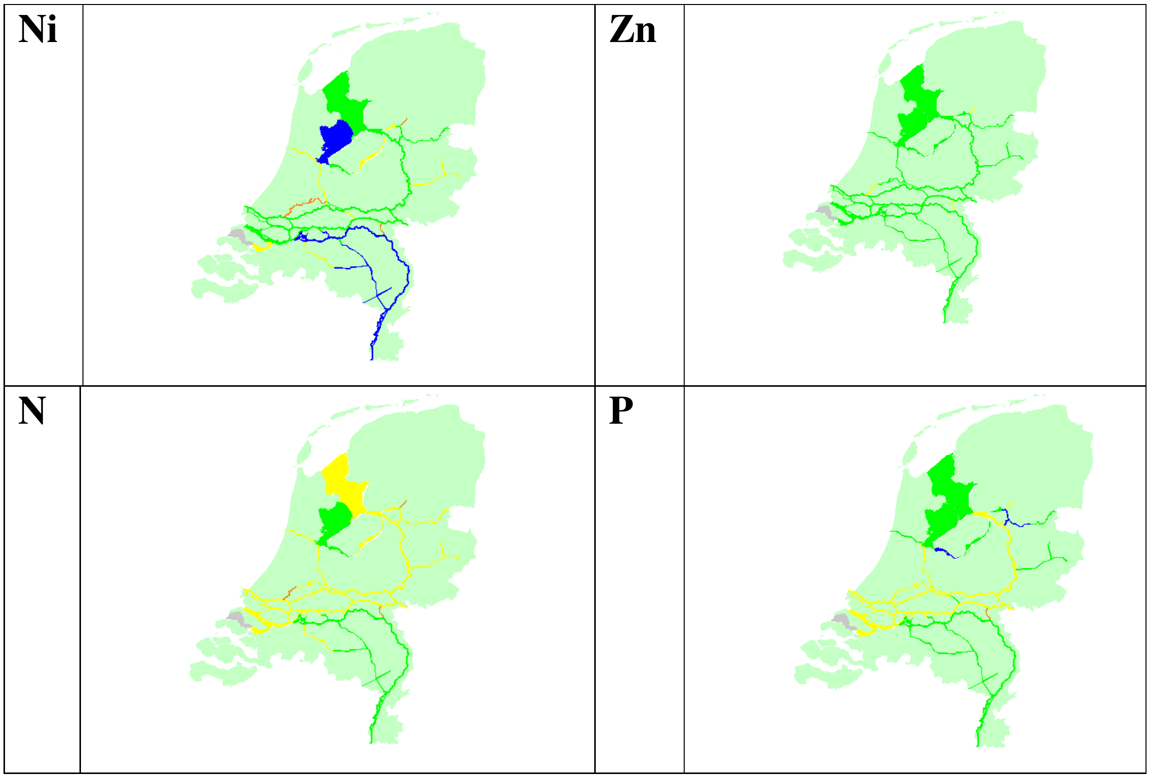


Figure 10. Water quality results for the Strict unilateral policy scenario

4.4 A LENIENT MULTILATERAL POLICY

In the alternative international setting, the multilateral scenario, the assumption that foreign policies to improve water quality are completely absent is dropped. Rather, given the European scope of the WFD we adopt the alternative assumption that the inflow of water from abroad is of quality that is at the MTR standard. The economic consequences of such foreign policies are virtually impossible to assess, let alone assess the impact of these policies on the Dutch economy. Therefore, we do not carry out new simulations with the economic module, but only simulate the effects of the multilateral policy on the water quality of Dutch water bodies. We do note, however, that additional efforts to improve water quality abroad do *ceteris paribus* reduce the necessary domestic efforts and therefore are likely to reduce the economic costs associated with implementing the WFD. This holds for all multilateral policies we investigate.

The water quality results for the Lenient multilateral policy scenario are depicted in Figure 11. As expected, the results are stringer than for the corresponding unilateral scenario, but even though the Dutch water quality depends to a large extent on foreign inflow, the lenient multilateral policy is insufficient to resolve all water quality problems, especially for copper, nickel and nitrogen.

