# Discussion Paper

Central Bureau of Statistics, P.B. 8131 Dep, 0033 Oslo 1, Norway

No. 64 July 1991

# A climate convention and the Norwegian economy: A CGE assessment

by

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**Abstract**

Using a multisector computable general equilibrium (CGE) model, the paper studies the impact of a climate convention on the Norwegian economy. A wide range of implications are discussed, including main macroeconomic indicators, economic growth, the market for energy, and the impact on emissions of other pollutants than $CO_2$. Utilizing the consumer expenditure survey data base, we also assess the impact of the reform on the distribution of welfare in the regional, socioeconomic and income dimensions. The results indicate that a climate convention will not dramatically reduce economic growth and welfare in Norway. $CO_2$ emissions will decrease, as will other emissions to air. Contrary to popular opinion, there are no particular impacts on redistribution in any of the dimensions studied.

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This paper is based on a joint work with Knut Moum, Einar Bowitz and Erik Storm. Thanks to Knut Alfsen for comments on an earlier draft.

# 1 Introduction

Global action is called for to cope with the greenhouse gas problem. From the point of view of economic efficiency, a global tax on greenhouse gases, or a transferable quota system are superior to alternative designs of a climate convention, like national policy targets. Countries have an interest in designing an efficient climate convention, at least if side payments can be made. This paper studies the consequences of an efficient climate convention on the Norwegian economy.

To assess the consequences for the Norwegian economy of a climate convention, we utilize a multisector, multihousehold computable general equilibrium model of the Norwegian economy. We employ the econometric approach to CGE modelling. Included in the model framework is a submodel for emissions to air of nine pollutants, and a submodel that calculates benefits of reduced local pollution due to the climate convention. Another submodel calculates the effects of the climate convention on the distribution of welfare of the 1500 representative households included in the consumer expenditure survey of Norway.

The computations involve a "baseline" scenario and a "climate" scenario. In the baseline scenario, we calculate a projection of the Norwegian economy based on the assumption that there will be no climate convention. We make exogenous projections of the work force, technological progress, oil and gas extraction (which are important in the Norwegian economy), and the basic state variables of the economy; the capital stock and the net foreign debt. A substantive amount of work is put into assembling the data set for exogenous variables, and forming a consistent baseline projection. The projection ends in the year 2025, which we assume to be before any substantial global warming takes place.

In the "climate" scenario, a time path for the carbon tax and for its impact on world market prices and world market growth is developed. This gives us a data set for the world economy under a climate convention. Our exogenous data set for the world economy given a climate convention is substituted for the world economy data set given no climate convention. It is assumed that the prices of energy intensive goods increase in the climate scenario, leading to a higher rate of overall inflation than in the baseline projection. Growth in world markets is somewhat reduced. Petroleum *sellers'* prices are expected to fall, affecting Norwegian terms of trade negatively. We compare the economy of the baseline and climate scenarios in the year 2025, which we take to be a proxy for the long term effect of a climate convention on the Norwegian economy.

The present paper extends the literature in several ways. As far as we know, it is the first study of the impacts of a global climate convention and a global carbon tax on a national scale. We believe analyses on a national level are useful to broaden the picture of the impact of a climate convention as described by global models.[1] National studies are also useful to check and correct the assumptions regarding national policy responses to carbon taxes that form the implicit basis for the calculation of the size of the carbon tax in global models. On a methodological level, the main innovations of this paper are the integration of economic and non-economic indicators, and the detailed outline of the consequences of environmental policy on income distribution.

Section 2 of the paper gives specifics of the model. Section 3 outlines the baseline and climate scenarios. Section 4 discusses the impacts on main macroeconomic variables and energy markets. Section 5 discusses the effects on distribution of welfare. Section 6 presents the impacts on pollutants and changes in non-economic welfare due to the climate convention. Section 7 concludes.

# 2 Model structure and baseline scenario

## 2.1 Structure of the model

The following is a brief account of the structure of the model. Holstmark et. al (1991) give a detailed documentation.

Private consumption is distributed on 14 consumption goods according to a linear expenditure system that includes demographic effects. The parameters are estimated using the

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[1]For instance Nordhaus (1977), Edmonds and Reilly (1983), Manne and Richels (1991) and Whalley and Wiggle (1990), where models of the world economy are employed to study the impact of a global agreement to curb $CO_2$ emissions. DRI (1990) analyses the effects on the Western European economies of a carbon tax. For studies on a national scale, see for instance Bergman (1991), who employs a CGE model of Sweden to assess general equilibrium effects of simultaneously achieving policy targets for $SO_2$, $NO_x$ and $CO_2$. Manne and Richels (1990) analyses the costs for the USA of a carbon emission limit. Jorgenson and Wilcoxen (1990) analyses the impact of lower oil prices on economic growth in USA, using an intertemporal, disaggregated model. The literature to date is surveyed in Nordhaus (1991). Among Norwegian studies are Bye et.al. (1989) and Glomsrød, Vennemo and Johnsen (1990) who analyses the impact on the economy and on air pollutants of stabilizing $CO_2$ emissions. Norwegian analysis are surveyed in Alfsen (1991).

latent variable method described in Aasness, Biørn and Skjerpen (1988). Each good of the model is a fixed coefficient mix of up to 40 Armington composites. Fuel, for instance, consists of the three composites gasoline, fuel oils and (in some sectors) wholesale and retail trade to take account of handling and service. CES elasticities of substitution between domestic and imported varieties of the most important composites are estimated on national accounts data from 1970 to 1987 (Svendsen (1990)). Exports are generally functions of relative prices, and world market indicators. The price and market elasticities are estimated on a 1968-1987 data set (Lindquist (1990)).

