Discussion Papers

Statistics Norway
Research department

No. 691
May 2012

Statistics Norway
Statistisk sentralbyrå

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Abstract:
This study tests whether the strong double dividend hypothesis holds within a setting where a uniform tax on green house gas emissions is raised above the international quota price within the Norwegian economy. The hypothesis does not hold within a framework where detailed technology choices contribute to lower the revenue recycled back to households. The hypothesis, however, holds when local external effects connected to cuing and accidents etc. within the transport sector are taken into consideration. The hypothesis also holds when the international quota price is increased, and oil prices drop in the long run

Keywords: Taxation, Doublel dividend, emissions

JEL classification: F41 H21 Q43 Q48

Acknowledgements: We wish to thank Mads Greaker, Erling Holmøy and Birger Strøm for valuable discussions and comments on earlier drafts. We are grateful to Birger Strøm for technical support.

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ISSN 0809-733X
Print: Statistics Norway

Sammendrag

Denne studien analyserer om det eksisterer en netto velferdsgevinst forbundet med å øke en uniform skatt på utslipp av klimagasser i kun den Norske økonomien utover en internasjonal kvotepris. Studien påviser et moderat velferdstap forbundet ved å øke en uniform nasjonal CO2 skatt fra 150 til 300 NOK/tonn. Utslippet av klimagasser faller med 11,7 prosent i 2050 som følge av skatteøkningen. Skatteøkningen innebærer at den direkte kostnaden per tonn reduksjon i utslippet koster mer enn kvoteprisen på 150 NOK/tonn. Utslippsteknologier som forsterker reduksjonen i utslippet øker derfor velferdstapet forbundet med skatteøkningen. Utslippsteknologier som forsterker utslippsreduksjonen bidrar også til å redusere skatteprovenyet som genereres av CO2 skatten ved at skattegrunnlaget reduseres. Dermed bidrar utslipsteknologiene til å redusere kutte i arbeidsgiveravgiften, siden proveny fra skatten på utslipp resirkuleres ved å kutte arbeidsgiveravgiften. Teknologiene bidrar på denne måten til å opprettholde avviket mellom samfunnsøkonomisk og privatøkonomisk avkastning av arbeid, som igjen innebærer velferdskostnader. Reallokering av ressurser fra metall industrien til andre sektorer demper velferdskostnaden. Skattereformen gir imidlertid en velferdsgevinst hvis man tar hensyn til at skatteøkningen reduserer lokale negative eksterne effekter som for eksempel køståing og ulykker i trafikken.

Studien påviser en moderat velferdsgevinst forbundet med en økning i en uniform global CO2 skatt fra 150 til 300 NOK/tonn. En slik skatteøkning innebærer at den internasjonale oljeprisen faller etter 2030 som følge av at innfasing av nye teknologier tar tid, og derfor gir store utslag i etterspørselen etter olje først på lang sikt. Det forventes at den Norske oljeproduksjonen da har falt så mye at Norge i liten grad rammes av dette prisfallet. Skatteøkningen innebærer også at verdensmarkedsprisene på energiintensive goder vil øke. Norge eksporterer energiintensive goder som f.eks. aluminium, og vil dermed tjene på at disse verdensmarkedsprisene stiger. Velferdsgevinsten forbundet med en slik skatteøkning er imidlertid kritisk avhengig av allokeringen av gratiskvoter til den Norske staten. Hvis omfanget av gratiskvoter reduseres må staten kjøpe kvoter fra utlandet. En prisøkning på kvoter vil dermed føre til et bytteforholdstap for Norge som kan føre til at samlet velferd faller.

1. Introduction

The strong double dividend (SDD) hypothesis, which states that a revenue neutral environmental tax reform which improves environmental quality also improves the overall economic efficiency, does not hold in general when tax revenue is recycled by cutting substantial tax wedges in the economy, see Goulder (1995), Goulder et al. (1997), Farrow (1999), Fullerton and Metcalf (1998), Parry et al. (1999) and Bovenberg (1999). The intuition is that in the absence of environmental concerns, the optimal pollution tax would be zero. Imposing a tax on pollution constitutes a step away from optimum when environmental concerns are excluded, see Christiansen (1996). Hence, non-environmental welfare is reduced which means that the SDD does not hold. The SDD hypothesis holds when specific conditions are satisfied, see e.g. Bovenberg (1999), Fullerton and Metcalf (1997), Bento and Jacobsen (2007), Böhringer and Rutherford (2008), Sancho (2010) and Jaeger (2011).

