The Timing of National Greenhouse Gas Emission Reductions in the Presence of Other Environmental Policies

Rob B. Dellink and Marjan W. Hofkes

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Rob B. Dellink, *Environmental Economics and Natural Resources Group, Wageningen University*
Marjan W. Hofkes, *Institute for Environmental Studies, Vrije Universiteit*

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Summary

This paper shows in an empirical context that substantial cost reductions can be achieved in the implementation of Dutch national climate policy by (i) targeting the policy at the stock of greenhouse gases, thus allowing polluters flexibility in their timing of emission reductions; and (ii) integrating climate policy with other policies, thereby optimising the restructuring of the economy needed to achieve environmental policy targets. A dynamic applied general equilibrium model with bottom-up information on abatement techniques is used to show that the optimal timing of GHG emission reductions tends to follow the timing for the other environmental themes with an additional emphasis on emission reductions in the later periods. The optimal mix of technical measures and economic restructuring as source of emission reductions is affected by the strictness of environmental policy targets for all themes and hence can only be derived from an integrated analysis of these policies.

Keywords: Economic growth, Applied general equilibrium model, Climate change, Environmental policy

JEL Classification: D58, H23, O41, Q28

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Address for correspondence:

Rob B. Dellink
Wageningen University
Hollandseweg 1
6706 KN Wageningen
The Netherlands
Phone: +31 317 482009
Fax +31 317 484933
E-mail: rob.dellink@wur.nl

1. INTRODUCTION

Designing and evaluating environmental policy requires detailed understanding of the relations between economy and environment. Using mathematical models that specify quantitative links between economic activity and environmental pressure can provide insight into the direction and size of economic implications of environmental policies. Given the increasing importance of implementing costly measures to achieve required emission reductions, the need for multi-sectoral economic models with special attention to emissions and abatement is eminent. This paper partially satisfies this need by specifying a dynamic applied general equilibrium model with emissions and abatement options for several environmental problems simultaneously.

Simultaneous analysis of several environmental problems is rarely addressed in the existing empirical literature. Many of the major integrated climate-energy-economy models (cf. Weyant, 1999) only deal with CO_2. A major advantage of this assumption is that for CO_2, end-of-pipe measures are prohibitively costly compared to fuel switches, and can therefore be neglected. Recently, some models do take more greenhouse gasses into account (*e.g.* Babiker *et al.*, 2001 and Hyman *et al.*, 2002), but extension of the models to include other environmental problems and policies remains largely absent. An exception is Vennemo (1997), who pays detailed attention to the feedbacks from the environment to the economy based on several air pollutants. These feedbacks go via the impact of environmental quality on utility, via reduced labour productivity and via increased capital depreciation. Using a dynamic AGE model of the Ramsey-type, he analyses what happens in the economy if these feedbacks are introduced and finds substantial reductions in consumption and GDP in the second half of the 21st century.

The optimal timing of GHG emission reductions also depends on the availability of abatement options. Jensen (2000) also uses a Ramsey-type model in an analysis of carbon taxes in Denmark. He shows that delaying the abatement activities, while keeping the accumulated emission reductions within the model horizon constant, can substantially reduce the economic costs of environmental policy. Rasmussen (2001) extends the Ramsey model with learning-by-doing in the renewable energy sector to capture endogenous technological progress. He finds that the presence of endogenous interactions between carbon abatement and technological progress leads to substantially lower abatement costs and a lower optimal level of short-term emission reductions due to rapidly declining abatement costs over time. Van der Zwaan *et al.* (2002) and Gerlagh and Van der Zwaan (2003) use a similar approach, while specifying multiple technologies. They find that including endogenous innovation will lead to earlier and cheaper emission reductions than models with exogenous technological change predict, especially through the development of carbon-free technologies.

In the literature on ancillary benefits (*e.g.* Ekins, 1996; Van Vuuren *et al.*, 2006), the positive impacts of greenhouse gas emission reductions on other environmental problems are stressed, for instance via the reduction of health costs due to improved local air quality as a result of lower emissions of fine dust. These studies ignore, however, that these other environmental problems are also subject to government policies, and hence that these policies should be studied simultaneously.

Isolated analysis of climate policy can lead to misleading policy recommendations. For a proper analysis of the optimal timing of greenhouse gas emission reductions, climate policy should be integrated with policies for other environmental problems. This integration is essential due to the many interactions between the environmental problems, either environmental, *e.g.* ancillary benefits, or economic, *i.e.* via economic restructuring. Co-ordination of these policies may have significant impacts on the economic costs of climate policy and the optimal timing of reductions.

This paper aims at investigating the interactions between climate policy and other environmental policies. To this end the dynamic applied general equilibrium model DEAN[1] that comprises several environmental themes is used. DEAN is also suited to analyse the influence of a stock-oriented climate policy versus a policy that directly controls flows of emissions. Hence, the second aim of the paper is to analyse the potential for cost savings if polluters have flexibility in the timing of their emission reductions, in the presence of other environmental policies.

This paper is organised as follows: in the next section, a brief overview of the DEAN model is given (Section 2). Then, the model calibration is discussed in Section 3, together with the policy scenarios under investigation. Section 4 discusses the results of the model simulations with two integrated environmental policies and with one stand-alone climate policy. Section 5 concludes.

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

2. DESCRIPTION OF THE MODEL

The DEAN model is a multi-sectoral dynamic applied general equilibrium (AGE) model for a small open economy with special attention to the specification of emissions and abatement for several major environmental themes simultaneously. The framework for the model is a Ramsey-type economic growth model with perfect foresight. A detailed description of the model, the treatment of environmental issues and data sources can be found in Dellink (2005); below, the main model characteristics are briefly sketched.

The AGE model describes the relationships between the economic agents. These economic agents can be households (consumers), firms (producers), other countries and the government. Firms are grouped together into production sectors. Producers operate under full competition and maximise profits subject to their production technology, for given prices. Under constant returns to scale, this leads to the first of the three basic conditions: the *zero profit condition*. Households are grouped into household groups. As the model assumes all households to behave identically, they can be aggregated into one representative consumer. Households maximise their utility subject to a budget constraint, for given prices and given initial endowments. This is the second basic condition: the *income condition*. The economy is said to be in equilibrium if every agent can satisfy his/her demand or supply for each good, given a set of (relative) market prices that is common to all agents. In other words, total demand must equal total supply on all markets. This is referred to as *market clearance*, the third class of basic AGE conditions. Equilibrium is attained through adjusting the relative prices; the resulting prices are called equilibrium prices.

The environment is treated as necessary input to production. An intuitive way of looking at this is to think of environmental services as input for production, for which emission permits are required. These environmental services can be regarded as the allowance to emit polluting substances to the environment. The costs associated with this input concern the payments for the emission permits that are required to use the environmental resource, *i.e.* a transaction between the polluter and the government. A similar approach is used in AGE modelling by, amongst others, Bergman (1990, 1991), Conrad and Schröder (1991, 1993), Robinson *et al.* (1994) and Welsch (1996).

The model contains seven environmental themes: Climate change, Acidification, Eutrophication, Smog formation, Dispersion of fine dust, Desiccation and Soil contamination. The main rationale for using environmental themes is that they form the basis for environmental policy in The Netherlands. Moreover, combining different related polluting substances in an environmental theme ensures that the interactions between the substances involved are properly taken into account. The emissions of different substances that contribute to a certain environmental theme are converted to theme-equivalents in order to be able to add them up. For Climate change, all major greenhouse gases (GHGs), including carbon dioxide, methane, nitrous oxide, CFCs, HCFCs, HFC and halons, are combined using long-term global warming potentials. Desiccation and Soil contamination concern cleaning up past pollution and are represented in the model by a fixed governmental expenditure on abatement, rather than emissions.