The domestic variety of each Armington composite is produced according to a fixed coefficient mix in one or more of the 27 sectors of production, of which 17 have endogenous behaviour.

Production behaviour and technology is modelled in dual terms by Generalized Leontief (GL) cost functions. Each sector produces several commodities. The national accounts of the model base year 1987 provides the coefficient matrices for determining the commodity mix. Gross production is the output measure, as opposed to value added in "calibrated" models. Output is produced according to a constant returns to scale technology subject to exogenous Hicks-neutral technological change. Two stage budgeting is assumed. At the ''top'' level there are four input factors, labour, real capital, material inputs and energy. At the ''bottom'' level, demand for energy is further divided into electricity and fuels according to a GL subfunction, and material input is determined as a fixed coefficient aggregate of the 40 Armington composites. All electricity in Norway is produced by hydro power.

The parameters of substitution are estimated on national accounts data by Bye and Frenger (1985). All factors (including capital) are assumed to be freely moveable and malleable.

The exchange rate is the numeraire of the model. Goods are measured in constant base-year value terms, as prices (except user costs of capital and wages) are equal to unity in the base year of the model. Gasoline and fuel oil are however measured in physical quantities as well as in base-year values.

Labour, real capital and the current account are exogenous on a macro level. Investment compensates for depreciation, and meets exogenous changes in the capital stock over time. The model can be interpreted as a general equilibrium model with exogenous state variables, or a dynamic Leontief model with endogenous coefficients and endogenous final demand. The fact that capital accumulates and depreciates, the assumption of technical progress, and the tradition of formulating realistic growth paths for important exogenous variables, give the model some dynamic elements.

To get an idea of the workings of the model at a given point in time, begin by arbitrarily fixing the wage rate and user costs of capital. The zero profit condition and the input demand functions will then simultaneously determine commodity prices and the cost-minimizing techniques in terms of input coefficients. The quantity side of the model may then be solved as a traditional input-output model with fixed coefficients. The scale of production is determined by the requirement that labour demand equals exogenous labour supply. The demand for real capital, and the current account follow as residuals. If the residual demand for real capital is too low compared to the exogenous supply, the *ratio* between the user cost and the wage adjusts downwards. If the residual current account surplus is too low compared to the exogenous requirement, the nominal *levels* of both the user costs and the wage also adjusts downwards, to improve ''competitiveness''. It is useful to think of the user cost and wage levels implicitly forming the exchange rate of the model.

Integrated in the model framework are submodels of emissions to air (Alfsen, Glomsrød and Vigerust (1986)), of economic benefits from reduced levels of local pollution (Brendemoen, Glomsrød and Aaserud (1991)), and of distribution across region, sociodemografic belonging and income.

Emissions to air of no less than nine pollutants, $SO_2$, $NO_x$, CO, Pb, VOC, $CO_2$, $CH_4$, $N_2O$ and particulates are calculated based on projections of fuel use and industrial process activity from the main model. Separate emission coefficients are estimated for stationary combustion, mobile combustion and industrial processes. Future environmental regulations are accounted for by modifying the emission coefficients for the appropriate sectors. For instance, as new cars are equipped with catalytic converters, the emission of $NO_x$ for a given amount of gasoline is assumed to fall gradually in the nineties.

In the submodel economic benefits of reduced local pollution, estimates of external costs are linked to emissions of $SO_2$, $NO_x$, CO and particulates, and to indicators of traffic volume. The submodel actually calculates the *difference* between welfare in two scenarios on the assumption that marginal costs are constant, reflecting the fact that estimates of full cost functions are not available at present. The marginal costs estimated are the costs at approximately the current level of pollution and traffic. Pollution costs included are acidification of lakes and forests, corrosion of some important materials due to an acid atmosphere, and costs of health deterioration.

Polluting activities also impose other externalities than pollution costs on the society. Traffic noise, accidents, road damage and efficiency loss during traffic congestion are specified in the model.

As external effects are not market activities, their values are difficult to estimate. The submodel for external costs and benefits are mostly based on pilot studies of the larger cities made by the State Pollution Authorities. The costs of health deterioration, for instance, are based on analyses of increases in sick leaves, decreased productivity, increased demand for health services, and decreased well-being from more respiratory illnesses of the urban population. Although all economic numbers are uncertain, the basis of the estimates of costs and benefits gives them an extra dimension of uncertainty as compared to the economic model.

The cost of living increases because of higher energy prices due to the carbon tax. The distributional effects of this are calculated using a data base consisting of the expenditure patterns of the 1500 households in the national Survey of Consumer Expenditure (CBS 1990). The households are grouped according to baseline income, type of household and region. Each household is assumed to maximize a Cobb-Douglas utility function. Using the property of constant budget shares, the relative compensating variation is then calculated for different groups of households.