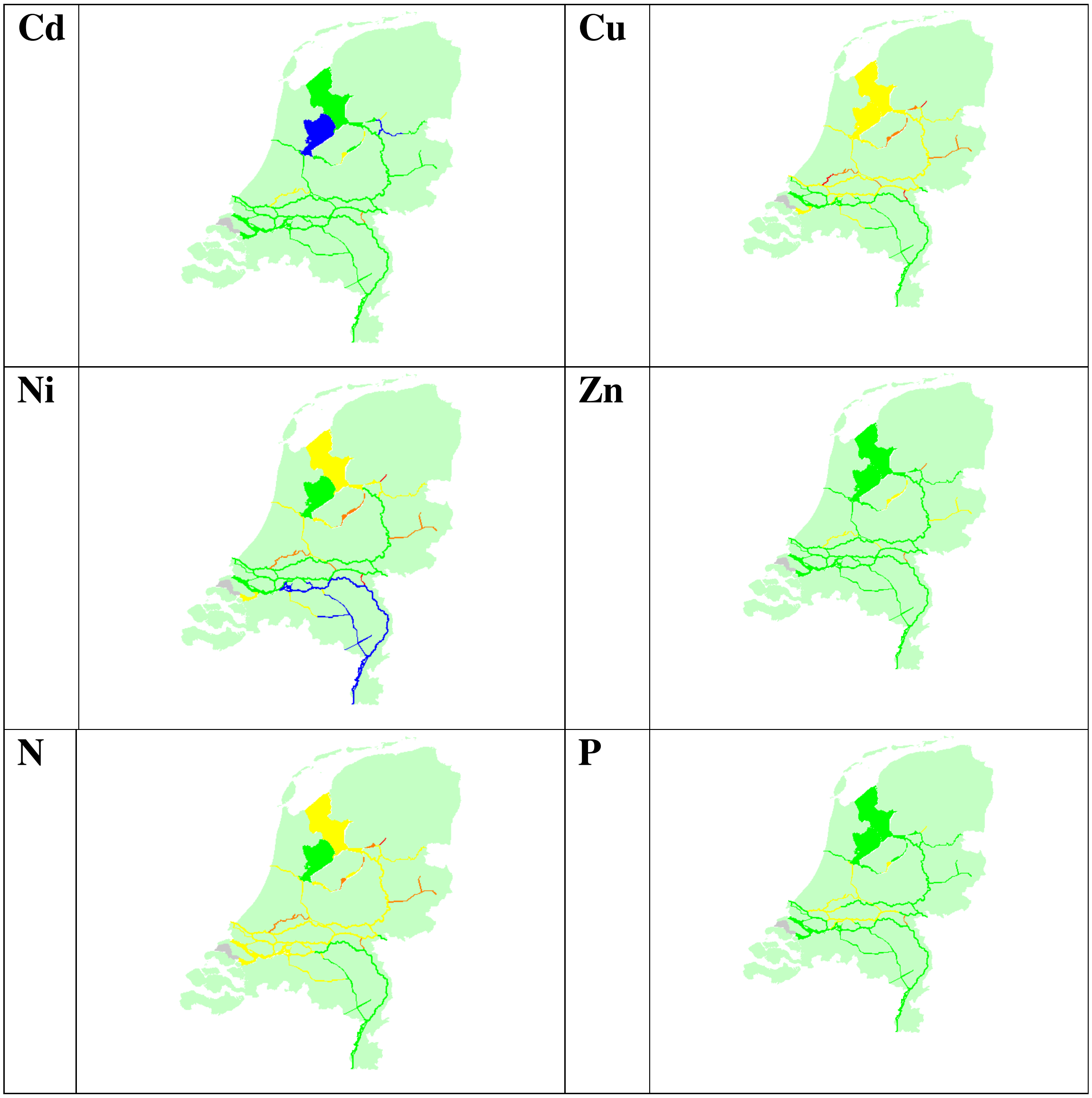


Figure 11 Water quality results for the Lenient multilateral policy scenario

4.5 A STRICT MULTILATERAL POLICY

Figurre 12 shows the results of the water quality assessment for a strict domestic policy in the multilateral setting. Surprisingly, even this strict policy with substantial efforts abroad is not stringent enough to improve water quality sufficiently in all water bodies and for all pollutants. The reduced inflow from abroad effectively dampens the effects that domestic reduction efforts have, and the number of water bodies that are of too poor water quality is only slightly smaller than in the unilateral case. Thus, we conclude that there are some water bodies, especially those that are linked to the river Rhine and to the IJsselmeer, in which certain pollutants, especially Copper and Nitrogen, form a persistent problem that requires very strict policies.