There are, however, several unresolved issues related to the SDD hypothesis. First, the ongoing climate negotiations show that climate treaties with broad participation will be difficult to reach in the coming decades. It is therefore of interest to study unilateral action as well as the case where all countries act in concert. With imperfect international treaties individual nations may set their own unilateral green house gas (GHG) emission reduction targets. Norway has done so as reflected in the Climate agreement among the political parties in the parliament. Second, detailed abatement technologies, which are regarded as a crucial measure to achieve emission targets, may alter the welfare effects of taxation. Detailed emission reducing abatement technology choices, which are omitted by most studies of SDD, may contribute to lower the tax revenue recycled back to households, and hence, lower the welfare gain of revenue recycling as the cut in substantial tax wedges are reduced. In contrast, Böhringer and Rutherford (2008) shows that the SDD holds when detailed abatement technologies are taken into consideration by linking a bottom-up model with a top down model, and the labour tax is cut to recycle tax revenue. The study do not explane why this result deviates from the result in e.g. Bovenberg (1999) but simply state that the excess burden of the environmental tax is smaller than the reduced excess burden of cutting existing taxes. Hence, the welfare effect of taxation in the presence of abatement technologies seems to be an unresolved issue. Third, local negative external effects connected to transport, like cuing and accidents, is likely to be reduced by a tax on GHG emissions. Felder and Schleiniger (2002) find that a policy aimed at internalizing such local external effects within Switzerland will lower GHG emission by 30-50 percent. Such a policy will fulfill Switzerland’s GHG emission target and generate a welfare gain. The impact of incorporating local external effects into studies of taxation of GHG emissions is substantial. The impact becomes less obvious when local external effects are taxed initially. More research is needed to illuminate on this issue.

This study will contribute to the literature by shedding light on these unresolved issues related to the SDD hypothesis. A uniform tax on GHG emissions in the Norwegian economy will be increased above the international quota price on emissions. The study will analyze whether such policy might be desirable for Norway when acting unilaterally as well as when all countries act in concert. The study will also incorporate local negative external effects and detailed choices of abatement technologies into the model framework to investigate how this affects the SDD hypothesis.

This study finds that the SDD does not hold when a uniform tax on emissions is increased above a global quota price in the Norwegian economy, and tax revenue is recycled by cutting the payroll tax rate. This result holds when detailed choices of abatement technologies are incorporated by soft-linking a bottom-up model with a top-down model of the Norwegian economy. The main reason is that the direct cost of emission reductions exceeds the price of emission reductions. Hence, abatement technologies lower emissions at a direct cost that exceeds the price of emission reductions. Abatement technologies also contribute to lower the tax revenue recycled. Hence, the scope for cutting existing tax wedges is reduced by the technology choices. This contributes to increase the welfare cost of the reform. These results are consistent with the results in Bovenberg (1999) which argue that environmental taxation can not be justified on non-environmental grounds, and that the optimal environmental tax rate is below the Pigouvian rate. The result is also consistent with the result in Klimakur 2020 (2010) which finds that the welfare cost of reaching the emission target set by the Norwegian government is substantial even when abatement technologies are incorporated into the model framework. The result in this study is in contrast to the result in Böhringer and Rutherford (2008). Note that Jacobs and de Mooij (2011) shows that the optimal environmental tax rate equals the Pigouvian rate within a simple Mirrlees economy. Revenue recycling aimed at reducing tax distortions in the labour market do not enhance welfare as the labour income tax is adjusted so that efficiency costs are balanced against redistributional gains.

The tax on local external effects connected to transport approximately equals the marginal damage within the Norwegian tax system, see Econ (2003). Studies which incorporates taxes on local external effects but excludes the benefits of reducing negative local external effects, like e.g. Klimakur 2020 (2010), are likely to overestimate the welfare cost of reducing GHG emissions. The present study employs a framework where both the tax on fuels and transport justified by such local external effects, and the local external effects itself is taken into consideration, and finds that the SDD holds. This result shows that local external effects of transport are an important element even when local external effects are taxed initially. This result complements the result in Felder and Schleiniger (2002).