# 3 Baseline and climate scenarios

## 3.1 The baseline scenario

The baseline scenario is based on projections of the world economy given that there will be no climate convention, and projections of the growth in the labour force, technological progress, oil and gas extraction, and the basic state variables in the economy; the capital stock and the net foreign debt.

It is assumed that Norwegian trade partners' imports grow around 4 per cent per year until year 2000. This is higher than assumed GDP growth of these countries, as it is assumed that world trade specialization continues (CBS 1991). After 2000, a somewhat lower international growth is assumed, as the work-forces of industrial countries begin to fall. Trade partners imports is assumed to grow 3 per cent per year on average.

Projections of growth in the labour force is based on official demographic projections (CBS

1991). It is assumed that employment grows faster than the work force until year 2000, reducing unemployment, which currently runs at around 5 per cent in Norway. After 2010, the growth of the work force levels out, as current small cohorts of children (and their children) move into the work force.

The projection of technological progress is based on estimates for the 60's, 70's and 80's. Following OPEC I in 1973, rates of technological progress decreased as compared to the 60's. In the baseline scenario, it is assumed that technological progress is similar to the average rates of the 70's and 80's.

Real oil and gas prices are assumed to increase in the baseline scenario, oil prices the most. Real oil prices increase by 3 per cent per year until year 2000, and .75 per cent from there on. Real gas prices increase by .75 per cent until year 2000, and 1.1 per cent from there on (CBS 1991). Oil extraction is assumed to peak in the mid nineties, falling to one seventh of current extraction in 2025. Gas extraction is however assumed to increase marginally even after 2000. Real revenues from oil and gas extraction is assumed to increase around 100 per cent until 2000, and then gradually to fall to a level below the current level in 2025.

Real investments will increase at a slower rate than has been the case historically, as population growth and growth in the labour force stagnates, decreasing the demand for real capital for production and housing.

The time path for revenues from oil and gas extraction motivates a reduction in foreign debt, and Norway eventually becomes a net creditor on foreign markets. Net foreign wealth is assumed to be around 20 per cent of GDP in year 2000. Thereafter, current account surpluses are reduced, reflecting lower oil and gas revenues, and the decline of the share of the working population to total population. The country however continues to accumulate net foreign wealth.

Except for the petroleum industry, the projections show a continued growth in the gross products of all main aggregates of industries. Employment in the manufacturing industries decline markedly, as the service industries continue to increase their share of the total work force. This is partly due to a higher assumed productivity growth in the manufacturing industries, and partly because of substitution.

GDP growth of mainland Norway (excluding oil and gas extraction), and growth in gross domestic demand are both estimated at around 2 per cent per year. The latter implies that revenues from oil and gas extraction partly is smoothed by private consumption. The baseline scenario shows an increase in total demand for hydro power of 1.2 per cent per year on average, while demand for fuel for heating and transport grows by 1.6 per cent on average. These growth rates are below consumption growth figures. The reason is that the real price of both electricity and fuel oil increase over the time horizon of the baseline scenario. Real gasoline prices increase by 2 per cent per year until 2000, and 0.75 per cent per year thereafter, reflecting the development of crude oil prices. Heating oil prices fall relative to electricity prices, contributing, along with a strong income effect on transport oil, to a stronger growth in fuel consumption than in electricity consumption.

Norwegian emissions of greenhouse gases, of which $CO_2$ is contributing 67 per cent in the base year when all emissions are measured in $CO_2$ equivalents, increase by 1.4 per cent per year on average in the baseline scenario. $CO_2$ emissions alone increase by 1.8 per cent on average. The growth picks up after year 2000, mainly because gas thermal power is assumed to meet increases in electricity demand from then on. A slower growth in oil and gas prices also contributes. The growth trends violates national Norwegian policy targets of stabilization of $CO_2$ emissions at the 1989-level. Targets on $NO_x$ emissions are also violated in the baseline scenario.

## 3.2 The climate scenario

In the climate scenario countries have agreed on an international climate convention. It is assumed that the aim of the convention is to achieve the emission levels from the "Control Policy Scenario" of the United Nation's Intergovernmental Panel on Climate Change (IPPC 1990). This implies that global emissions of $CO_2$ are stabilized at the 1987-level by 2000, and increase by approximately 0.6 per cent per year thereafter. The global $CO_2$-target is reached by imposing a tax on carbon.

The assumed time path for the carbon tax and its impacts on world market prices and world market growth is based on a fairly extensive evaluation of national and global studies. The carbon tax necessary to stabilize global $CO_2$ emissions varies between the different studies. The time path of the tax in our study is based upon DRI (1990) up to year 2000 and on ECON (1990) for the years from 2000 to 2025. The tax is imposed in 1995 and increases from 40 1987-US$ per ton carbon to $700 in 2025.

It is assumed that the decrease in the world market growth rate will be equal to the DRI (1990) estimate of the decrease in GDP growth in Europe, that is a reduction of 0.25 per cent in annual growth rate. This is in the same range as several other international studies concluding that annual world growth rates will be reduced by somewhat below 0.3 per cent.

