Dynamic AGE model for water economics in the Netherlands (DEAN-WEMPA): An update

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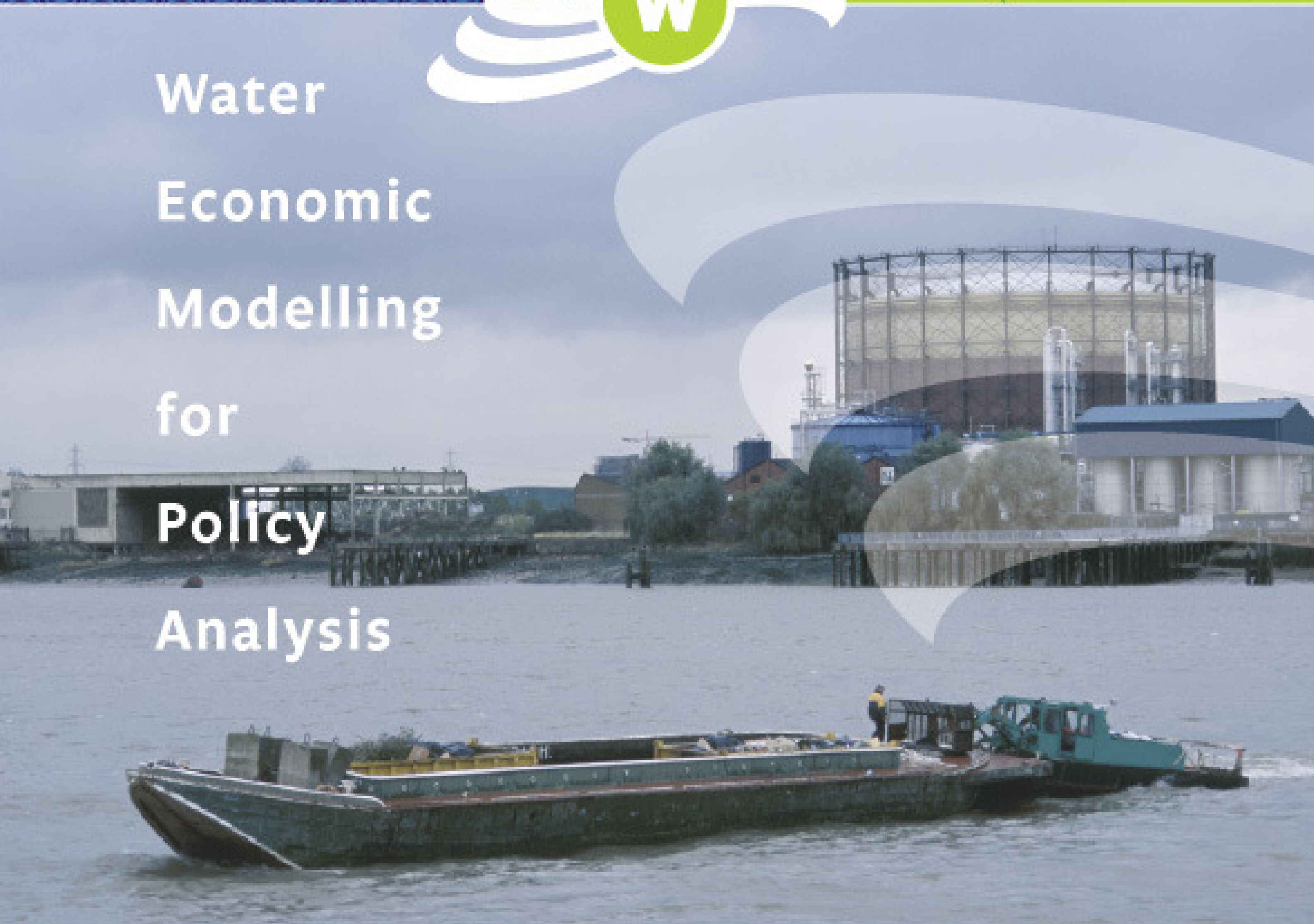

Dynamic AGE model for water economics in the Netherlands (DEAN-WEMPA)

An update

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Summary

This report presents updated preliminary results of using a dynamic Applied General Equilibrium (AGE) model for the Netherlands to study water issues. We simulate the economic consequences for different emission reduction scenarios ranging from 10 to 50 percent emission reduction from 2015 onwards with respect to emission levels in 2000, and compare these to results for scenarios with a derogation of the target until 2027. As marginal abatement costs for small amounts of reduction are relatively cheap, the first 10% of emission reductions can almost completely be achieved through the implementation of technical measures. The macroeconomic results suggest that these adjustments in the economy are virtually costless. Though production levels of the Agricultural and Manufacturing sectors decrease, this is compensated by increases in the Abatement sector. As the stringency of the policy target increases, the impacts become visible at the macro-economic level: GDP and NNI levels are decreasing, and the welfare loss, measured via the Equivalent Variation, equals almost 1.5 percent when 50 percent emission reduction is imposed.