The study further shows that a national tax combined with a global and uniform CO2 tax increase generates a positive change in welfare for the Norwegian economy. This happens even though the oil price drops, and even if we are not taking into account the reduction in local pollution. The fall in the oil price does not take place before 2030 because it takes time to replace old technologies with new technologies which generates large drops in the demand for oil. Since Norway becomes an importer of oil in the long run, the country benefits from the drop in the oil price. The payroll tax will drop due to the revenue from the tax, and this generates a substantial welfare gain. Further, the world market prices of emission intensive goods increase. This contributes to increase the welfare as Norway is an exporter of such goods, and thus, enjoys a positive terms-of-trade effect.

The paper is organized as follows. Section 2 presents the choice of method and describes the models. The two policy reforms are analyzed in section 3. Section 4 concludes.

2. Choice of method and models

We compare three scenarios; a reference scenario and two policy scenarios. In the reference scenario both the Norwegian and a global carbon taxes equal 150 NOK/ton CO_2, i.e. the climate policy in all countries is relatively lax, but coordinated. In the first policy scenario Norway unilaterally increases its carbon tax till 300 NOK/ton CO_2 while climate policies in all other countries stay at 150 NOK /ton CO_2. In the second policy scenario the rest of the world follows the example of Norway and increases the carbon tax til 300 NOK/ton CO_2. In this policy scenario estimated world market price changes of energy and energy intensive goods is determined by the global carbon pricing regime. Norway’s allocation of emission quotas is kept constant across the scenarios, and the budget of the Norwegian government is balanced by lowering the payroll tax rate. The tax changes are introduced in 2004 and kept constant in all future periods. Further in the paper we define the reference scenario, the first policy scenario and the second policy scenarioe as “150 GLO”, “300 NAT” and “300 GLO” respectively. Table1.1 summarizes all three scenarios analyzed in the paper.

Table 1.1 Scenarios

Global climate policy → Norwegian carbon tax ↓	*International quota price is NOK 150/ton CO2*	*International quota price is NOK 300/ton CO2*
Carbon tax is NOK 150/ton CO2, *Tax implanted across all sectors*	Reference scenario; No changes in oil price, export prices.	Not analyzed
Carbon tax is NOK 300/ton CO2, *Tax implanted across all sectors*	Unilateral policy scenario “300 NAT”; No changes in oil price, export prices.	Global policy scenario “300 GLO”; Producer price of oil falls, export prices for emission intensive products increase.

In order to analyse the three scenarios we combine and iterate the outcomes of two models. Our main workhorse is a dynamic computable general equilibrium (CGE) model called MSG6, see Heide et al. (2004). When a carbon tax is increased in the MSG6 model consumers respond by substituting away from emission intensive products and producers respond by substituting away from emission intensive inputs. In addition a carbon tax is likely to stimulate the use of alternative technologies. However, choices between a detailed set of discrete energy technologies are not incorporated in the basic MSG6 model due to computational difficulties. We have therefore chosen to link MSG 6 with the IFE-MARKAL bottom-up technology choice model, which is an optimisation model of the Norwegian energy system[1]. In MARKAL most new, emerging low carbon emission technologies are represented. Thus, combining these models improves the relevance and realism of our analysis.

2.1 The MSG6 model

The MSG6-model gives a detailed description of the structures of economic policy, production, and consumption in the Norwegian economy. The model has 41 private and 8 governmental production activities; see Table A1 in appendix. Fæhn and Holmøy (2000) give a more extensive verbal description of the model, while Heide et al. (2004) also include a formal, one-sector version. The MSG6 model is designed to incorporate substitution away from emission intensive inputs and goods, as well as downscaling of emission intensive sectors. The model incorporates empirical estimates of a detailed set of substitution parameters on the production side, see Bjertnæs and Andreassen (2006), and on the consumer side, see Aasness and Holtsmark (1993). The climate emission is linked to each sector specific input and production as well as consumer goods, see Strøm (2000). Hence, the model offers a detailed description of substitution and scale effects generated by a tax on climate emissions.

Consumption, labour supply, and savings result from the decisions of an infinitely lived representative, forward-looking consumer, who maximises present value of utility subject to an intertemporal budget constraint. Utility originates from material consumption and leisure consumption, according to an Origo-adjusted Constant Elasticity of Substitution function (OCES) with 26 different consumer goods. (see figure A1 in appendix). The OCES specification allows the income elasticities to vary among goods.