As in DRI (1990), world market prices, except on energy intensive goods, petroleum and natural gas, are increased by 0.5 per cent per year until 2000, as the tax is carried over to other markets. The growth in prices is prolonged for the years from 2000 to 2025.

If the prices on energy intensive goods were to grow at the same rate as the other world market prices, the simulated domestic prices on energy intensive goods would increase far more than the world market prices on these goods. Production of energy intensive goods is however less $CO_2$-intensive in Norway than in most other countries, as the Norwegian production is based on hydro power. As a rough approximation, the time path of world market prices on energy intensive goods is assumed to follow the path of the simulated domestic prices on the same goods. Most other prices turn out to increase more than the corresponding domestic prices.

The world market demand for petroleum and natural gas is expected to fall in the face of an international climate convention. The growth rate of real world market price of petroleum and natural gas is expected to decrease by approximately 0.5 per cent per year, compared to the baseline scenario. As Norway depends on oil and gas for its exports, the impact of the carbon tax on the world market price of natural gas and petroleum is very important to its economy.

In the baseline scenario, demand for electricity in the next century is assumed to be met by gas thermal power. The carbon tax will lead to a significant increase in the price of gas thermal power, and make hydro power and other clean, renewable energy sources more competitive. Part of this power is hydro power which for conservationist or other reasons is not exploited in the baseline scenario.

Higher energy prices will also increase the energy conservation potential. Studies by the energy authorities indicates that a considerable amount of energy can be saved by better maintenance of the hydro power plants, instalment of heatpumps in dwellings and buildings, and extended use of biomass energy. The cost per energy unit saved is considerable, but lower than the price of thermal power including the carbon tax. Based on estimates of hydro power and conservation potentials by the energy authorities, a long term marginal cost curve of renewable, $CO_2$-free electric power is constructed for the climate scenario. Marginal costs are increasing along this curve. The price of gas thermal power including the carbon tax is the "back-stop" price.

# 4 Main indicators

## 4.1 Macroeconomic impacts

Table 1. Changes in main macroeconomic variables relative to the baseline scenario. Per cent. 2025.

| | |
|---|---|
| GDP | - 3.2 |
| Import | -11.2 |
| Export | - 5.1 |
| Private consumption | -10.8 |
| Investments | - 1.2 |

Measured in 1987 prices, the level of GDP in year 2025 is 3.2 per cent lower in the climate scenario than in the baseline scenario, see table 1. The annual growth rate is reduced by 0.1 per cent. Because the economy is able to substitute away from fuel (see below), restricting fuel consumption does not obstruct output and economic growth seriously. From figure 1 it appears that the GDP growth quickly settles on a lower growth path. The changes in the composition of GDP along the baseline are thus not very important for the impact of the climate convention on the GDP growth.

Imports is the category of final demand that is reduced the most. There are two reasons for this. One is that the domestic activity level is reduced. The activity level measured as gross production falls by 6.4 per cent in year 2025 relative to the baseline scenario. At constant prices, this leads to decreased demand for imports. The other reason is that world market prices generally increase more than domestic competitors' prices. The basis for this is the assumption that Norwegian products, being produced by $CO_2$ free electricity, are less $CO_2$ intensive than many international competitors' products. As domestic competitors' prices are lowered relative to world market prices, home production is substituted for imports. This effect adds to the "activity effect". In the case of exports, the "activity effect" and "price effect" work in the opposite directions. The activity effect is the effect of shrinking world markets, as the world economy is assumed to grow at a slower rate than in the baseline scenario. The price effect this time leads to an increase in exports, as the competitiveness of Norwegian exports is improved. All in all, export quantities fall by a smaller amount than imports. This is particularly pronounced in the early and middle stages of the time period. The reason is that the large oil and gas exports quantities in these years are not affected by the

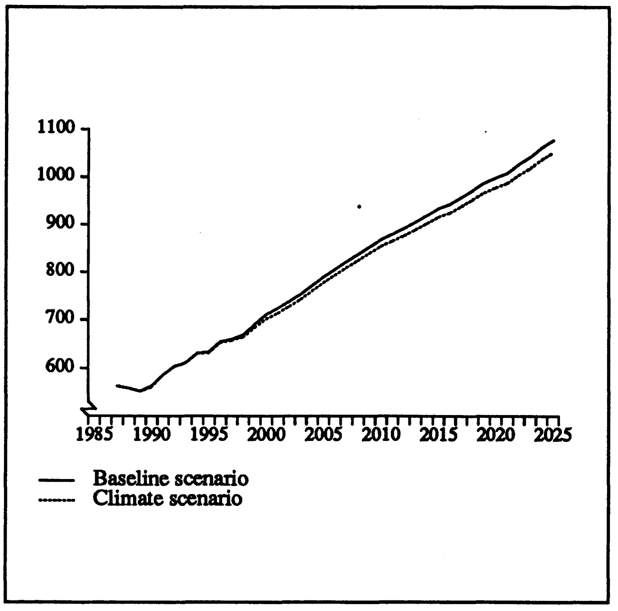


Figure 1. GDP in the baseline and climate scenarios. Billion 1987 NOK.