1. Introduction

The aim of the WEMPA project is to develop an integrated and operational water and economy model that will enable us to determine the economic effects of measures to improve the water quality and subsequently the ecological quality of rivers, regional and local waters. An important requisite of this model is that it must be shaped in such a way that it is suitable for applying cost effectiveness analysis of implementing measures within the EU Water Framework Directive (WFD) (2000/60/EC) in the Netherlands. The existing models used to assess cost-effectiveness of measures are usually not integrated and are either pure hydrologic models or economic models. With this integrated model, we will be able to analyse the economic effects of implementing measures in a particular economic sector, and the impacts on other economic sectors as well. Eventually, the integrated water and economy model should be able to select the most efficient combination of measures to fulfil the goals of WFD.

For the Netherlands, there is no comprehensive hydro-economic model to calculate the economic consequences of the WFD (see Reinhard and Linderhof, 2006). In fact, there is no economic model that explicitly includes physical water flows. 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 focuses on comparative static analyses (short run) and ignores the long-run impacts, which are particularly interesting in the case of analyzing the impact of the implementation of the WFD in 2015. Therefore, we adopt the DEAN model as described in Dellink (2005) and Dellink and Van Ierland (2005) to study the economic impacts of the implementation of the WFD. This report presents updated preliminary results of using a dynamic Applied General Equilibrium (AGE) model for the Netherlands to study water issues[1]. The model, DEAN-WEMPA, is an adaptation of the DEAN model and it incorporates similar elements as the static AGE model of Brouwer *et al.* (2007).

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 10 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-WEMPA model, the required 50 percent emission reduction in 2015 is roughly equiva-

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[1] First preliminary results, using 1990 as the base year, were presented in Dellink and Linderhof (2006).

lent 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. Other assumptions might change these results. Note that these scenarios differ from the scenarios presented in Dellink and Linderhof (2006) in two ways. First, Dellink and Linderhof (2006) assume that the emission reduction scenarios are effectively implemented in the year 2015 instead of a gradual implementation from 2008 onwards. Secondly, they also assume that emission reduction scenarios are related to the benchmark or the business-as-usual scenario instead of a norm with respect to the emission level in a particular year.

Section 2 describes the general features of the DEAN model, and the way it is adapted to study water economics. Section 3 deals with the calibration of the model, and Section 4 presents the results of the first, preliminary calculations. Section 5 concludes.

2. Model description

2.1 General description of the DEAN model[2]

DEAN[3] is a forward-looking neo-classical growth model. 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). A full set of model equations is given in Dellink (2005); 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.

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[2] This section is based on Dellink (2005) and Dellink and Van Ierland (2005).

[3] Acronym for "*D*ynamic applied general *E*quilibrium model with pollution and *A*batement for the *N*etherlands".

2.2 Pollution and abatement

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[4] 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 (*cf.* Dellink, 2005). 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 governs how much additional abatement effort is needed to reduce pollution by one additional unit. The estimated CES-elasticity describes the environmental theme-specific possibilities to substitute between pollution and abatement goods (the Pollution – Abatement Substitution or PAS curve) and 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 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

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[4] 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.

exogenous parameters. Nonetheless, the model does contain endogenous diffusion of existing abatement technology.

2.3 Adaptations of the model for WEMPA

In order to investigate the economic consequences of the implementation of the WFD properly, DEAN-WEMPA differs in a number of aspects from DEAN. First, the time horizon of DEAN-WEMPA has been truncated to 2050, as the actual implementation of the WFD is due in 2015, with possible derogation of efforts to 2027[5]. Secondly, DEAN considers time periods of 5 years; given the much shorter model horizon in the DEAN-WEMPA model, this level of aggregation is unnecessary. Therefore, annual results are calculated for the period 2000 – 2049. Thirdly, DEAN considers policies for several environmental themes that are not directly relevant here. These policies are removed from the analysis, as they might interfere with the analysis of the water-related policies. Fourthly, DEAN does not consider the environmental theme 'Dispersion of toxic substances to Water'. The information on this environmental theme, as available in WEMPA, has been incorporated into the model.

Together, these changes ensure that a suitable tool is used for the analysis of the economic impacts of the water related policies discussed above.

The main differences between this second interim report and the first interim report (Dellink and Linderhof, 2006) is the change of the base year in the model from 1990 to 2000. This implies that a completely new set of data was used for the initial equilibrium as well as the environmental parameters (social accounting matrix, emissions, and abatement cost curves).

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[5] Given the forward-looking behaviour of agents in the model, and the calculation of an infinite horizon welfare change, it is essential to use a model horizon that is sufficiently far in the future. As an indication: the present value (in year 2000) of a hundred Euro in 2050 using a discount rate of 5 percent is almost 9 Euro (excluding inflation).

3. Data and scenarios

3.1 Calibration of the base year

The base year data are taken from historical data for the Netherlands, as reported in Hofkes *et al.* (2004). More recent data that is available for economic activity and emissions is used to calibrate the model parameters. 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.