Abatement is an economic activity and should be modelled as such. Many models ignore the interactions between abatement activities and the rest of the economy, even though these interactions may be significant. In DEAN, essential bottom-up information on abatement measures is integrated in a top-down framework, thereby allowing a detailed analysis of the direct and indirect costs of environmental policy. Key information included in the model is (i) the abatement costs at different levels of abatement (the abatement cost curves), (ii) the technical potential of emission reduction that can be achieved by implementing existing technical abatement measures and (iii) the cost components of these technical abatement measures. These cost components describe the inputs used in the abatement process and include labour costs, capital costs and energy costs. Note that the abatement cost curves contain all known available technical options to reduce pollution, both end-of-pipe as well as process-integrated options, including substitution between different inputs (*e.g.* fuel-switch). All these elements are specified in a dynamic manner. Polluters have the endogenous choice between paying for emission permits or increasing their expenditures on abatement. The extent to which this substitution is possible and the characteristics of producing abatement are derived from empirical abatement cost curves.

Emissions are related to the output levels of producers and consumption levels of consumers. This implies that GHG emissions are not directly linked to fuel use (as an input). Though this specification matches the set-up of the abatement cost curves (as changes in fuel mix and their impacts on emissions are incorporated there), it denies the indirect effects of abatement on the demand for fuels[2]. The advantage of our approach over the common approach in integrated climate-energy-economy models is that all possible options, including end-of-pipe measures, are taken into account; this is especially relevant for other pollutants than CO_2.

[2] The impact of this approximation remains limited, as shown in Verbruggen *et al.* (2000).

It should be noted that the DEAN model does not aim at providing an optimal climate policy. For that purpose, the global energy-economy models discussed above are better suited. The strength of the DEAN model lies in the ability to embed climate policy in a wider national environmental policy plan. The results below should therefore be interpreted with care and focus should primarily be put on the comparison of the different scenarios.

It makes sense to model not only the flow of emissions but also the stock of GHGs. As GHGs mix uniformly in the atmosphere, the relevant stock to be modelled is the global stock. However, emissions in The Netherlands only comprise a small fraction of global emissions (less than 1%, RIVM, 2002a). Moreover, national environmental policy can only influence domestic emissions. Therefore, not the global stock of GHGs is modelled and controlled in the DEAN model, but rather the contribution of The Netherlands to the stock over the model horizon (the “GHG stock addition”).[3]

The climate module that is needed to calibrate the GHG stock addition of The Netherlands is kept very simple. Based on the DICE model (Nordhaus, 1994), first an annual decay factor (δ_M) for the existing stock of GHGs is specified. This decay factor is assumed to apply to all contributions of The Netherlands to the stock of greenhouse gasses and is used to calculate how much of the GHG stock addition in a period carries over to the next period. Secondly, a marginal retention rate (ε_M) determines how much emissions contribute to the stock addition. Since not all emitted GHGs remain in the atmosphere, this retention rate is smaller than unity. These two items imply that the addition to the stock caused by one unit of emissions is lower than unity and varies over time.

Let M_t denote the GHG stock addition of The Netherlands from the base year of the model, 1990, up to and including year *t* and let $E_{GHG,j,t}$ denote greenhouse gas emissions of polluter *j* in period *t*. Then the development of the GHG stock addition can be calculated as

$$M_t = \left(1-\delta_M\right)\cdot M_{t-1} + \varepsilon_M \cdot \sum_{j=1}^{J} E_{GHG,j,t} \qquad (1)$$

At the start of the base year of the model, the stock addition equals zero: $M_{1989} = 0$.

[3] Alternatively, one could identify the contribution to temperature increase or climate impacts, but this depends on other countries’ actions and goes beyond the scope of the current paper.

3. CALIBRATION AND POLICY SCENARIOS

3.1. Calibration of the model

The base year data are taken from historical data for 1990 for the Netherlands, as reported in Dellink (2005) and summarised in Table 1. The Netherlands is chosen because of the wide availability of data. More recent data, that are available for economic activities and emissions, are used to calibrate the dynamic model parameters. The benchmark projection consists of the balanced growth path that is determined by the base year accounting matrix and a balanced growth rate of 2% per year. 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. The largest sectors in terms of production value are Non-commercial services (18%) and Commercial services (16%).

Table 1. Production values (1990 prices) and emission shares in The Netherlands for 1990

	Production	Climate change	Acidifi-cation	Eutrophi-cation	Smog formation	Disp. of fine dust
Measurement unit	*mln Euro (%)*	*%*	*%*	*%*	*%*	*%*
Agriculture and fisheries	17154 (4.5)	20.0	42.1	68.3	1.9	9.8
Extraction of oil and gas	8061 (2.1)	5.2	0.2	0.0	4.5	0.0
Other mining and quarrying	430 (0.1)	0.0	0.1	0.0	0.0	0.1
Food and food products ind.	28588 (7.5)	2.3	0.8	3.0	2.0	9.5
Textiles, clothing, leather ind.	3355 (0.9)	0.2	0.1	0.1	0.5	0.2
Paper and –board industry	3075 (0.8)	0.7	0.2	0.9	0.7	0.1
Printing industry	7453 (1.9)	0.1	0.1	0.0	2.9	0.1
Oil refineries	8176 (2.1)	3.8	6.0	0.3	3.0	8.4
Chemical industry	15537 (4.1)	10.4	4.2	9.0	6.6	5.8
Rubber and plastics industry	3711 (1.0)	3.5	0.0	0.0	1.5	0.0
Basic metals industry	4044 (1.1)	2.7	1.6	0.3	1.3	13.0
Metal products industry	8231 (2.1)	0.6	0.4	0.2	4.6	0.8
Machine industry	7225 (1.9)	0.2	0.1	0.0	0.5	0.6
Electromechanical industry	9587 (2.5)	0.8	0.2	0.1	1.5	0.6
Transport equipment industry	7633 (2.0)	0.2	0.1	0.0	3.0	1.5
Other industries	9585 (2.5)	1.8	1.9	0.5	2.1	2.8
Energy distribution	8120 (2.1)	16.3	7.8	1.2	0.2	1.9

	Production	Climate change	Acidifi-cation	Eutrophi-cation	Smog formation	Disp. of fine dust
Measurement unit	*mln Euro (%)*	*%*	*%*	*%*	*%*	*%*
Water distribution	874 (0.2)	0.1	0.0	0.0	0.0	0.0
Construction	28359 (7.4)	0.7	1.2	0.3	6.4	2.3
Trade and related services	54178 (14.1)	1.6	1.4	0.4	5.7	1.3
Transport by land	8760 (2.3)	2.5	5.0	1.3	1.7	7.4
Transport by water	2904 (0.8)	2.4	9.7	1.7	0.2	10.5
Transport by air	3276 (0.9)	3.6	2.0	0.5	0.1	0.2
Transport services	5448 (1.4)	0.2	0.3	0.1	0.1	2.7
Commercial services	60460 (15.8)	1.4	2.0	0.5	4.5	2.2
Non-commercial services	68191 (17.8)	3.2	2.1	0.4	2.6	1.4
Other goods and services	922 (0.2)	0.5	0.3	0.1	3.3	0.2
Private households	-	15.0	10.1	10.8	38.7	16.7
Government	-	0.0	0.0	0.0	0.0	0.0
Total	383337 (100)	100	100	100	100	100

For the environmental theme Climate change, the shares of the largest three polluters are relatively small (just over fifty percent of total) and emissions are rather evenly spread across sectors. This is in line with the intuition that energy use is widespread across all sectors. Another relatively even spread environmental theme is Dispersion of fine dust. Other environmental themes are much more concentrated. For example, Acidification and Eutrophication are concentrated to a large extent in the Agricultural sector. Agriculture and Private households are among the largest polluters for several environmental themes in absolute terms. The agricultural sector is well known for its environmental impact, though it may seem surprising that it is also the largest emitter of GHGs (caused primarily by CH_4 and to some extent by N_2O emissions).