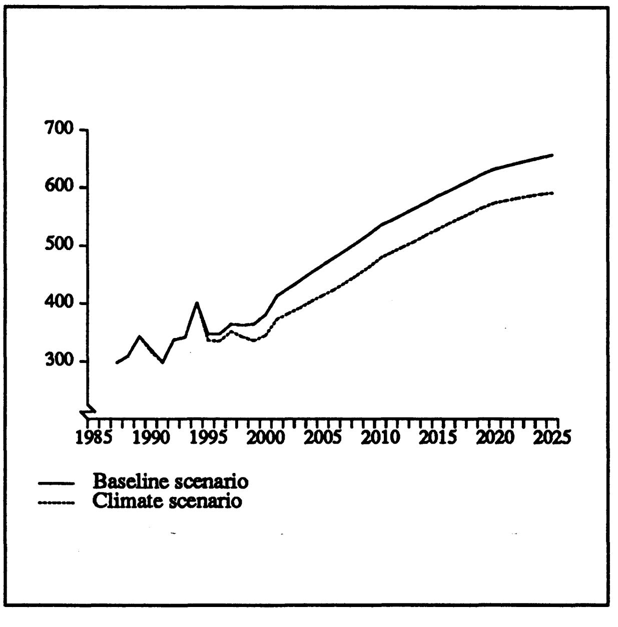


Figure 2. Private consumption in the baseline and climate scenarios. Billion 1987 NOK.

climate convention. But the value of these exports is reduced, requiring, from the current account constraint, a relative increase in traditional exports.

In the Norwegian debate on climate policy, the fact that an international climate convention is likely to improve the competitiveness of Norwegian producers, both importers and exporters, is considered a positive event. The logic of the general equilibrium model however says exactly the opposite: when export production increases relatively to imports, less resources can be devoted to domestic demand. Neither will the current account improve, as the mirror image of increased export quantities is a decrease in the price of these exports.

As real investment is tied up by the exogenous time path of capital, private consumption experiences a drop that is considerably larger than the fall in GDP. In fact, as figure 2 shows, private consumption drops at once when the carbon tax is introduced. The reason is that the negative terms of trade effect is especially large in the early and middle years of the simulation period.

The fall in aggregate investments is due to a switch in the aggregate capital mix from short lived machinery to long lived buildings. It takes less investments to meet the exogenous increase in capital. Less investments modifies the fall in private consumption.

Sectoral outputs change much more than the macro variables. The economy restructures towards traditional exporting sectors like mining and quarrying and industrial and manufacturing production. The rate of return decreases in the climate scenario and output from the housing sector, which produces housing services primarily out of housing capital, increases. Output from sheltered sectors like services and primary production, falls. The income elasticity of services is quite large, and this industry is thereby severely affected by the fall in private consumption.

## 4.2 Impacts on energy markets

Table 2. Changes in energy prices and energy demand relative to the baseline scenario. Per cent. 2025.

| | Prices | Demand |
|---|---|---|
| Households | | |
| gasoline | 60 | -48 |
| heating oil | 140 | -90 |
| electricity | 22 | 6 |
| Industries | | |
| fuels | 144 | -37 |
| electricity | 22 | -9 |

Table 2 shows the effects of the carbon tax on the price and use of energy. There is no gas thermal power in the climate scenario because of the carbon tax. Electricity is produced by hydro power and other $CO_2$-free energy sources. Since electricity in Norway is considered a non-traded good, the electricity price is far less affected by the carbon tax than the price of fuels. Thus, the price of electricity is reduced relative to the price of fuels. The rise in the electricity price is caused by increasing marginal costs in the electricity production. Within the households, electricity is substituted for fuels, and this explains the increased demand for electricity. However, the consumption of electricity increases less (when measured in energy units) than the reduction in the consumption of heating oil. The household demand for electricity and heating oil is 11 per cent lower in 2025 than it is in the baseline scenario.

The use of energy in the industries decreases by 27 per cent, relative to the baseline scenario in year 2025, which is far more than the 3.2 per cent drop in GDP or the 6.4 per cent drop in gross production. One explanation is that the carbon tax induces a change in the composition of output in the direction of less energy intensive sectors. Second, the fall in the production of services and other sheltered sectors allows the traditional exporting sectors to increase their use of labour and capital. Energy and materials are substituted for labour and capital in these sectors, and production increases despite the fall in energy use.

# 5 Effects on distribution

Table 3 shows the relative compensating variations due to the $CO_2$-tax for different groups of households. The average household will need an increase in income of 22 per cent to maintain the utility level from the baseline scenario when facing the prices from the climate scenario. The income changes necessary to compensate the various households for the price changes are almost identical, varying from a 19 per cent increase to 24 per cent relative to the income in the baseline scenario in 2025. The reason is that the price changes on the different goods work in opposite directions.