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

Sector number & description[1]		SBI-code (1993)[2]	Production 2000 mln Euro	Production 2000 (share)	Consumption 2000 mln Euro	Consumption 2000 (share)
1	Agriculture and fisheries	01 – 05	18,378	(2.9%)	1,796	(0.8%)
2	Extraction of oil and natural gas	11	10,946	(1.7%)	298	(0.1%)
3	Other mining and quarrying	10, 14	906	(0.1%)	60	(0.0%)
4	Food and food products industry	15, 16	36,006	(5.7%)	14,411	(6.2%)
5	Textiles, clothing and leather industry	17 – 19	3,507	(0.6%)	5,651	(2.4%)
6	Paper and –board industry	21	4,293	(0.7%)	476	(0.2%)
7	Printing industry	22	11,016	(1.7%)	3,410	(1.5%)
8	Oil refineries	23	19,412	(3.1%)	3,533	(1.5%)
9	Chemical industry	24	23,226	(3.7%)	3,482	(1.5%)
10	Rubber and plastics industry	25	5,315	(0.8%)	662	(0.3%)
11	Basic metals industry	27	4,989	(0.8%)	259	(0.1%)
12	Metal products industry	28	11,237	(1.8%)	541	(0.2%)
13	Machine industry	29 – 31	12,278	(1.9%)	1,219	(0.5%)
14	Electromechanical industry	32, 33	14,840	(2.4%)	2,368	(1.0%)
15	Transport equipment industry	34, 35	10,243	(1.6%)	2,463	(1.1%)
16	Other industries	20, 26, 36, 37	14,910	(2.4%)	5,879	(2.5%)
17	Energy distribution	40	13,280	(2.1%)	6,289	(2.7%)
18	Water distribution	41	1,681	(0.3%)	1,158	(0.5%)
19	Construction	45	46,282	(7.3%)	8,695	(3.7%)
20	Trade and related services	50 – 55	92,234	(14.6%)	14,753	(6.3%)
21	Transport by land	60	12,650	(2.0%)	2,311	(1.0%)
22	Transport by water	61	4,185	(0.7%)	128	(0.1%)
23	Transport by air	62	7,176	(1.1%)	961	(0.4%)
24	Transport services	63	10,414	(1.7%)	3,682	(1.6%)
25	Commercial services	64 – 74	134,903	(21.4%)	46,245	(19.8%)
26	Non-commercial services	75 – 95	104,718	(16.6%)	94,877	(40.5%)
27	Other goods and services	99	1,221	(0.2%)	8,513	(3.6%)

[1] Goods are represented by their production sector.

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

Some characteristics of production in The Netherlands in 2000 are given 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).

Emissions of euthrophying substances are concentrated to a large extent in the Agricultural sector. As shown in Table 2, this sector accounts for around two-thirds of all emissions. In addition, the Agricultural sector emits hardly any toxic substances. The Chemical industry is responsible for more than one-fifth of the dispersion of toxic substances to water (see Section 3.3 for the definition of the individual substances of this theme). Also, private households emit around one-fifth of the total toxic substances dispersed to water.

Table 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	90.44	(65.8%)	0.85	(1.0%)
2	Extraction of oil and natural gas	0.10	(0.1%)	0.02	(0.0%)
3	Other mining and quarrying	0.05	(0.0%)	0.01	(0.0%)
4	Food and food products industry	4.33	(3.1%)	6.30	(7.1%)
5	Textiles, clothing and leather industry	0.20	(0.1%)	3.78	(4.3%)
6	Paper and –board industry	1.13	(0.8%)	1.19	(1.3%)
7	Printing industry	0.02	(0.0%)	0.73	(0.8%)
8	Oil refineries	0.42	(0.3%)	0.52	(0.6%)
9	Chemical industry	6.05	(4.4%)	18.12	(20.5%)
10	Rubber and plastics industry	0.03	(0.0%)	0.39	(0.4%)
11	Basic metals industry	0.43	(0.3%)	12.02	(13.6%)
12	Metal products industry	0.10	(0.1%)	7.46	(8.4%)
13	Machine industry	0.05	(0.0%)	2.33	(2.6%)
14	Electromechanical industry	0.09	(0.1%)	3.05	(3.5%)
15	Transport equipment industry	0.03	(0.0%)	2.96	(3.4%)
16	Other industries	0.46	(0.3%)	2.70	(3.1%)
17	Energy distribution	1.40	(1.0%)	0.02	(0.0%)
18	Water distribution	0.01	(0.0%)	0.00	(0.0%)
19	Construction	0.93	(0.7%)	0.13	(0.1%)
20	Trade and related services	0.69	(0.5%)	0.33	(0.4%)
21	Transport by land	2.93	(2.1%)	0.57	(0.6%)
22	Transport by water	4.46	(3.2%)	4.46	(5.0%)
23	Transport by air	1.49	(1.1%)	0.00	(0.0%)
24	Transport services	0.07	(0.0%)	0.02	(0.0%)
25	Commercial services	0.75	(0.5%)	0.49	(0.6%)
26	Non-commercial services	1.12	(0.8%)	1.87	(2.1%)
27	Other goods and services	0.10	(0.1%)	0.09	(0.1%)
Private households		19.59	(14.3%)	17.91	(20.3%)
Total		137.46	(100%)	88.34	(100%)

One technical problem that has to be dealt with is the fact that waste handling facilities (part of the Non-commercial services) prevent substantial eutrophying emissions, mainly 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 eutrophying emissions in the other parts of the Non-commercial services, and consequently the total sector Non-commercial services would have a negative emission coefficient for eutrophication. This can lead to technical problems in the model if a system of pollution permits is introduced; therefore these eutrophication 'sinks' are re-attributed to the sectors in which these emissions have originated, such as the agricultural sector and the households.

3.2 Calibration of the abatement cost curve for Eutrophication

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 1.