The economy-wide technical potential for each environmental theme for 1990 can be directly derived from the abatement cost curves. These abatement cost curves are described in Dellink (2005). For climate change, the curve consists of several hundreds of measures, with marginal costs ranging from zero for a number of measures to more than 1000 Euro per ton CO_2-equivalents for the least-cost-effective measures. In 1990, just over 87 billion kg CO_2-equivalents can be reduced at annual costs of a little more than 1.6 billion Euro. For the other environmental themes, similar abatement cost curves are constructed.

3.2. Policy scenarios

Three policy scenarios are constructed and analysed: the *Integrated Stock Policy* scenario, the *Integrated Emission Policy* scenario and the *Stand-Alone Policy* scenario. The environmental policy targets for the year 2030 used in these scenarios are based on the Dutch National Environmental Policy Plan 4 (VROM, 2001).

Table 2. Policy targets for environmental themes in The Netherlands for 2030

	reduction target 2030 (%-change compared to 1990)
Climate change	-50%
Acidification	-85%
Eutrophication	-75%
Smog formation	-85%
Dispersion of fine dust	-90%

Though the policy targets as summarised in Table 2 are undoubtedly based on thorough analysis, they are not necessarily efficient. The analysis presented here aims at assessing the economic costs of the exogenous targets, not at explaining or evaluating these targets. This does not mean that the model set-up is inherently unsuitable for efficiency analysis. Once a realistic empirical module to capture the benefits of the policies will be available, this could be added to the model and optimal policy levels could be assessed.

For the themes Acidification, Eutrophication, Smog formation and Dispersion of fine dust, the policy targets act as a restriction on the maximum allowable emissions in the target year 2030. For the policy simulations with DEAN, these targets have to be translated into maximum allowable emission paths. In other words, an exogenous supply of emission permits has to be imposed for all periods in the model horizon. Since no explicit goals exist for periods before or after the policy target year, the *ad hoc* assumptions are made that (i) in periods 1 to 4 (1990-2009) emissions can follow the benchmark projection[4]; (ii) from period 5 (2010-2014), a reduction path towards the target is imposed, which is linear in terms of reduction percentages, as this allows for a gradual adjustment process, and (iii) after the policy target is reached, emissions are not allowed to increase. Below we will describe the three different policy scenarios. Then, in Section 4. we will discuss the simulation results.

[4] Note that one period spans over 5 years. Period 4 starts in 2005, period 5 in 2010.

In the *Integrated Stock Policy* scenario[5], the government aims at controlling the concentrations of greenhouse gases in the target year 2030 and beyond, while for the other environmental themes tradable emission permits are auctioned by the government. To reflect the stock pollutant property of greenhouse gasses, the government does not auction GHG emission permits, but 'GHG stock addition permits'. The government sets a policy target on the total stock addition of The Netherlands, *i.e.* restricts the number of permits to be auctioned over the whole model horizon, and polluters have to buy the GHG stock addition permits to be able to emit GHGs. Hence polluters have annual expenses on GHG permits, even if the target for the total stock addition is not yet met. Note that only domestic emissions and domestic stock additions are controlled in this manner.

For Climate change, the emission target as laid down in the environmental policy plans is specified in terms of emission reductions. This target is translated into a target for total allowable addition to the stock of greenhouse gasses over the model horizon (2099), *i.e.* a maximum constraint on the value of the GHG stock addition in the final period (M_{2099}). The emission reduction target for the target year gives insufficient information to calculate the stock addition target, as the emissions in other years are in principle unrestricted. Therefore, a two-step approach is used. Firstly, a proposed path of GHG emissions is formulated that is consistent with the actual emission policy target for 2030, analogue to the maximum allowable emission paths for the other environmental themes (*i.e.* a linear reduction path between 2005 and 2030 and constant emissions thereafter). Secondly, the stock addition over the model horizon that would result from this emission path is calculated, using equation (1). The calculated stock addition for the final period, M_T, is then taken as the maximum allowable stock addition in the *Integrated Stock Policy* scenario. It should be stressed that the proposed emission path is not imposed in this scenario: emissions can fluctuate over time, as long as the stock addition target is not exceeded.

In the *Integrated Emission Policy* scenario, Climate change is specified as a flow pollutant, like the other environmental themes. That is, the *proposed path* of emission reductions is imposed, and the government issues emission permits instead of stock addition permits. Note that environmental pressure, as measured by total addition to the stock of GHGs, is identical for both specifications.

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[5] Note that the name of the scenario does not imply that a coordinated integration effort by the government is required. Rather, the government creates the circumstances in which polluters are capable of integrating their reduction efforts.

Finally, the *Stand-Alone Policy* scenario mimics the *Integrated Stock Policy* scenario for Climate change, but no policies are formulated for the other environmental themes.

The total addition to the stock of greenhouse gases is identical across the scenarios. There may be a slight difference in environmental quality, as earlier emission reductions imply smaller radiative forcing.

4. RESULTS

4.1. Macroeconomic impacts

As one could expect, all policy scenarios show that enforcement of the environmental policy targets as described above leads to a reduction of economic activity. The development of GDP over the periods is shown in Figure 1.