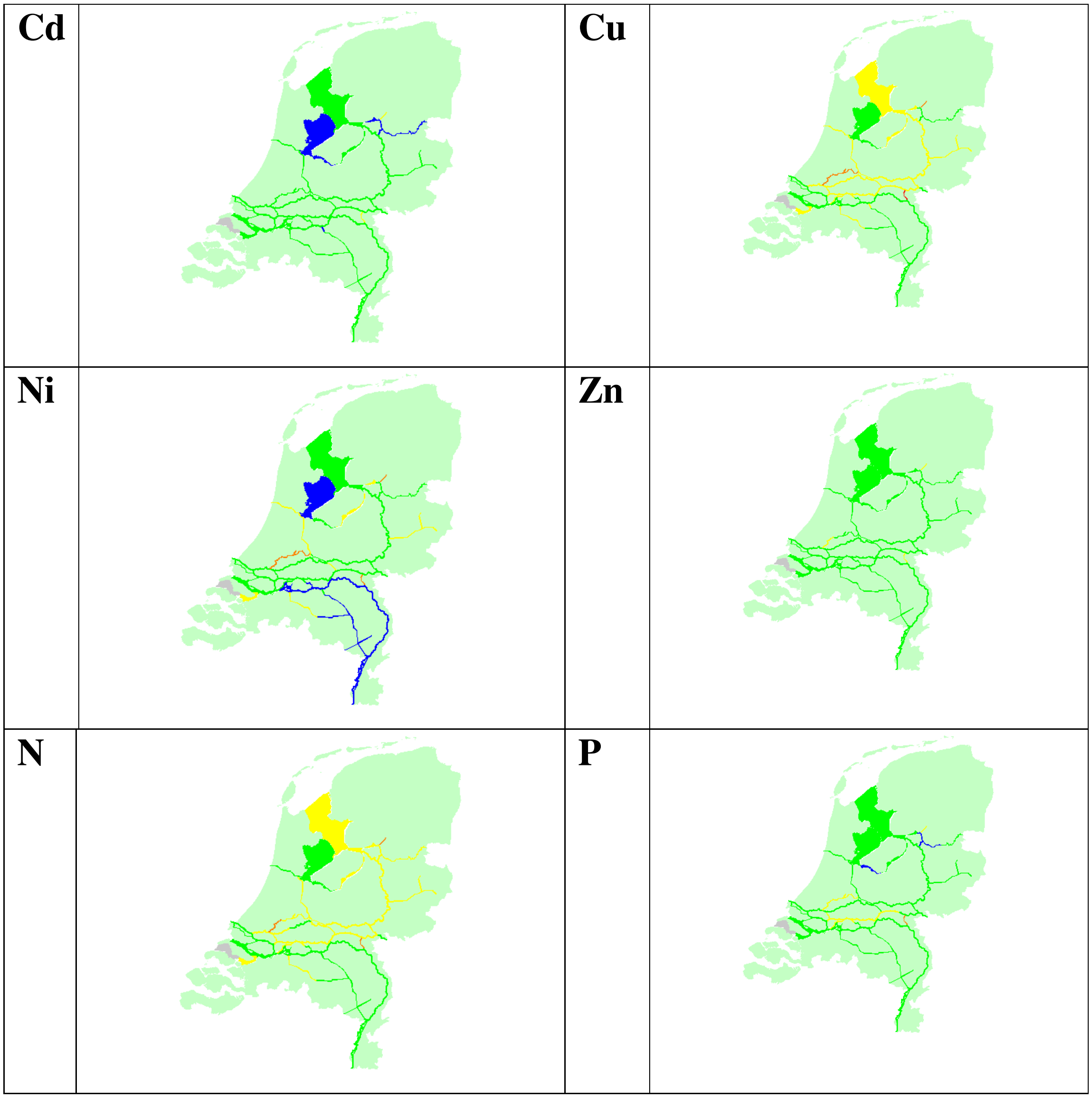


Figure 12. Water quality results for a Strict multilateral policy scenario

4.6 A DEROGATED STRICT POLICY

In the simulations presented above, the reduction target is introduced gradually and is fully met by 2015. The Water Framework Directive does, under special circumstances, allow for a derogation of these targets to 2027. This delayed target is simulated assuming that the gradual adjustment process will start immediately, but is prolonged until 2027, when the targets are fully met. The main results for this scenario are presented in Table 8. Obviously, this affects the economy between 2010 and 2027, but once the emission reduction targets are fully implemented, the impacts are comparable to the scenario with targets for 2015. Thus, it can be concluded that the derogation has only a temporary effect on the economy. As the long-term effects on water quality are also very similar, the results of the hydrological module are not presented here.

Table 8. Main results for a ***derogated*** *strict policy scenario*

	2010	2015	2020	2030
Macroeconomic results (%-change in volumes compared to benchmark projection)				
GDP	-0.1	-0.2	-0.3	-0.8
NNI	0.0	-0.1	-0.1	-0.8
Total private consumption	0.1	0.1	0.1	-0.2
Total production	-0.1	-0.2	-0.3	-1.5