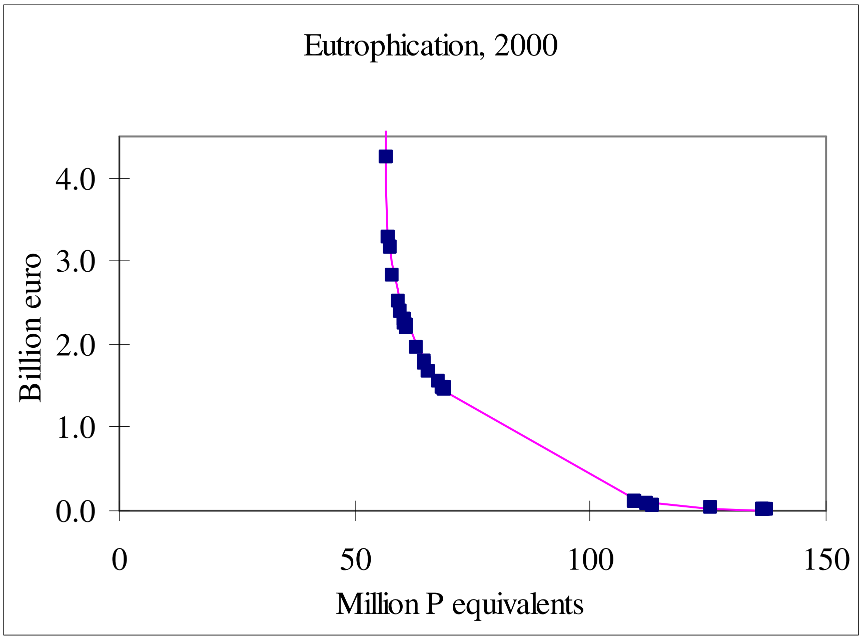

Figure 1: Abatement cost curve for eutrophication in 2000.

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.

3.3 Calibration of the abatement cost curve for Dispersion to Water

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. 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 2 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.

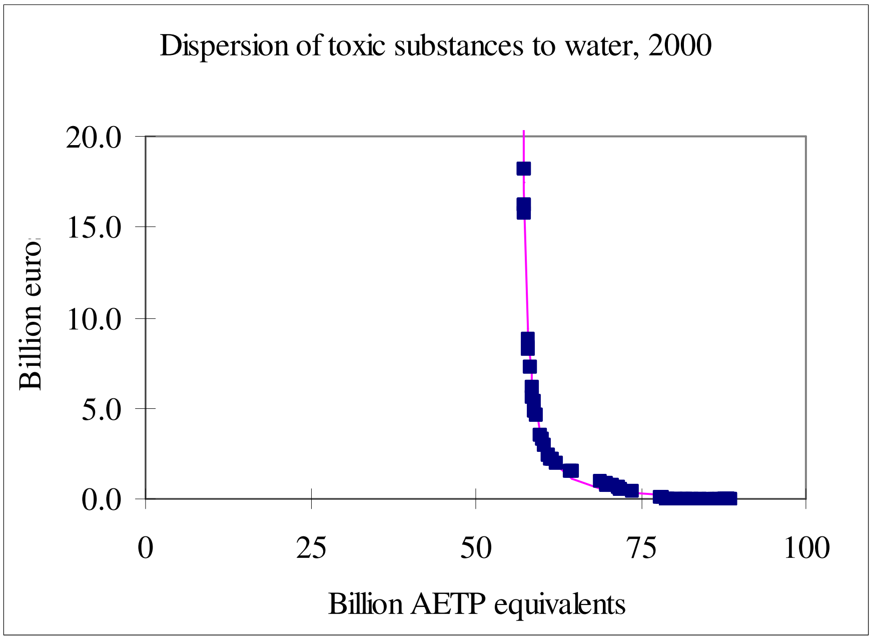

Figure 2. Abatement cost curve for dispersion of toxic substances to water in 2000.

The three main contributors to the dispersion of toxic substances to water are the chemical industry (38%), households (25.2%), and the textiles, clothing and leather industry (11.7%).

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

Dispersion of toxic substances to water	
1 million kg 1.4-dichlo-robezene equivalent =	
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

3.4 Calibration of the parameters

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 5% is used. 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.

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; Brouwer et al., 2007). 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.[6] The autonomous abatement efficiency improvement is calibrated to 0.5 percent per year throughout the model horizon.

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[6] 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.

4. Results

4.1 Attaining the reduction target by 2015

The main results of the environmental policy where the emissions for Eutrophication and Dispersion simultaneously have to be reduced by 20 percent with respect to the emission level of 2000 are represented in Table 4. Given the reduction in emissions between 2000 and 2015 as a result of existing policies (see Section 3.4), the target for Eutrophication is not 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 in Table 3), 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 technical measures. The macroeconomic results suggest that these adjustments in the economy are virtually costless.

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, that induce compensating price increases; this effect carries over from the benchmark to the counterfactual simulations.