Producer behaviour is generally specified at the firm level. The structure of the production technology is represented by a nested tree-structure of CES-aggregates, see figure A2 in appendix. All factors are completely mobile and malleable[2]. There is decreasing returns to scale in the production of goods and

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[1] For alternative solutions chosen in the literature, see e.g. Energy Economics (2006).

[2] On exception is the production of electricity, see Holmøy et al. (1994).

services. The manager of the representative firm is assumed to be rational and forward-looking and maximise the present value of the cashflow to owners; see details in Holmøy, Nordén and Strøm (1994).

The export markets and the home markets are assumed to be segregated, due to firms' adjustment costs of reallocating deliveries between the two markets. World market prices are assumed to be exogenous. Domestic and imported products are imperfect substitutes according to the Armington hypothesis. The domestic market structure is assumed to be a large group case of monopolistic competition, where each firm has some market power, but only in their respective home markets. Each firm produces a variety of a product that is an imperfect substitute for other varieties of this product (represented by Spence-Dixit-Stiglitz preferences). According to evidence on markup pricing by Norwegian firms (Klette, 1999 and Bowitz and Cappelen, 2001), market power is small; in most industries markups are set to 5 percent. The elasticity of substitution among the varieties of a product is calibrated to be in line with the estimated markup ratios.

The Norwegian supply of electricity is based on hydropower, which is exogenous in the model, and gas power, which is implemented as a backstop technology. Unilateral taxation of GHG emissions is accompanied with restrictions on trade with electricity to improve the effectiveness of the policy with respect to emission reductions. Restrictions on international trade with electricity prevent that foreign high emission electricity production, which do not face higher emission taxes, crowd out domestic low emission electricity production. Such barriers to trade prevent leakage, and hence, improve the effectiveness of unilateral taxation of GHG emissions.

The government collects taxes, distributes transfers and purchases goods and services from the industries and abroad. Overall government expenditure is exogenous and increases at a constant rate. The model incorporates a detailed account of the government’s revenues and expenditures. In the policy experiments it is required that the nominal deficit and real government spending follow the same path as in the baseline scenario, implying revenue neutrality in each period.

2.2 The MARKAL model

The technological changes in the energy system are calculated using a standard MARKAL model (Fishbone and Abilock, 1981) of the Norwegian energy system. MARKAL is a bottom-up engineering linear programming model with perfect foresight that optimizes the energy system – matching supply and demand - by minimizing cost. The model thus assumes that all agents have access to all information, make optimal decissions, and that no market powers are exerted. The MARKAL model includes the complete energy system from resources through processes and conversion to end-use demand. The model is especially suited to study changes in technology as a result of taxation of climate emissions. Costs of available technologies in MARKAL is based on empirical observations of costs and scope for productivity improvements. Hence, the model offers a detailed description of choice of technology generated by a tax on climate emissions. However, MARKAL does not incorporate future unknown technologies, which may have a drastic impact on future choices of technologies.

The energy economy consists of five main categories:

- Demands, representing the energy services
- Energy sources, representing methods of acquiring energy carriers
- Sinks, representing exports
- Technologies or processes, transforming energy to another form or to a service
- Commodities, consisting of e.g. energy carriers, materials and emissions

The technologies are assembled in a hierarchy where the top level are the categories constituting the energy economy. Within these categories there may be sub-sets e.g. metal industry and pulp and paper industry that again may be further divided. The lowest level is called a technology class. Using several technology classes we may include measures affecting the same industry but at different costs e.g. within pulp and paper industry there is four classes with different energy efficiency measures.

A reference energy system is defined with a set of sources, sinks, technologies, commodities and demands. The future demand for energy, which is exogenous in MARKAL, is determined by the MSG6 model. The demand for heat and electricity is divided into six categories depending on season – summer, winter and intermediate – and daytime or night. The end use demand is given in terms of energy service e.g. comfort temperature in housing and tonnes of steel produced. Some energy demands may be satisfied by both electricity and thermal energy. The model calculates an electricity balance and a heat balance to ensure that both demands are satisfied individually.

Results from the model are an optimal choice of technologies conforming to a set of technological, economic and environmental external constraints. The external technological conditions are the parameterization of direct regulations of the technologies available at any time. This may be done through limiting the availability of system components e.g. bound on energy production or consumption. Furthermore, external constraints can be implemented through forcing existing technologies to be phased out or in or force a percentage of a new technology to be utilized.