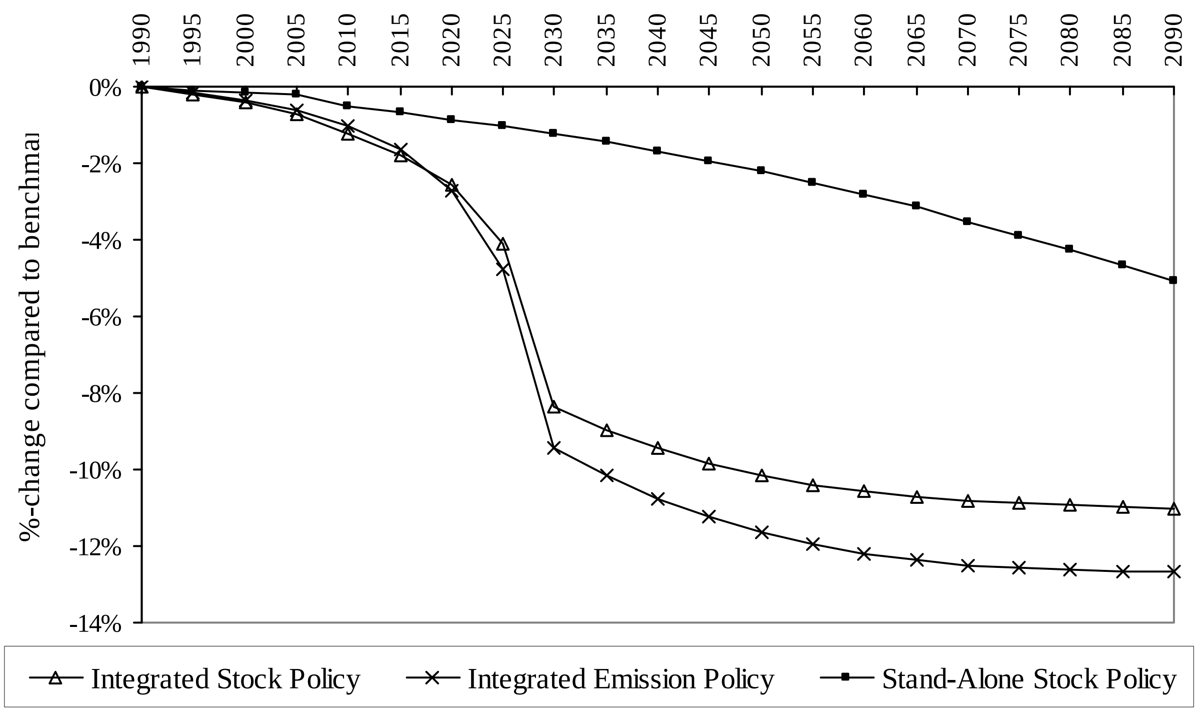

Figure 1. Results of the environmental policies on the development of GDP

In the *Integrated Stock Policy* scenario, GDP levels drop in the long run to around 10 to 11 percent below the benchmark projections. This does not mean that absolute levels of GDP are declining over time; the annual growth rate of GDP stays well above zero for all periods. Clearly, these numerical results have to be interpreted with care, given the limitations in the model specification. Though the macro-economic costs of environmental policy cannot be disregarded, they may be characterised as modest, in light of the significant reductions in environmental pressure for several environmental themes simultaneously. For comparison, current environmental expenditures in The Netherlands amount to slightly more than 3 percent of GDP (RIVM, 2002a), though it should be noted that this figure includes the costs of waste management, a theme not present in the DEAN model.

Though the private households have perfect foresight on the future level of environmental policy and know the future prices of environmental permits, the path of GDP is not completely smooth. Consumers only adapt their consumption patterns to a limited extent, to avoid large shocks in utility. The extent to which consumers switch between current and future consumption is driven by the constant intertemporal elasticity of substitution (this CIES equals 0.5 for the private households). The properties of the CIES utility function imply that the further the consumers shift their consumption away from the original equilibrium, the less they can fulfil their preferences and the larger the disutility that is associated with this shift. Therefore, the costs, in terms of a decrease in utility, increase more than proportionally if more consumption is shifted intertemporally.

As noted before the drop in GDP growth does not mean that absolute GDP levels are declining. Whereas in the benchmark the growth rate of GDP equals 2 percent, the economic growth rate remains in all scenarios above 1 percent throughout the model horizon. In fact, the growth rate of the economy comes very close to the benchmark level in the second half of the century, implying that the environmental policy, which has constant emission reduction percentages in the long run, has only a temporary effect on the growth rate of the economy. The decrease in the absolute level of GDP is, however, lasting. From Figure 1 we may conclude that a structural reduction of emissions of at least 50 percent for all environmental themes in the DEAN model will lead to a GDP that is structurally around 10 to 11 percent below what it would have been without the environmental policy.

For the *Integrated Emission Policy* scenario, the GDP-losses are roughly 2 percent-point larger, while the growth rate of GDP is in the long run hardly affected by the alternative policy assumption. As there is less flexibility on the market for GHG permits under this scenario, it is not surprising that the economic costs are larger than in the stock-oriented policy. In this scenario, the constant reduction targets for all environmental themes after 2030 imply that the *undiscounted* marginal costs are equal over time, as there are no possibilities to shift part of the burden to other periods.

For the *Stand-Alone Policy* scenario, the macro-economic costs of the policy are purely determined by the costs of greenhouse gas emission reductions and these are minimised by equalising *discounted* marginal costs. Consequently, the undiscounted marginal costs of climate policy increase exponentially over time. Until 2020, the costs are below 1 percent compared to the benchmark, but in the long they increase to 2.2 percent in 2050 and around 5 percent at the end of the century. In the Integrated Stock Policy scenario, the intertemporal trade-off of greenhouse gas reduction costs is complicated by the required reductions for the other themes, as these influence the marginal costs of economic restructuring. Though the impact on GDP of the Stand-Alone Policy scenario is smallest, this does not imply that the costs of climate policy are smallest, as these GDP figures cannot be directly compared: the integrated scenarios cover many more environmental themes, while the Stand-Alone Policy scenario only covers the costs of climate change policy. A direct comparison is possible by comparing permit prices, as is done in Section 4.2 below.

Since the monetarised benefits of environmental policy are not analysed in this paper, it is impossible to say whether the costs are justified. It is up to policy makers to decide whether the environmental benefits outweigh the economic costs or not. The DEAN model can play a role in assessing the economic costs and show relevant mechanisms that influence the interactions between environmental pressure, economic growth and sectoral structure.

4.2. Environmental results

Figure 2 shows the development of greenhouse gas emissions over time according to the three scenarios. These differ solely in the timing of emission reductions; the total contribution of The Netherlands to the global stock of greenhouse gases, *i.e.* the GHG stock addition M_t, is identical across the scenarios.[6]

In the stock-oriented scenarios, *Integrated Stock* and *Stand-Alone Stock*, some GHG emissions are reduced in 1990, even though the assumption is made that between 1990 and 2005 no technical abatement measures are available. The 1 percent reduction in GHG emissions is therefore fully achieved via a restructuring of the economy, *i.e.* via the reduction of agricultural and industrial production.

The flexibility in the timing of GHG emission reduction is used by the polluters to place some more emphasis on reductions in the later periods, allowing for higher emissions in the early periods (compare the *Integrated Stock Policy* to the *Integrated Emission Policy* scenario). The

[6] Note that the surface under the graph differs between the scenarios, as early emissions decay more until the end of the century than later emissions (cf. equation 1).

path of emission reductions that emerges for the stock policies is based on an equalisation of discounted marginal costs over time.