Table 4: Main results for a required 20% reduction in emissions

	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	0.0	0.0	0.0	0.0
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	0.0	0.1	0.1	0.1
Sectoral production Industry	0.0	0.0	0.0	0.0
Sectoral production Services	0.0	0.0	0.0	0.0
Sectoral production Abatement services	1.3	4.1	4.1	4.1
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Eutrophication	0.7	1.8	1.8	1.8
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	1.6	1.8	2.1
Price Dispersion permits (bm. index = 1)	1.6	2.5	2.8	3.4

Table 5 gives the main results for the more stringent policy where emission reductions of 50 percent (compared to emission levels in 2000) are required. As the costs of the policy increases, the impacts become visible at the macro-economic level: GDP and NNI levels are decreasing. For both themes, the more stringent target is binding, and emissions have to be reduced below benchmark projection levels by 36 and 43 percent, respectively. This stimulates production in the Abatement services sector.

Table 5. Main results for a required 50% reduction in emissions

	2010	2015	2020	2030
Macroeconomic results (%-change in volumes compared to benchmark projection)				
GDP	0.0	-0.1	-0.2	-0.3
NNI	0.0	0.0	-0.1	-0.2
Total private consumption	0.0	0.2	0.1	-0.1
Total production	0.0	-0.9	-1.0	-1.2
Capital investment	-0.2	-1.0	-1.1	-1.3
Sectoral results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	0.0	0.1	0.0	-0.1
Private consumption Industry	0.0	-0.2	-0.3	-0.5
Private consumption Services	0.0	0.5	0.4	0.2
Sectoral production Agriculture	-0.6	1.9	1.6	1.2
Sectoral production Industry	-0.1	-4.0	-4.1	-4.3
Sectoral production Services	0.0	0.6	0.6	0.4
Sectoral production Abatement services	22.1	152.7	151.8	150.3
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)	2.1	4.8	5.3	6.5
Price Dispersion permits (bm. index = 1)	3.6	166.2	182.8	221.3

Rather surprisingly, the Agricultural sector does not reduce its production levels, even though this sector is the largest emitter of eutrophying substances. The reason for this is the dominance of the theme Dispersion to water: Agricultural emissions of these pollutants are relatively small. Production levels of the industrial sectors decrease by several percentages. Thus, a shift in production from industry to agriculture and services 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 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 3 shows the development of the percentage change in GDP over. 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 natural: 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.

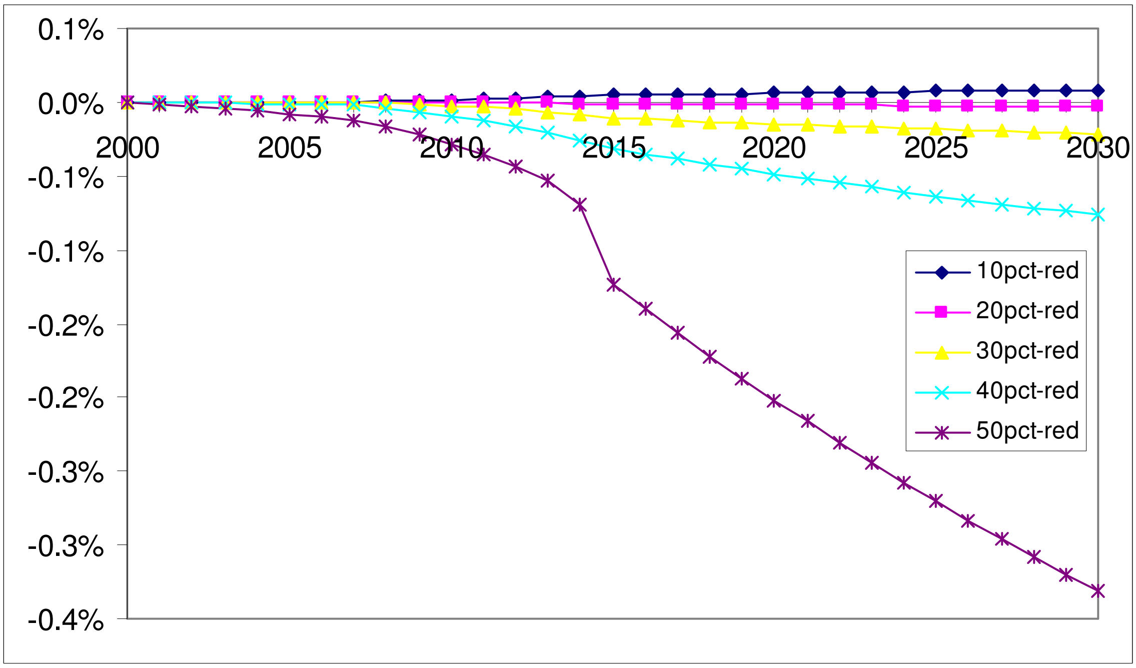

Figure 3. Percentage change in GDP – development over time

From Figure 4 the differences in impact of the environmental policy on production levels are clearly visible. As expected, magnitudes are larger when environmental policies are stricter. This also means that the sectors that can benefit from the new policy, including not only the Abatement sector (cf. Tables Table 4 and Table 5), but also for example Transport by Air is best served by a stringent policy. 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 dispersion emissions attributed to this sector, whereas the other transport modes have substantial emissions. 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.