The Norwegian MARKAL model database contains more than 400 technologies with energy sources (38), processes (76), electricity- and heat conversion technologies (78) and demand technologies (229). They are allocated to the sectors residential, industry, transport, and agriculture, service and commercial. Most of the demand technologies are in the industry and residential sector while transport has 29 technologies and agriculture only 1. In the national database the energy efficiency potential is divided into four cost classes. The full potential is related to existing buildings while new buildings have different cost classes depending on the specific energy demand, e.g. better insulation reduces energy demand and increase cost.

The Markal and MSG6 models are informally linked and communicate using a common protocol. Coherent national boundary conditions e.g fossil fuel price and key national data e.g. cost of electricity conversion are assured. The Markal model is also linked to the global energy system model Energy technology Perspectives (IEA, 2008). The effect of technology learning in the global market is imported exogenously into the Markal model. The influence of global technology learning on the future technology composition of the Norwegian energy system and system costs is included. The global reference scenario provides boundary conditions for the national reference scenarios. The global energy system also generates world market prices of e.g. oil and gas for the two global scenarios which is included in this study.

The MARKAL database and reference energy system is an important element in the application of the MARKAL modelling tools. The Norwegian taxation scheme for the energy sector includes a general electricity tax, tax on emissions of CO_2, NO_x and SO_2 as well as a tax on energy consumption financing the state energy fund. Part of the energy intensive industry is exempt from the general electricity tax. Furthermore, the energy intensive industry has benefited from long-term contracts for energy at prices below the current market price. The current contracts are gradually phased out. A general subsidy of wind power is also granted and included in the database. Furthermore, there is a tax on waste differentiated according to the emissions released during combustion. However a subsidy designed to stimulate utilization of the waste heat for energy purposes is also introduced, and the sum of the two is about zero.

Implementation of new technologies requires substantial investments in general. Old production equipment and buildings are gradually replaced or modified over a long period of time. This process is reflected in the subsequent demand for different types of energy over time. The investments are affected by the interest rate, which for energy production equals 7 percent including a risk factor.

2.3 Linking the two models

The method used to link the two models, MSG6 and MARKAL, is determined by the following sequence of steps:

1. Reference scenarios in both MSG6 and MARKAL are established based on identical tax systems. The reference scenario in MSG6 is a growth path for the Norwegian economy from 2004 to 2100. Most exogenous estimates are taken from the baseline scenario in the Long Term Program (LTP) for Norway; see appendix and the Norwegian Ministry of Finance (2001). Production and consumption quantities from the reference scenario in MSG6 are implemented as exogenous inputs into the MARKAL reference scenario. MARKAL determines the technology choices. A detailed description of how these reference scenarios are established is given by Martinsen (2009).
2. The CO2 tax is increased in the MARKAL shift scenario. All other exogenous variables from the reference scenario are unchanged. The choice of technologies are adapted to the new tax regime, as costs including the new CO2 tax are minimized with respect to choice of technology. The MARKAL model calculates an overall present value of costs (net of taxes) for each scenario. The increase in present value cost is transformed into infinite annuities and allocated to sectors of the MSG6 model. These new technologies are more costly but emissions are reduced.
3. The reform scenarios are compared to the reference scenario where the national uniform CO2 tax equals the international quota price of 150 NOK/ ton CO2 emission. The first reform scenario (300 NAT) consists of implementing a national uniform CO2 tax of 300 NOK/ ton. The second reform scenario (300 GLO) consists of implementing both a national uniform CO2 tax and an international emission quota price of 300 NOK/ ton. The government budget constraint is satisfied by adjustments in the pay roll tax rate in all reform scenarios. The cost increases and emission reductions from the MARKAL reform scenario, in addition to the CO2 tax, is incorporated into the MSG6 shift scenario. The emission reduction is implemented directly into the CO2 tax base of the government, as well as into the emission quota budget of the government. Hence, MARKAL emission reductions lower CO2 tax revenues as well as emission quota purchases.