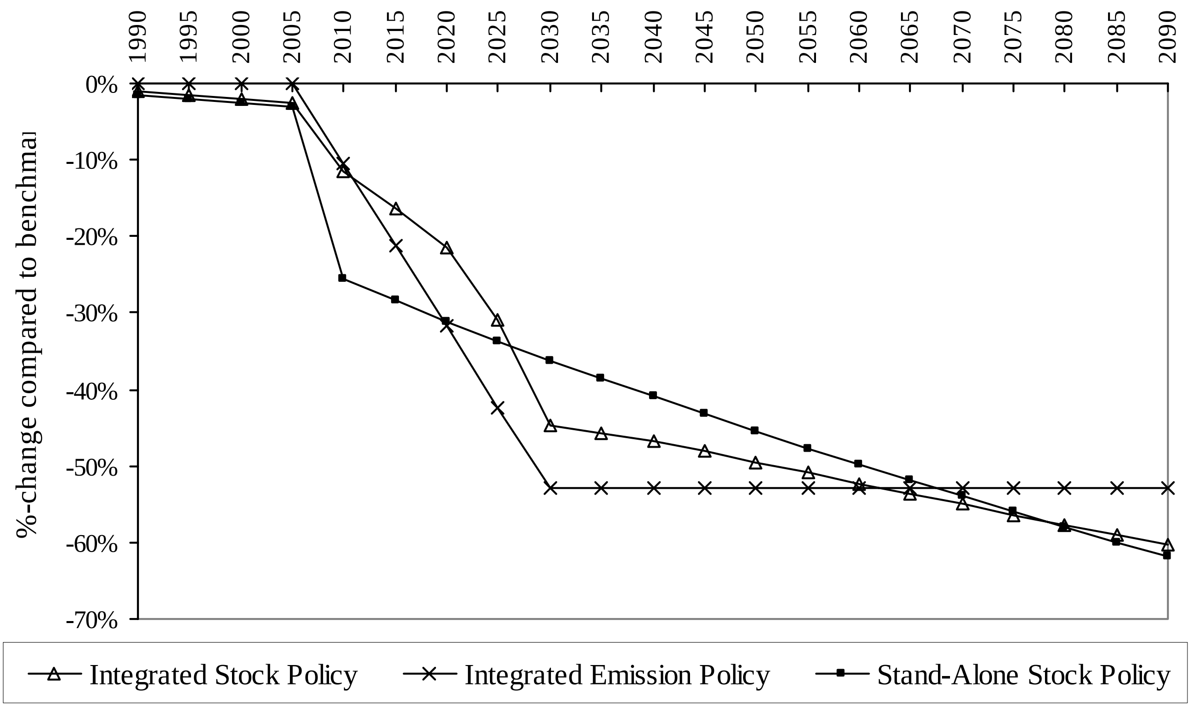

Figure 2. Results of the environmental policies on the development of GHG emissions

One mechanism that drives the timing is the positive discount rate, which implies that late emission reductions are relatively cheap in net present value terms. A second mechanism is the increasing marginal abatement costs with increasing abatement levels. This leads to a smooth path of emission reductions over time, avoiding peaks in any period. The third mechanism is given by the interaction with other environmental policies. *Ceteris paribus*, it is efficient to time GHG emission reductions to coincide with the reductions of emissions for the other environmental themes, as these induce changes in the economic structure that also influence GHG emissions (compare the *Integrated Stock Policy* to the *Stand-Alone Policy* scenario). This also explains the kink in the lines for the scenarios *Integrated Stock Policy* and *Integrated Emission Policy* around 2030: until 2030 the required reduction percentages for the other environmental themes increase, while from 2030 onwards they are stable (cf. Section 3.2). A relatively smooth path of GHG emission reductions emerges, avoiding peaks in any period and with additional emphasis on late reductions. This means that emission reductions can be limited for the first few decades.

Emissions per unit production or consumption are declining for each theme, indicating a decrease in environmental intensity of production and consumption. Moreover, in absolute terms, emissions are declining, while economic growth levels are positive. Therefore, the conclusion can be drawn that both a relative and absolute decoupling of economic growth and environmental pressure is possible, given the availability of the abatement measures.

The permit prices for GHG emissions can be reported either as the price of one kilogram of stock addition or as the price of one kilogram of emissions. These two prices differ as one kilogram of CO_2-equivalent emissions leads to less than one additional kilogram stock of CO_2-equivalents, given the calibrated marginal retention rate which is smaller than unity. In Figure 3 the GHG permit prices are given in Euros per ton of emissions in CO_2-equivalents. Total expenditures on GHG permits do not depend upon the way the permit prices are represented. The reported permit prices are comparable to those found in the literature, especially in the more elaborate global energy-economy models (Weyant, 1999).

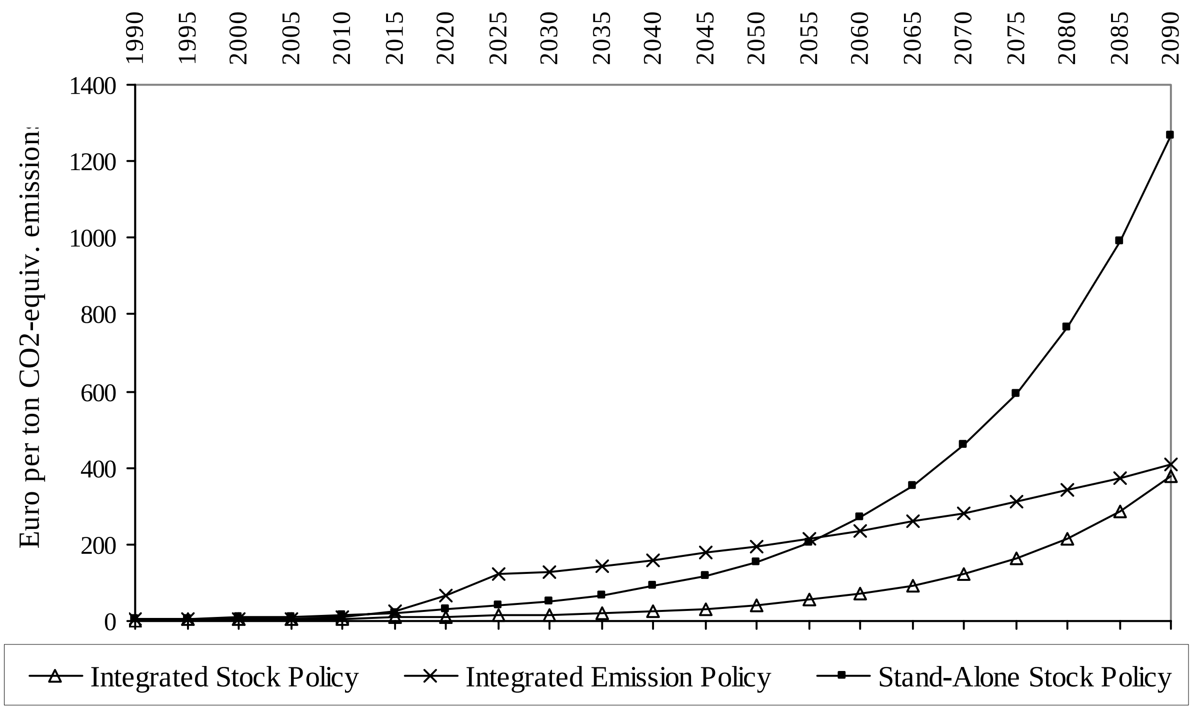

Figure 3. Results of the environmental policies on the development of GHG permit prices

For the Stock-oriented policies, the price of GHG permits and hence the costs of Climate change policy increase steadily over time, as abatement efforts increase. The undiscounted price of GHG permits increases exponentially over time, reflecting an equalisation of discounted costs for GHG permits, in line with the Hotelling rule.

The price of emission permits for Climate change ranges from around 45 to 195 Euro per ton in 2050, depending on the scenario. The conclusion is that the costs of environmental policy can be reduced substantially by (i) allowing flexibility in the timing of GHG emission reductions; and/or (ii) integrating Climate change policy with other environmental policies.

Note that the analysed Climate change policy implicitly assumes that all emission reductions are realised domestically. If flexible mechanisms, as mentioned in the Kyoto Protocol (Joint Implementation and Clean Development Mechanism), are allowed, the economic costs of Climate change policy could be lower.

It is not likely that policy makers are able to predict the optimal path of emissions in the highly complex surroundings of simultaneous policies for different environmental themes, since they don't have all information that individual polluters have. Fixing a path of emission reductions by government by implementing a system of emission permits may then lead to substantially higher economic costs than implementing a system of stock addition permits. The emission policy may lead to a somewhat higher environmental quality, as polluters have an incentive to delay their reduction efforts when timing is flexible. Early emission reductions will lead to less radiative forcing, less temperature rise and hence less damages. However, this environmental difference turns out to be less than 0.1 percent of global radiative forcing throughout the model horizon. Therefore, if policy makers for some reason prefer an emission-oriented policy to a stock-oriented policy, they have to be aware of the additional economic costs of an emission policy.