Table 3. Compensating variations. Per cent. 2025.

| | |
|---|---|
| All households | 22 |
| Households grouped according to average 1986-88 income. NOK. | |
| Less than 50 000 | 20 |
| 50 000 - 109 999 | 21 |
| 110 000 - 159 999 | 22 |
| 160 000 - 219 999 | 22 |
| 220 000 - 299 999 | 22 |
| 300 000 and more | 23 |
| Households grouped according to type. | |
| One person households | 21 |
| Couples without children | 23 |
| Couples with youngest child 0-6 years | 19 |
| Couples with youngest child 7-19 years | 22 |
| Single parent household | 20 |
| Other households | 24 |
| Households grouped according to region. | |
| Sparsely populated area | 22 |
| Densely populated area | 22 |
| Three largest cities | 22 |

The welfare loss of the carbon tax is increasing slightly with income as the budget share for gasoline consumption increases with income. This effect is however partly compensated by the decreasing budget share for heating and fuel. The income redistribution effect is therefore small.

The distributional effect is slightly larger when the households are grouped according to type. The single parent households, couples with small children and the one person households are least affected by the tax. This is partly because these households spend a smaller part of their income on gasoline. The other reason is that the fall in the rate of return reduces the price of housing. The budget share for housing is especially large in these households. The budget share for housing is small for couples without children and for the group "other households", while the budget share for gasoline is quite large. This explains the relatively large welfare loss of this group.

The carbon tax will have no impact on the regional distribution of welfare, since there are no significant differences in expenditure patterns across the regions. There is for instance no tendency for rural households to spend more of their income on gasoline than households in the capital Oslo.

# 6 Effects on emissions of local air pollutants and economic benefits from reduced pollution levels

## 6.1 Pollution

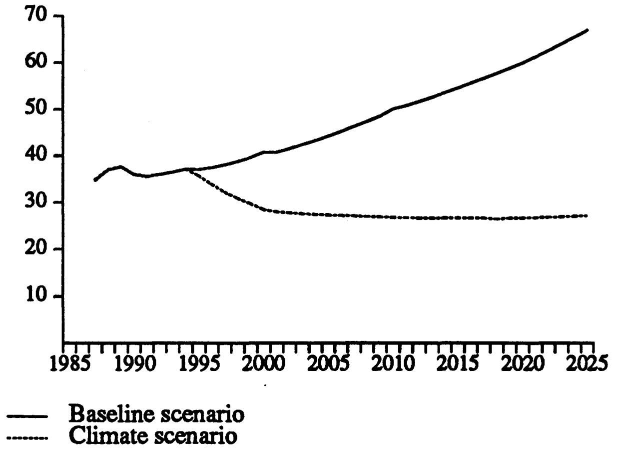

Figure 3. National $CO_2$-emissions in the baseline and climate scenarios. Mill. tons.

Emissions paths for $CO_2$ in the baseline and climate scenarios are shown in figure 3. $CO_2$ emissions are 60 per cent lower in the climate scenario than in the baseline scenario in year 2025. Almost half of the reduction occurs because gas thermal power is replaced with $CO_2$-free electricity. The rest is due to reduced transportation activities, reduced fuel oil consumption and reduced emissions from industrial processes. No new measures directed at curbing non-$CO_2$ emissions are implemented in the climate scenario. There is accordingly no motivation for producer and consumers to change their behaviour with respect to non-$CO_2$ emissions, except what follows from the higher fuel price.

Table 4 shows that emissions of all main pollutants fall considerably in the climate scenario,

Table 4. Changes in emissions relative to the baseline scenario. Per cent. 2025.

| | |
|---|---|
| $SO_2$ | -39 |
| $NO_x$ | -45 |
| CO | -45 |
| VOC | -16 |
| $CO_2$ | -59 |
| $CH_4$ | -3 |
| $N_2O$ | -38 |
| Particulates | -28 |

mainly because demand for fuel oil is reduced[2]. VOC emissions however falls less than most other pollutants. The main source of VOC emission is evaporation associated with the production of crude oil and natural gas, witch is not affected by the carbon tax. $SO_2$, $N_2O$ and particulates mainly stems from the traditional exporting sectors. The production in these sectors increase in the climate scenario. The reduction in $SO_2$, $N_2O$ and particulates emissions are therefore smaller than that of $NO_x$ and CO which mainly stems from transportation and service sectors. $CH_4$ stems from domestic animals and the reduction in the emissions occurs because of reduced production in the agriculture sector. The reduction in all the greenhouse gases (CO, $CO_2$, $NO_x$, VOC, $N_2O$ and $CH_4$) added up and measured in $CO_2$ equivalents, is 54 per cent relative to the baseline scenario in 2025.

## 6.2 Economic benefits of reduced local pollution

Table 5 lists some benefits that may be obtained from a climate convention. Adding together the local benefits of a carbon tax policy, we arrive at 27.1 billion 1987 NOK (around 4 billion US dollars). This outweighs about 40 per cent of the consumption loss due to the carbon tax, and about 80 per cent of the GDP loss.

The gain from less acidification included in the model, is the yearly value of increased forest growth and recreational gains from less acidification of soil and lakes. Acidification causes high costs in Norway, but stems almost exclusively from long range transboundary pollution. An international agreement on a carbon tax will reduce emissions of $SO_2$ and $NO_x$ abroad but the beneficial effects of this on Norwegian forests and lakes are not included in the estimates. Reducing domestic emissions thus gives small reductions in acidification costs.