Capital investment	-0.5	-0.7	-1.0	-0.7
Sectoral results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	-0.1	-0.1	-0.1	-3.0
Private consumption Industry	0.1	0.0	0.0	-0.9
Private consumption Services	0.1	0.1	0.1	0.1
Sectoral production Agriculture	-1.6	-2.0	-3.0	-33.2
Sectoral production Industry	-0.3	-0.4	-0.6	-4.1
Sectoral production Services	0.0	0.0	0.0	1.3
Sectoral production Abatement services	28.5	39.4	56.7	93.6
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Eutrophication	-5.5	-14.6	-23.7	-36.4
Emissions Dispersion to Water	-6.5	-17.4	-28.2	-43.4
Prices of main variables (constant 2000 prices)				
Wage rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Exchange rate index (benchmark index = 1)	1.0	1.0	1.0	1.0
Price of abatement services (bm. index = 1)	1.0	0.9	0.9	0.9
Price Eutrophication permits (bm. index = 1)	1.1	1.3	1.5	1.6
Price Dispersion permits (bm. index = 1)	1.2	2.0	4.5	173.8

Figure 13 shows how the permit price for Dispersion to Water increases when the environmental policy is implemented. These results confirm the discussion above. Notable is that the derogation of the policy target has no impact on the price of dispersion permits in the long run: these are solely determined by the strictness of the long-run policy.