The economic costs of the integrated environmental policies can be attributed to the policies for the different environmental themes using the permit prices. From 2030 onwards, the economic costs of the policy on Smog formation are very high and this theme dominates the other themes (see the Appendix). Given the limited potential to reduce the associated Volatile Organic Compounds (VOC) emissions via technical abatement measures (estimated to be around one third of emissions), a strict policy target induces large decreases in the production of those sectors emitting VOCs. Secondly, a relatively large part of VOC emissions are attributed to consumers. There are several reasons why this results is not realistic; most importantly, polluters will react on the high permit price for Smog formation by investigating new technologies to reduce their VOC emissions and thus avoid paying for expensive permits. The DEAN model does not capture such endogenous innovation effects. The results do, however, show the potential threat for the economy stemming from current Smog formation policy if no additional effort is placed on researching VOC-reducing technologies.

4.3. Sectoral results

The impacts of environmental policy on individual sectors are much more diverse than the macro-economic results suggest, *cf.* Figure 4. The impacts of environmental policy differ substantially among sectors.

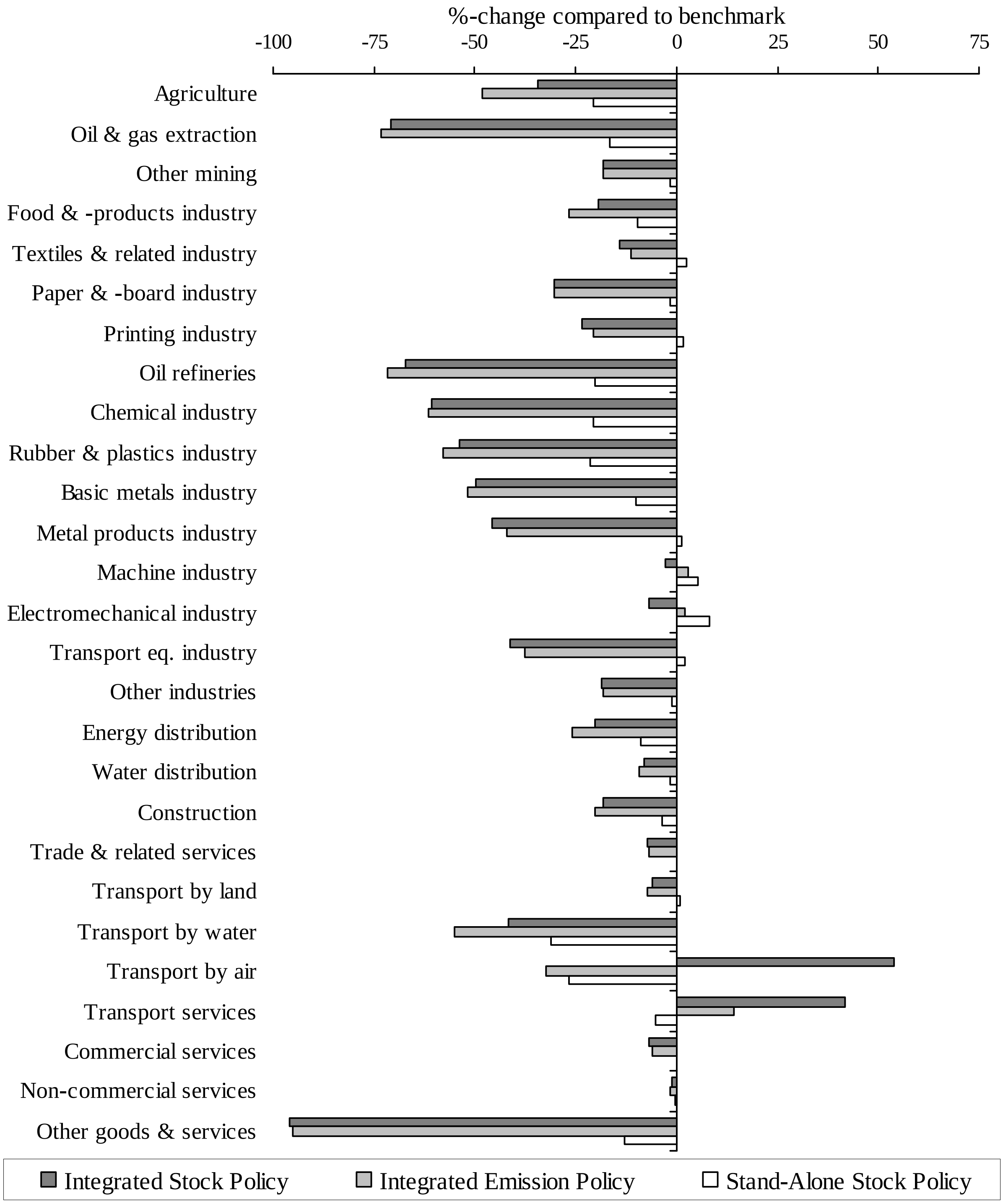

Figure 4. Results of the environmental policies on production (year 2050)

While some emission-intensive sectors are severely affected by environmental policy, this does not hold for all production sectors. In fact, it is very likely that some production sectors can even benefit from stricter environmental targets. These include the sector that provides the abatement technology (not represented in Figure 4), but also sectors that produce relatively clean services. Environmental policy will generate not only losers, but also winners. The shift from dirty to clean sectors is relatively important in the DEAN model, as the possibilities to reduce emissions via technical abatement measures are limited.

Some sectors that will have to reduce their production substantially are Oil and gas extraction, Oil refineries, the Rubber and plastics industry and Other goods and services (a heterogeneous set of small subsectors, some of which have high VOC-emissions). At the other end, there are the Abatement services and Non-commercial services: the Abatement services sector increases its production value considerably, while the Non-commercial services are hardly affected by environmental policy. The Machine and Electromechanical industries can also benefit from the environmental policy, especially if only a stringent Climate change policy is implemented; this result is related to the substitution from heavy polluters towards these relatively more environmentally friendly sectors, both domestically and via exports.

Two other sectors that can benefit from the strict integrated environmental policies for multiple environmental themes as analysed in the model are Transport by air and Transport services. This is primarily due to their low VOC-emissions, especially in comparison to their closest domestic competitors, *i.e.* the other transport sectors. A low ratio of VOC emissions to total value added for these sectors is also present in the data sets for 1995 (Hofkes *et al.*, 2002) and in other official statistics (Statistics Netherlands, 2002), at least in comparison to the other transport sectors. This suggests that the stringency of the VOC-targets is the dominant factor explaining the beneficial impact of environmental policy on Transport by air and Transport services, as confirmed by the results for these sectors in the *Stand-Alone Stock Policy* scenario.

Policy makers should pay attention to the economic opportunities induced by a stringent environmental policy. Analysis of environmental policy mostly focuses on the economic threats of these policies, *i.e.* on sectors that are negatively affected by the policy. The opportunities that environmental policy creates for other production sectors, including the abatement sector and potentially also some services sectors, are often ignored. The implementation of environmental policy boils down to a re-allocation of resources in the economy, not just a shrink of economic activity. Consequently, the macro-economic impact of stringent environmental policies is relatively modest, though certainly not negligible, and the growth rate of the economy is only temporarily affected.