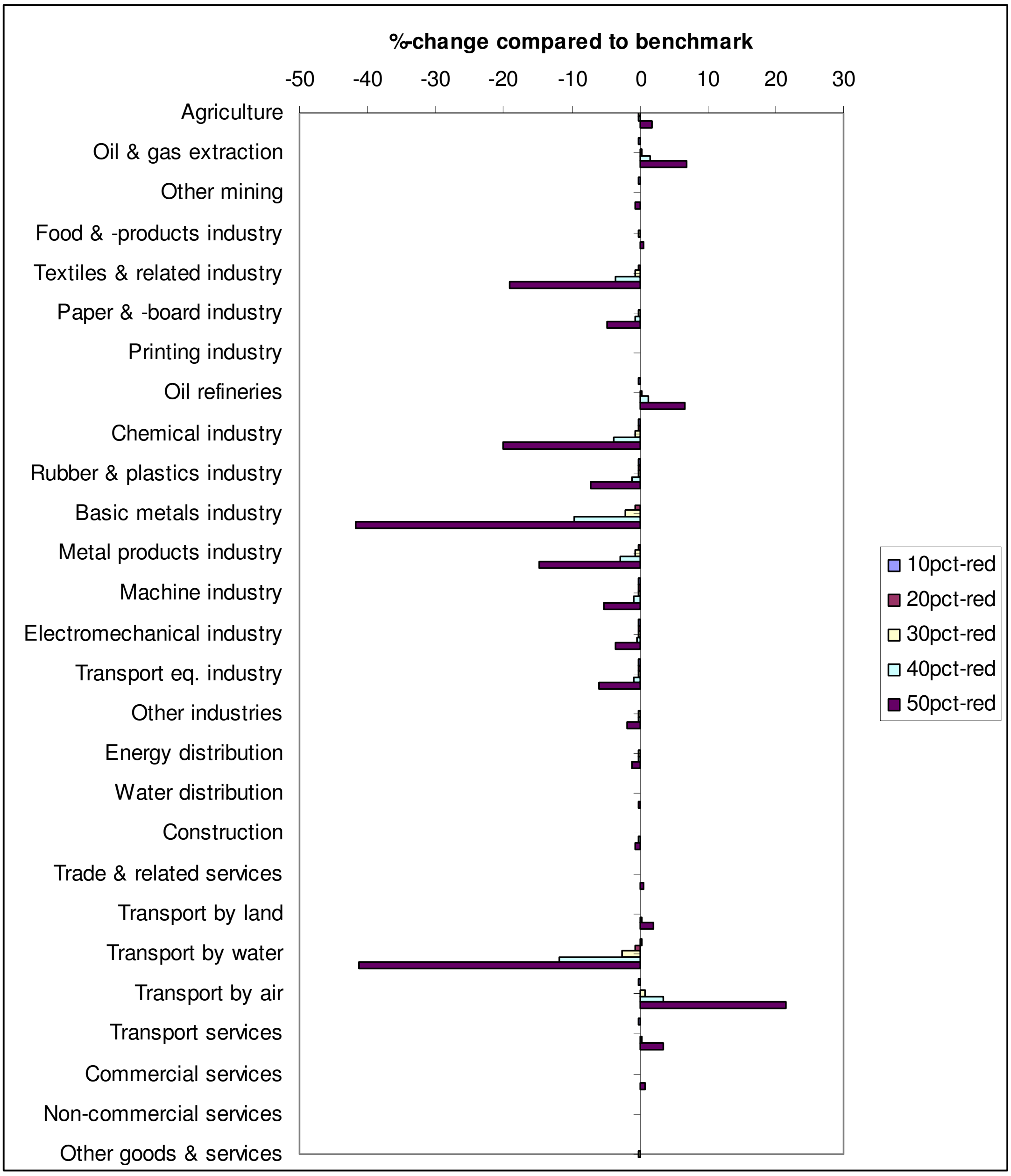

Figure 4. Percentage change in sectoral production levels in 2015

Finally, a preliminary assessment of the impact of the economic changes on emissions of individual water pollutants has been carried out. By assuming fixed emission intensities per unit of production, the changes in economic activity and in emissions of the theme equivalents can be translated into changes in emissions for these individual pollutants (i.e., per sector the same reduction percentages hold for all substances within a theme). It is assumed that no action is undertaken to deliberately reduce emissions for individual substances; they are rather the by-product of the environmental policies on Eutrophication and Dispersion. It should be stressed that this crude way of modelling the individual pollutants is far from perfect, as not all measures implement to achieve the reduction targets for the themes will influence the associated substances equivalently. Therefore, a more refined approach is advocated for further study. Nonetheless, the approach used here gives insight into the interlinkages between the changes in economic activity and theme-equivalent emissions invoked by the water policy and the emissions of a wide range of pollutants. The results are given in Table 6.

Table 6: Impact of the policies on individual pollutants in 2015 (%-change compared to benchmark projection)

	10% reduction	20% reduction	30% reduction	40% reduction	50% reduction
Eutrophication aggregate	*14.5*	*1.8*	*-11.0*	*-23.7*	*-36.4*
P	14.2	1.8	-10.8	-23.5	-36.3
N	14.7	1.8	-11.0	-23.8	-36.5
Dispersion aggregate	*1.8*	*-9.5*	*-20.8*	*-32.1*	*-43.4*
Hg	1.6	-8.8	-19.7	-30.9	-40.8
Cd	1.5	-8.3	-18.9	-30.3	-41.5
Pb	1.5	-7.6	-17.5	-28.7	-37.7
Zn	1.6	-7.9	-18.0	-28.8	-37.2
Cu	1.6	-8.7	-19.4	-30.4	-40.1
Ni	1.9	-9.9	-21.4	-32.8	-44.6
Cr	1.9	-9.8	-21.3	-32.4	-43.3
As	1.3	-7.0	-16.6	-27.5	-35.9

It is clear that the emissions of the individual pollutants decrease more or less in line with the theme equivalent emissions. There, however, are some differences within the theme Dispersion; especially the emissions of As, Pb and Zn are reduced less than the theme aggregate. This illustrates that the emissions for these pollutants are less closely linked to the same economic activities as the emissions of the other pollutants.