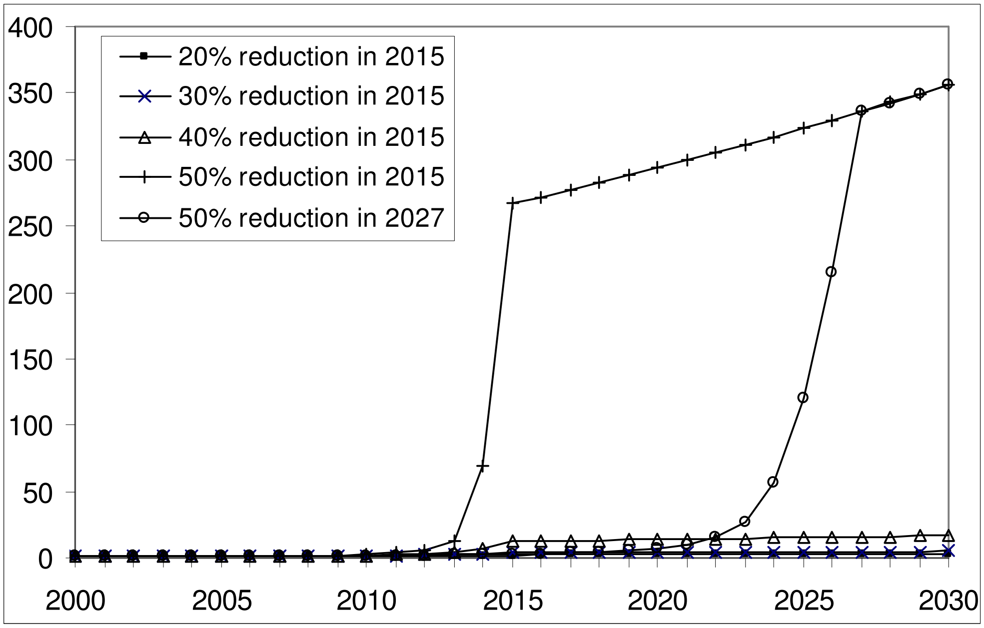


Figure 13. Permit price of Dispersion to Water – development over time

5. CONCLUDING REMARKS

In this paper, we introduce and apply an integrated economic and hydrological model to assess the consequences of implementation of the European Water Framework Directive on the Dutch economy and the main water bodies in the Netherlands. Since the water quality impacts of emission reduction scenarios are uncertain and since the WFD targets for water quality are yet unknown, we calculated several scenarios to meet the WFD requirements of good water quality status in all surface water in the Netherlands. At low levels of environmental policy there are opportunities for the economic agents to adjust to the new circumstances at relatively low costs. The impact of such a lenient policy on water quality of the various water bodies is, however, also very limited. A multilateral policy, where the concentrations of pollutants in water at the border is not exceeding the MTR standard, can reduce the problems in Dutch water bodies, but is insufficient to reach the MTR-target for all pollutants in all water bodies. The main problems are related to the river Rhine and to the pollutants Copper, Nickel and Nitrogen.

Therefore, more strict policies are required. An optimal mix arises from the trade-off between the implementation of technical measures, a restructuring of the economy and a temporary slowdown of economic growth (i.e. increasing short-term consumption at the expense of savings). Especially emission intensive sectors such as Agriculture and a number of the Industrial sectors suffer from more stringent emission reduction scenarios. On the other hand, a few sectors (Abatement, for instance) benefit from the emission reduction. A strict policy, whether it is implemented unilaterally or multilaterally, will improve water quality for most pollutants and most water bodies, but even the most strict scenario investigated, with 50 percent reduction in domestic emissions and an inflow from abroad that does not exceed the MTR standard will not resolve all water pollution problems in the Netherlands. Derogation of the target to 2027 may lead to smaller economic effects in the short term, but are likely to only postpone the economic and hydrological impacts of the policy.

There are some obvious areas for improvement of our analysis. First, the model represents a national economy, where the environmental issues at stake are largely regional. Regionalising the model will improve the link between economic activity and water pollution, as the activities can be closely linked to specific water bodies. This comes at a cost, however, that a lower geographical scale of analysis will complicate the description of economic interactions. At the national level, relevant data exists on how different sectors interact, but at the regional level, serious data problems arise. Secondly, the representation of water quality is highly stylized and deserves a more disaggregated approach; this requires a more direct integration of the economic and hydrological modules and as the hydrological module requires a spatial analysis, this connects back to the first area for improvement. Finally, the abatement cost functions used can be specified for individual sectors when the appropriate data are available.

While it might be infeasible to extent the model in all directions simultaneously, it is desirable to provide further insights into many of these issues in order to come to the best available assessment of the economic impacts of the WFD. Nonetheless, the current analysis provides the strong message that strict environmental policies are necessary to improve water quality of the Dutch water bodies, and the economic consequences of these policies are certainly not negligible.

REFERENCES

Barro, R.J. and X. Sala-i-Martin (1995). *Economic Growth*. New York. McGraw-Hill.

Brouwer, R. (2005). Toekomstige beleidsvragen en hun implicaties voor de ontwikkeling van een integraal water-en-economie model (in Dutch). Water Economic Modelling for Policy Analysis report-01. Institute for Environmental Studies, Vrije Universiteit, Amsterdam. 19 pp.

Brouwer, R., M. Hofkes & V. Linderhof (2007). *An applied general equilibrium approach to the estimation of the direct and indirect costs of water quality improvements in the WFD*. Forthcoming in *Ecological Economics*.

Brouwer, R., S. Schenau, and R van der Veeren (2005). Integrated river basin accounting in the Netherlands and the European Water Framework Directive. *Statistical Journal of the United Nations ECE* 22 (2005) 111-131.