Moreover, changes in sectoral structure of the economy (economic restructuring) are as important for reaching the environmental policy targets at minimum costs as the implementation of technical abatement measures are. Both sources of emission reductions are vital in terms of their contribution to achieving the policy targets as well as in terms of the associated costs. More stringent environmental policies imply more emphasis on economic restructuring as a means to achieve the targets. If policy makers impose restrictions on the changes in sectoral structure, *e.g.* by providing additional support to specific sectors or exempting some economic activities from the policy, they have to be aware of the fact that the macro-economic costs of the policy may increase substantially and/or that the policy target may not be reached.

5. CONCLUDING REMARKS

This paper uses an integrated environment-abatement-economy model, DEAN, to assess the importance of flexibility in the timing of greenhouse gas emission reduction efforts in the presence of other environmental policies. The results show that substantial cost reductions can be achieved by allowing polluters to co-ordinate their abatement efforts over time and over the environmental themes.

The enforcement of the environmental policy targets as laid out in the latest National Environmental Policy Plan (the *Integrated Stock Policy* scenario), via a system of tradable emission permits, leads to a reduction of economic activity: GDP levels drop in the long run to around 10 to 11 percent below the benchmark projections. According to the model, it will be possible for the Netherlands to decouple environmental pressure and economic growth, given the empirical availability of technical abatement measures and substitution possibilities within the economy. The impacts of environmental policy differ across sectors. There is a substantial shift in production from the relatively dirty agricultural and industrial sectors to the relatively clean services sectors. Consumption patterns are adjusting much less than production, because part of the environmental problems can be “transferred abroad” by importing more dirty goods and exporting more clean goods. Domestic emissions can be reduced substantially through this leakage effect, but in the case of transboundary environmental problems this may not be desirable from an environmental point of view.

Many imperfections remain in the analysis. Firstly, the model does not capture the benefits of environmental policy. Apart from the specification of damages, as is common in the global climate-energy-economy models discussed in Section 1, this should also include the impact of environmental quality on utility of consumers (Hofkes, 2001). The absence of a feedback link from environment to economy implies that the optimal policy levels cannot be determined. However, by analysing scenarios that result in identical environmental quality, cost-effective actions of polluters can still be inferred.

Secondly, the linking of GHGs to economic activity is too crude for detailed analysis of optimal climate mitigation strategies. By linking emissions directly to the energy inputs in production, fuel switches can be modelled more precisely. This warrants further research. Thirdly, the model is formulated for a national economy. To analyse optimal climate mitigation strategies a global model is more suited; this would, however, complicate the formulation of more regional environmental problems and associated policies.

Fourthly, technological development is specified in an exogenous manner in the model. Recent literature indicates that high permit prices are likely to induce innovation of new abatement technologies (*cf.* Löschel, 2002). Though endogenous innovation will influence the numerical results, it does not alter the main conclusions of this paper.

Given these caveats, the strength of the approach lies in the inclusion of bottom-up information on abatement technology for several environmental themes into a top-down framework and the integration of climate policy in a wider environmental policy plan. As a consequence, both the direct and indirect costs of environmental policy can be assessed and the importance is shown of taking the interactions with other environmental policies into account for a proper policy advice on climate change.

REFERENCES

Babiker MH, Reilly JM, Mayer M, Eckaus RS, Wing IS and Hyman RC. The MIT emissions prediction and policy analysis (EPPA) model: revisions, sensitivities and comparison of results. Joint program on the science and policy of global change report 71. MIT: Cambridge; 2001.

Bergman L. Energy and environmental constraints on growth: a CGE modeling approach. Journal of Policy Modeling 1990; 12; 671-691.

Bergman L. General equilibrium effects of environmental policy: a CGE-modeling approach. Environmental and Resource Economics 1991; 1; 43-61.

Böhringer C, Rutherford TF. Carbon abatement and international spillovers: a decomposition of general equilibrium effects. Environmental and Resource Economics 2002; 22; 391-417.

Conrad K, Schröder M. Economic impact: an AGE model for a german state. Environmental and Resource Economics 1991; 1; 289-312.

Conrad K, Schröder M. Choosing environmental policy instruments using general equilibrium models. Journal of Policy Modeling 1993; 15; 521-544.

Dellink RB. Modelling the costs of environmental policy: a dynamic applied general equilibrium assessment. Edward Elgar: Cheltenham / Northampton; 2005.

Ekins P. How large a carbon tax is justified by the secondary benefits of CO_2 abatement? Resource and Energy Economics 1996; 18; 161-187.

Gerlagh R, Van der Zwaan BCC. Gross World Product and consumption in a global warming model with endogenous technological change. Resource and Energy Economics 2003; 25; 35-57.

Hofkes MW. Environmental policies: short term versus long term effects. Environmental and Resource Economics 2001; 20; 1-26.

Hofkes MW, Gerlagh R, Lise W, Verbruggen H. Sustainable National Income: a trend analysis for The Netherlands for 1990 – 1995. Institute for Environmental Studies Report R-02/02. Vrije Universiteit: Amsterdam; 2002.

Hyman RC, Reilly JM, Babiker MH, DeMasin A., Jacoby HD. Modeling non-CO2 greenhouse gas abatement. Joint program on the science and policy of global change Report 94. MIT: Cambridge; 2002.

Jensen J 2000. How valuable are delayed cutbacks in Danish carbon emissions? In: Harrison GW, Hougaard Jensen SE, Haagen Pedersen L, Rutherford TF (Eds), Using dynamic general equilibrium models for policy analysis. North-Holland: Amsterdam; 2000.

Jorgenson DW, Wilcoxen PJ. Reducing U.S. carbon dioxide emissions: an assessment of different instruments. Journal of Policy Modeling 1993; 15; 491-520.

Löschel A. Technological change in economic models of environmental policy: a survey. Ecological Economics 2002; 43; 105-126.

Nordhaus WD. Managing the global commons. MIT: Cambridge; 1994.

Rasmussen TN. CO2 abatement policy with learning-by-doing in renewable energy. Resource and Energy Economics. 2001; 23; 297-325.

RIVM. Milieubalans 2002. Rijksinstituut voor Volksgezondheid en Milieu: Bilthoven; 2002.

Robinson S, Subramanian S, Geoghegan J. 1994. Modeling air pollution abatement in a market-based incentive framework for the Los Angeles basin. In: Klaassen G, Foersund FR (Eds), Economic instruments for air pollution control. Kluwer: Dordrecht; 1994.

Statistics Netherlands. 2002. Statline, http://statline.cbs.nl.

Vennemo H. A dynamic applied general equilibrium model with environmental feedbacks. Economic Modelling 1997; 14; 99-154.

Verbruggen H, Dellink RB, Gerlagh R, Hofkes MW. 2000. Calculations of a sustainable national income: four variants. In: Verbruggen H (Ed.), Final report on calculations of a sustainable national income according to Hueting's methodology. Institute for Environmental Studies O00-10. Vrije Universiteit: Amsterdam; 2000. 171-207.

VROM. National Environmental Policy Plan 4. Dutch Ministry of Housing, Spatial Planning and the Environment: The Hague; 2001.

Vuuren D. van, Cofala J, Eerens HE, Oostenrijk R, Heyes C, Klimont Z, den Elzen MGJ, Amann M. Exploring the ancillary benefits of the Kyoto Protocol for air pollution in Europe. Energy Policy 2006; 34; 444-460.

Welsch H. Recycling of carbon/energy taxes and the labor market. Environmental and Resource Economics 1996; 8; 141-155.

Weyant J. (Ed.). The cost of the Kyoto protocol: a multi-model evaluation. Special issue of the Energy Journal; 1999.