4.2 Derogation of reduction targets to 2027

In the base simulations presented above, the reduction target is introduced gradually and has to be 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. 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.

Table 7. Main results for a ***derogated*** *required 50% reduction in emissions*

	2010	2015	2020	2030
Macroeconomic results (%-change in volumes compared to benchmark projection)				
GDP	0.0	0.0	-0.1	-0.2
NNI	0.0	0.0	0.0	-0.1
Total private consumption	0.0	0.0	0.0	0.1
Total production	0.0	-0.1	-0.1	-1.0
Capital investment	-0.1	-0.2	-0.3	-1.2
Sectoral results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	0.0	0.0	-0.1	0.0
Private consumption Industry	0.0	0.0	0.0	-0.3
Private consumption Services	0.0	0.0	0.1	0.4
Sectoral production Agriculture	-0.2	-0.6	-0.7	1.6
Sectoral production Industry	0.0	-0.1	-0.5	-4.1
Sectoral production Services	0.0	0.0	0.0	0.5
Sectoral production Abatement services	7.2	24.2	56.4	151.6
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)	1.7	2.4	3.5	6.5
Price Dispersion permits (bm. index = 1)	1.9	4.4	16.2	222.4

Figure 5 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.

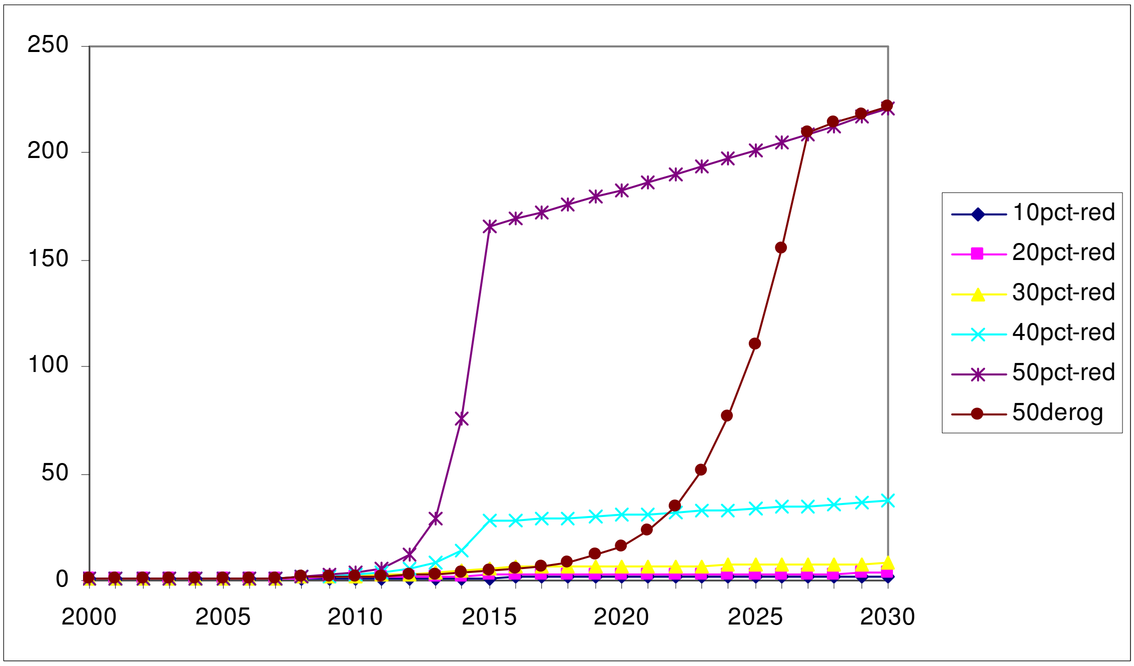

Figure 5. Permit price of Dispersion to Water – development over time

5. Concluding remarks

At low levels of environmental policy, say a 20 percent reduction in eutrophying emissions and toxic substances dispersed to water, there are good opportunities for the economic agents to adjust to the new circumstances. Relatively cheap technical measures are implemented to reduce emissions, and the macroeconomic impacts of the policy remain very limited. At more stringent levels of policy the alternatives to adjust disappear. Then, 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). Note that the DEAN-WEMPA is applied to long-term or mid-term analysis, so that annual economic fluctuations (business cycle effects) are ignored.

If we compare the results of DEAN-WEMPA and the static AGE model in Brouwer et al. (2007), the decline in Net National Income seems to be much lower in the dynamic model than in the static model. As the dynamic model predicts a 0.2 percent loss in NNI compared to the benchmark in 2015, the static model predicts a 10 percent loss in NNI. Apart from differences caused by the different base year (2000 vs. 1990), the dynamic aspects of autonomous emission efficiency and developments in the abatement costs curves are ignored in the static model results. Similar differences between the dynamic and static model (both calibrated to 1990) in the evaluation of a wide range of environmental problems are found in Dellink (2005), who analyses the differences in detail.