Dellink, R.B. (2005). *Modelling the costs of environmental policy: a dynamic applied general equilibrium assessment*. Cheltenham: Edward Elgar.

Dellink, R.B. (2008). Wat zijn de directe en indirecte sectorale kosten van implementatie van de Kader Richtlijn Water in Nederland? forthcoming as WEMPA Working Paper. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Dellink, R.B., R. Gerlagh, M.W. Hofkes and L. Brander (2001). *Calibration of an applied general equilibrium model for the Netherlands in* 1990. IVM report W-01/17. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Dellink, R.B. and E.C. van Ierland (2005). Pollution abatement in the Netherlands: a dynamic applied general equilibrium assessment. *Journal of Policy Modelling* 28, 207-221.

Dellink, R. and V. Linderhof (2006). *Dynamic AGE model for water economics in the Netherlands (DEAN-WEMPA): first results*. WEMPA Working Paper 04. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Dellink, R. and V. Linderhof (2007). *Dynamic AGE model for water economics in the Netherlands (DEAN-WEMPA): an update*. WEMPA Working Paper 05. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Delsman, J. (2007). Verkenner Chemie, Totstandkoming KRW Verkenner toepassing Rijkswateren Chemie; Ministerie V&W, RWS-RIZA; 31 januari 2007.

Gerlagh, R., R.B. Dellink, M.W. Hofkes and H. Verbruggen (2002). A measure of Sustainable National Income for the Netherlands. *Ecological Economics* 41, 157-174.

Hofkes, M.W., R. Gerlagh, W. Lise and H. Verbruggen (2002). *Sustainable National Income: a trend analysis for the Netherlands for* 1990 – 1995. IVM report R-02/02. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Hofkes, M., Gerlagh, R. & Linderhof, V. (2004). *Trend analysis of sustainable national income for the Netherlands, 1990-2000*. IVM report (R04-02). Institute for Environmental Studies, Vrije Universiteit Amsterdam, 62 pp.

Huijbregts M.A.J., U. Thissen, J.B. Guinée , T. Jager, D. Kalf, D. van de Meent, A.M.J. Ragas, A. Wegener Sleeswijk, L. Reijnders (2000). Priority assessment of toxic substances in life cycle assessment. Part I: Calculation of toxicity potentials for 181 substances with the nested multi-media fate, exposure and effects model USES-LCA. *Chemosphere* 41, 541-573.

Hueting, R. (1996). Three persistent myths in the environmental debate. *Ecological Economics* 18, 81-88.

Linderhof, V., S. Reinhard, R. Brouwer and J. Icke (2007). Up-scaling and down-scaling of WEMPA models. WEMPA report-09.

Reinhard, S. and V. Linderhof (2006). *Inventory of economic models*. Water Economic Modelling for Policy Analysis report-03. Institute for Environmental Studies, Vrije Universiteit, Amsterdam. 49 pp.

Statistics Netherlands (2007). Milieurekeningen 2005, Voorburg.

Stone (2008). Koppeling economie en stofstromen model. WEMPA working paper-11.

Stone, K., R. Dellink., V. Linderhof., R. Brouwer and J. Icke (forthcoming) – De consequenties van de Kaderrichtlijn Water (KRW) op de Nederlandse economie en waterkwaliteit: integratie van economie en waterkwaliteit modellen op nationaal niveau. WEMPA report-06. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Van de Veeren, R. (2005). *Development of policy scenarios and measures*. Water Economic Modelling for Policy Analysis report-04. Institute for Environmental Studies, Vrije Universiteit, Amsterdam. 31 pp.

Van der Woerd, F., E. Ruijgrok & R. Dellink (2000). Kosteneffectiviteit van verspreiding naar water. IVM report E-00/01. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Willems, W.J., Beusen, A.H.W., Renaud, L.V., Luesink H.H., Conijn, J.G., Oosterom, H.P., Born, G.J. van der, Kroes, J.G., Groenendijk, P., Schoumans, O.F. (2005). Nutrientenbelasting van bodem en water: verkenning van de gevolgen van het nieuwe mestbeleid. MNP Rapportnr. 500031003, 111 pp.