Zwaan BCC van der, Gerlagh R, Klaassen G., Schrattenholzer L. Endogenous technological change in climate change modelling. Energy Economics 2002; 24; 1-19.

APPENDIX. MAIN RESULTS OF THE POLICY SCENARIOS

Table A.1. Results of the Integrated Stock Policy scenario

	1990	2010	2030	2050
Macro-economic results (%-change in volumes compared to benchmark projection)				
GDP	-0.02	-1.22	-8.35	-10.16
NNI	0.32	-0.20	-6.14	-8.49
Total private consumption	0.93	1.10	-5.90	-10.24
Total production	-0.24	-1.84	-15.95	-16.44
Savings / capital investment	-1.79	-6.65	-20.04	-19.02
International trade results (%-change in volumes compared to benchmark projection)				
Total imports	-0.48	-2.76	-23.16	-22.99
Total exports	-0.48	-2.70	-22.85	-23.08
Trade balance (in % GDP)	0.99	1.01	0.82	0.70
Sectoral[1] results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	0.43	0.05	-6.76	-9.23
Private consumption Industry	0.87	0.94	-8.63	-11.96
Private consumption Services	1.02	1.32	-2.95	-8.45
Sectoral production Agriculture	-1.01	-6.14	-32.58	-34.45
Sectoral production Industry	-0.57	-3.01	-35.23	-30.72
Sectoral production Services	0.09	-0.56	0.71	-3.64
Sectoral production Abatement services	-0.03	3.60	16.56	15.67
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Climate change	-1.02	-11.62	-44.63	-49.46
Emissions Acidification	0.00	-13.10	-65.52	-65.52
Emissions Eutrophication	0.00	-9.84	-49.21	-49.21
Emissions Smog formation	0.00	-10.39	-51.96	-51.96
Emissions Dispersion of fine dust	0.00	-12.59	-62.93	-62.93
Prices of main variables (constant 1990 prices)				
Exchange rate index (benchmark index = 1)	1.00	1.01	0.82	0.89
Price of abatement services index (bm. index = 1)	1.00	1.00	0.67	0.77
Price Climate change permits[2] (Euro / ton CO_2-eq.)	2.0	6.6	15.9	42.0
Price Acidification permits (Euro / acid-eq.)	3.9	17.1	944.1	1111.5
Price Eutrophication permits (Euro / P-eq.)	0.6	1.9	7.5	11.4
Price Smog formation permits (Euro / kilogram)	0.1	0.9	1292.6	1372.1
Price Fine dust permits (Euro / kilogram)	0.1	0.7	83.8	105.5

[1] The 27 production sectors are grouped into three categories. [2] Expressed in terms of emissions.

Table A.2. Results of the Integrated Emission Policy scenario

	1990	2010	2030	2050
Macro-economic results (%-change in volumes compared to benchmark projection)				
GDP	-0.01	-1.03	-9.46	-11.64
NNI	0.27	-0.10	-7.10	-9.82
Total private consumption	0.79	1.11	-7.06	-11.97
Total production	-0.09	-1.54	-17.90	-18.51
Savings / capital investment	-1.52	-5.95	-21.92	-21.31
International trade results (%-change in volumes compared to benchmark projection)				
Total imports	-0.16	-2.23	-25.50	-25.18
Total exports	-0.16	-2.17	-25.27	-25.35
Trade balance (in % GDP)	0.99	1.01	0.79	0.66
Sectoral[1] results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	0.46	0.16	-9.08	-11.62
Private consumption Industry	0.76	0.98	-10.09	-13.81
Private consumption Services	0.83	1.28	-3.76	-10.01
Sectoral production Agriculture	-0.07	-5.26	-45.73	-48.07
Sectoral production Industry	-0.31	-2.49	-35.89	-31.75
Sectoral production Services	0.08	-0.48	-1.43	-5.66
Sectoral production Abatement services	0.01	1.29	24.56	20.66
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Climate change	0.00	-10.58	-52.91	-52.91
Emissions Acidification	0.00	-13.10	-65.52	-65.52
Emissions Eutrophication	0.00	-9.84	-49.21	-49.21
Emissions Smog formation	0.00	-10.39	-51.96	-51.96
Emissions Dispersion of fine dust	0.00	-12.59	-62.93	-62.93
Prices of main variables (constant 1990 prices)				
Exchange rate index (benchmark index = 1)	1.00	1.01	0.84	0.91
Price of abatement services index (bm. index = 1)	1.00	1.00	0.68	0.78
Price Climate change permits[2] (Euro / ton CO_2-eq.)	2.8	8.7	127.1	194.8
Price Acidification permits (Euro / acid-eq.)	3.7	20.7	701.4	1031.5
Price Eutrophication permits (Euro / P-eq.)	0.5	2.0	4.0	5.7
Price Smog formation permits (Euro / kilogram)	0.1	1.1	1193.5	1203.8
Price Fine dust permits (Euro / kilogram)	0.1	0.8	64.3	98.8

[1] The 27 production sectors are grouped into three categories. [2] Expressed in terms of emissions.

Table A.3. Results of the Stand-Alone Stock Policy scenario

	1990	2010	2030	2050
Macro-economic results (%-change in volumes compared to benchmark projection)				
GDP	-0.01	-0.52	-1.23	-2.20
NNI	0.12	-0.30	-0.90	-1.74
Total private consumption	0.35	-0.16	-0.88	-1.95
Total production	-0.39	-1.22	-2.47	-4.25
Savings / capital investment	-0.69	-1.63	-3.00	-4.63
International trade results (%-change in volumes compared to benchmark projection)				
Total imports	-0.83	-2.21	-4.22	-7.07
Total exports	-0.82	-2.21	-4.24	-7.12
Trade balance (in % GDP)	0.99	0.98	0.96	0.93
Sectoral[1] results (%-change in volumes compared to benchmark projection)				
Private consumption Agriculture	-0.10	-0.81	-1.82	-3.36
Private consumption Industry	0.25	-0.36	-1.20	-2.50
Private consumption Services	0.47	0.06	-0.49	-1.32
Sectoral production Agriculture	-2.61	-6.49	-12.14	-20.48
Sectoral production Industry	-0.67	-1.86	-3.71	-6.46
Sectoral production Services	0.03	-0.26	-0.67	-1.13
Sectoral production Abatement services	-0.03	6.06	9.44	13.83
Environmental results (%-change in volumes compared to benchmark projection)				
Emissions Climate change	-1.57	-25.45	-36.23	-45.46
Emissions Acidification	-2.04	-4.99	-9.25	-15.47
Emissions Eutrophication	-2.15	-5.41	-10.17	-17.23
Emissions Smog formation	-0.30	-1.28	-2.78	-5.01
Emissions Dispersion of fine dust	-1.38	-3.49	-6.54	-11.06
Prices of main variables (constant 1990 prices)				
Exchange rate index (benchmark index = 1)	1.00	1.01	1.01	1.02
Price of abatement services index (bm. index = 1)	1.00	0.99	0.99	0.98
Price Climate change permits[2] (Euro / ton CO_2-eq.)	5.2	16.6	51.4	155.7
Price Acidification permits (Euro / acid-eq.)	0.0	0.0	0.0	0.0
Price Eutrophication permits (Euro / P-eq.)	0.0	0.0	0.0	0.0
Price Smog formation permits (Euro / kilogram)	0.0	0.0	0.0	0.0
Price Fine dust permits (Euro / kilogram)	0.0	0.0	0.0	0.0

[1] The 27 production sectors are grouped into three categories. [2] Expressed in terms of emissions.

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