The gain from better health is based on analyses made by the Norwegian State Pollution Control Authority concerning the urban population. Emissions has to exceed a certain level

[2]Lead is not included in the table as it is expected to be only a minor environmental problem even in the baseline scenario.

Table 5. Some economic benefits of a climate convention. Billion 1987 NOK. 2025.

| | |
|---|---|
| Forests and lakes | 0.1 |
| Health benefits | 10.6 |
| $NO_x$ | 9.8 |
| CO | 0.0 |
| $SO_2$ | 0.5 |
| Particulates | 0.3 |
| Corrosion | 0.1 |
| Traffic accidents | 3.9 |
| Traffic congestion | 4.2 |
| Road damage | 5.2 |
| Noise | 3.0 |
| Total | 27.1 |

to cause health damage. Only the parts of the reduction in emissions that occurs in densely populated areas will lead to health benefits.

Much of the $NO_x$ reduction affects densely populated areas, as it mainly stems from cars and other mobile sources. The other pollutants by contrast affect more sparsely populated areas. Reducing $NO_x$ emissions thus affects more people than reducing $SO_2$ emissions. This is the main reason for the considerable benefit associated with reductions in $NO_x$ emissions. Second, $NO_x$ emissions are quite high in the baseline scenario. A 45 per cent reduction in $NO_x$ therefore means a greater absolute reduction than a 45 per cent reduction in, say, $SO_2$. The reason why the aggregate benefit from CO reduction is small, is that few people are exposed to hazardous concentrations in the baseline scenario.

Benefits from reduced transport activity turn out to be considerable. Society benefits from less noise, fewer accidents and less road damage, in addition to a considerable road traffic efficiency gain. The benefit of less noise is estimated at around 2000 NOK per person affected by noise (a discrete incident). The cost of an average traffic accident is estimated at almost 30 000 NOK. As for the health benefits from less pollution, the benefits from reduced traffic volume depends on where the reduction takes place. A traffic reduction in a large city could yield a considerable benefit from less noise and congestion. This would not be the case if the same reduction took place in a sparsely populated area. In the comparison of benefits, the part of the traffic reduction that will lead to benefits is assumed to be fixed from the model base year.

One may argue that our model of external effects understates the benefits, as marginal costs of pollution may be increasing. The emission levels in the baseline scenario are considerably higher than the emission levels which the marginal cost estimates are based upon. Second, if the population continues to move to the cities, more people will be exposed to emission levels above the critical level and larger parts of emissions and traffic will cause damages. Furthermore, important beneficial effects are not included in the model, e.g. the decrease in ozone levels brought about by reduced $NO_x$ in combination with VOC or CO. A decrease in ozone is expected to improve health. Neither are the possible benefits from reduced global heating included.

# 7 Conclusions and suggestions for further research.

In this paper we have attempted to assess the effects of an international climate convention on the Norwegian economy. We summarize our main findings in the following conclusions:

1. The GDP growth rate is reduced by 0.1 per cent, leading to 3.2 per cent lower GDP in year 2025 relative to the baseline scenario. Due to negative terms of trade effects, private consumption falls more than GDP and is 10.8 percent lower than in the baseline scenario.

2. The climate convention has no significant effects on distribution of income.

3. $CO_2$ emissions are reduced 60 per cent in the climate scenario. Almost half of this reduction occurs because gas thermal power is replaced with hydropower.

4. Reducing $CO_2$ emissions significantly reduces emissions of other pollutants to air. The benefits of this, together with the beneficial effects of reduced transport activity makes up for about 40 per cent of the loss in private consumption and 80 per cent of the GDP loss.

We note that our estimate of the reduction in GDP growth is in the same range as estimates by other authors. The global studies to date agrees that annual world growth rates are reduced by 0.05 to 0.3 per cent by limiting $CO_2$ emissions.

Earlier studies in Norway (Glomsrød, Johnsen and Vennemo (1990)) concludes that in the case of a national carbon tax, private consumption will fall less than GDP. This implies that it is the negative terms of trade effect, caused mainly by the fall in the oil sellers' price, that causes the consumption drop. This is in line with Whalley and Wigle (1990) who conclude that it is the oil exporting countries that will experience the greatest losses in the case of a global carbon tax. Norway is however not grouped among the oil exporters in the paper of Whalley and Wigle. The countries in this category are more dependent on oil exports than Norway is, and the losses caused by the global carbon tax are therefore larger than in our study.

The 60 per cent reduction in $CO_2$ emission brought about by the $700 tax per ton carbon is somewhere between the estimates for USA in Manne and Reichels (1990) and the DRI (1990) estimates for the EC. The tax is stricter than needed to stabilize emissions in Norway, but it is not enough to secure the 50 per cent fall in oil use, compared to 1987, indicated by eg. the World Commission on Environment and Development (1987) to be desirable in industrialized countries.

This study has overlooked some aspects of a climate convention. Perhaps most important, it is likely that the basic state variables in the economy, the capital stock and the net foreign debt, will change as the economy restructures to a different (optimal) dynamic path under a climate convention. Such restructuring is not captured by the present model. Allowing for dynamic effects will presumably make the cost of a climate convention lower than estimated in this study, as there is always the option of not changing the state variables, replicating the results found here.