There are some obvious areas for improvement of our analysis. First, updates of the data for base year 2000 will be made available by Statistics Netherlands; this also allows a further disaggregation of production activities. Secondly, the balanced growth path assumed in the model is relatively simple, and disregards structural changes in preferences and the structure of the economy. It is expected that most service (sub-)sectors in the economy show an more than proportional growth rate, while the reverse is the case of the agricultural sector. Thirdly, the model represents a national economy, where the environmental issues at stake are largely regional. Though it is possible to softlink these national results with more detailed models at the scale of individual river basins, such as the Substance Flow model for surface water quality in the Netherlands, a more direct link would improve the analysis. Fourthly, the representation of water quality in the model is highly stylised and deserves a more disaggregated approach. A first step is to consider individual substances instead of environmental themes, although we might run into problems with the data availability of the Pollution-Abatement curves. Finally, the abatement cost functions used can be specified for individual sectors when the appropriate data are available. Note that it might be infeasible to extent the model in all directions simultaneously.

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WEMPA Report-02	Paul Baan Aline te Linde	Inventory of water system models
WEMPA Report-03	Stijn Reinhard Vincent Linderhof	Inventory of economic models
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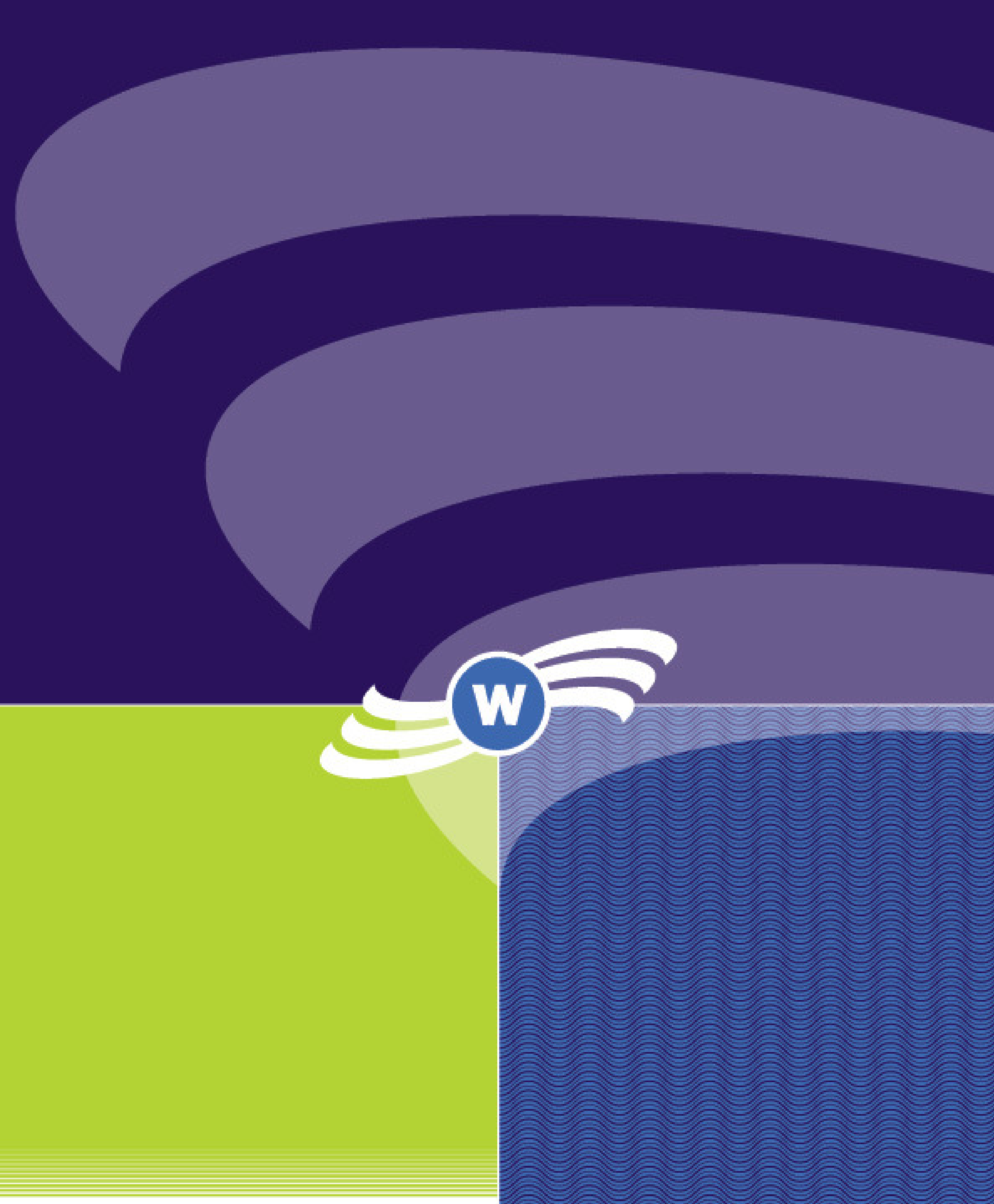

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