Another neglected effect is fuel-specific technical change. The model does endogenously determine (considerably) higher fuel efficiency, but only as a substitution effect in the cost functions. In addition to this effect, it is reasonable to assume that a (large) tax on $CO_2$ will initiate R&D investments directed at fuel-specific technical change. It is usually held that this will reduce the costs of $CO_2$ control. In our view, this may be true, but it is a somewhat partial statement: If the total R&D budget is given, it is not altogether clear whether changing R&D priorities in the direction of fuel specific technical change will increase growth. If the total R&D budget increases, it has a cost in the form of lower capital investments, or lower consumption. But again, there is always the option of not changing R&D priorities, so that endogenized technical change cannot make the economy worse off.

The benefits from reduced emissions of various pollutants have important links back into the main model in the areas of productivity, capital depreciation etc. It is likely that including such links will increase productivity and the provision of private consumption goods. This effect is not captured by our calculations of benefits from reduced emissions, but could further reduce the welfare cost of $CO_2$ control.

While our study assumes that the carbon tax is rebated to consumers in a lump sum fashion, it will in reality substitute for other taxes. In a second best world it is not generally true that the latter is a better reform than the former, but it does seem likely! The precise consequences of the omitted effects are left for further research.

**References:**


Aasness J., E. Biørn and T. Skjerpen (1988): Engel functions, panel data and latent variables. Discussion paper no. 41, Central Bureau of Statistics, Norway.

Alfsen K. H., S. Glomsrød and B. Vigerust (1986): Method for forecasting emissions to air. Report for the research program "Natural resources and the society" (NTNF). Norway. (In Norwegian)

Alfsen, K. H. (1991): Use of macroeconomic models in analyses of environmental problems in Norway and consequences for environmental statistics. Discussion paper no. 61. Central Bureau of Statistics, Norway.

Bergman L. (1991): General Equilibrium effects of environmental policy: An AGE-modelling approach. Environmental and Resource Economics, vol 1, no 1.

Brendemoen A., S. Glomsrød and M. Aaserud (1991): Benefits from environmental control policy. Forthcoming report, Central Bureau of Statistics, Norway. (In Norwegian)

Bye B., T. Bye and L. Lorentzen (1989): SIMEN. Studies of industry, environment and energy towards 2000. Discussion paper no. 44, Central Bureau of Statistics, Norway.

Bye T. and P. Frenger (1985): Factor substitution, non-homoteticity and technical change in the Norwegian production sector. Unpublished paper, Central Bureau of Statistics, Norway.

Central Bureau of Statistics (1990): Survey of consumer expenditure 1986-1988. NOS 1990. Norway. (In Norwegian)

Central Bureau of Statistics (1991): Climate, Economy and Control policy. Report to the Interdepartmental Climate Group. Norway. (In Norwegian)

DRI/McGraw-Hill (1990): Green Europe: Economic implications and Business opportunities.

ECON (1990): Effects of climate policy on oil and gas markets. ECON-Report no. 10/90, Norway. (In Norwegian).

Edmonds, J. and J. Reilly (1983): Global energy and $CO_2$ to the year 2050. Energy Journal, vol 4, no 3, 1983.

Glomsrød, S., T. Johnsen and H. Vennemo (1990): Stabilization of $CO_2$: A CGE assessment. Discussion paper no. 48, Central Bureau of Statistics, Norway.

Holstmark B., H. Vennemo, E. Holmøy and J. Aasness (1991): A new general equilibrium model. Forthcoming as Discussion Paper, Central Bureau of Statistics, Norway.

Intergovernmental Panel on Climate Change (IPCC) (1990): Climate change: the IPCC scientific assessment. Cambridge University Press.

Jorgenson, D.W. and P.J. Wilcoxen (1990): Global change, energy prices and US economic growth. Discussion Paper no. 1511, Harvard institute of economic research, Harvard University, USA.

Lindquist K. G: (1990): Modelling Norwegian exports of different manufacturing goods on annual data. Unpublished paper, Central Bureau of Statistics, Norway.

Manne A. S. and R. G. Richels (1990): $CO_2$ emission limits: A economic cost analyses for the USA. The Energy Journal, vol 11 no. 2 1990.

Manne A. S. and R. G. Richels (1991): Global $CO_2$ emission reductions - the impact of rising energy costs. The Energy Journal, vol 12, no. 1 1991.

Nordhaus, W. D. (1977): Economic growth and climate: The carbon dioxide problem. American Economic Review, vol 67, no. 1, 1977.

Nordhaus, W. D. (1991): The cost of slowing climate change: a survey. The Energy Journal, vol 12, no. 1 1991.

Olsen Ø. and T. Haugland (1990): ECON-energy: A model for global energy and environmental analyses. ECON-report no. 11, Norway. (In Norwegian).

Svendsen I. (1990): The import submodel of MODAG and KVARTS. Rapporter 90/20, Central Bureau of Statistics, Norway. (In Norwegian)

Whalley J. and R. Wigle (1990): The International Incidence on Carbon Taxes. Pater prepared for the conference "Economic Policy Responses to Global Warming". Rome 1990.

World Commission on Environment and Development (1987): Our Common Future. Oxford University Press, Oxford, New York.

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