The welfare cost of the CO2 tax reform is found by comparing the present value of utility of the MSG6 shift scenario with the MSG6 reference scenario. The total emission reduction consists of the emission reduction from the MARKAL scenarios plus the emission reduction generated by the tax reform implemented in the MSG6 scenarios. The welfare is given by the present value of future material consumption and leisure. An alternative welfare measure incorporates local external effects like noise and accidents etc. The magnitude of the local external effects connected to the use of cars is set according to an empirical estimate in Econ (2003). Estimates vary with type of vehicle, density of the population, and time of driving. However, the average estimate for the use of petrol cars equals the present Norwegian tax on petrol net of the tax on GHG emission. These welfare measures do not incorporate gains connected to lower domestic emissions of green house gasses since Norwegian emission reductions have a marginal effect on global warming. The welfare measure, however, does not take account of costs associated with reallocation of physical capital and resources from emission intensive sectors. Such costs might be substantial within the Norwegian energy intensive industry, as local communities tend to be severely hit by the reform. Note, however, that welfare gains of uniform energy taxation in many cases can be preserved by introducing different forms of subsidies to the industry, se Bovenberg and Goulder (2001).

Choices of technology may lead to drastic changes in demand for input factors that are neglected by the linking method. E.g. a change from refined diesel to bio diesel would lead to a drastic drop in demand for refined fossil fuel, and a drastic increase in demand for bio fuels delivered from the agricultural sector. The linking method described is only able to capture costs and emission reduction due to the change from fossil to bio diesel. It is unable to incorporate effects from the change in demand for refined fuels and fuels delivered by the agricultural sector. This shortcoming is a disadvantage connected to soft-linking of two models. The advantage is substantial simplification. For a solution along these lines, see Fæhn et al (2010) which describes a model that includes estimated technological abatement functions for selected industries.

3. The tax reforms

3.1 The 300 NAT reform

The second step of the liking procedure consists of increasing the uniform CO2 tax rate from 150 to 300 NOK/ton in all periods within a MARKAL shift scenario. The section below describes the effects of this tax shift generated by the MARKAL model. The results are given in table 3.1.

The effect of an increase in the uniform CO2 tax from 150 to 300 NOK/ton in MARKAL generates incentives to employ technologies that lead to lower emissions of green house gasses. In 2020 the electricity production from gas power plants is reduced from 8.2 TWh to 6.1 TWh while in 2050 it is reduced from 18.2 TWh to 11.4 TWh. In both 2020 and 2050 the onshore wind power is higher in the 300 NAT reform scenario compared with the reference scenario. In 2050 near shore electricity (offshore wind and wave) has increased to 9.2 TWh. The electricity generation has also increased by 2.3 % (3.7 TWh) because of a shift to electricity as energy carrier, and to satisfy higher demand including electrification of oil platforms. Hence, emission reductions within the electricity sector are generated by technology changes within other sectors and new technologies to produce electricity, see table 3.1. Note that the Klimakur reference scenario (Klimakur 2020 (2010) assumes a high degree of abatement from gas power production through CCS; thus emissions are already low within power generation and no wind power introduction takes place in the Klimakur scenarios.

Table 3.1 Emission reductions and cost increases generated by technology changes

Demand categories	**CO_2 emission 2020**	**CO_2 emission 2050**	**Increase in cost (discounted)**
	Kt	kt	Mill NOK (2005)
Paper and paper products	0	0	30.58
Industrial chemicals – MTBE	-477	-290.459	57.754
Iron and steel manufacturing	0	0	86.488
Non-ferrous metal manufacturing	-17.544	0	52.786
Other manufacturing industries	-172.66	-14.742	75.489
Agriculture and fishing stationary	0	0	60.13
Energy use refineries	0	-26.715	116.41
Electricity production	-702.48	-2274.62	7253.8
Residential, commercial	-58.526	0	412.64
Transport sector	116.97	-2669.06	1831.8
Dsl engine offshore + gas +oil production	-368.74	-796.514	463.09

The emission reduction within the transport sector is substantial compared to the other sectors. The main explanation is a transition from petrol and diesel towards bio diesel. This change of energy source is more substantial for trucks. A change of energy source also takes place within offshore oil production. Electrification of oil platforms is both increased and introduced at an earlier stage. The use of gas turbines is reduced, and thus, emissions are reduced.

The industrial chemical sector replaces oil burners with LNG burners in 2020. A small investment in conservation of electricity and other non-substitutable fuels is made in 2040 to 2050. Furthermore, in the last periods the LNG boiler capacity is reduced and partly replaced by electric boilers. The oil boiler capacity is increased around 2040 within both the reference scenario and the reform scenario. However the increase is slightly larger in the reform scenario.

More energy conservation is implemented in new single houses within the residential buildings sector in the reform scenario compared to the reference scenario. In old single houses a small capacity of oil boilers is replaced by district heating in the earlier periods before the oil boilers is phased out. The amount of district heating, also using some fossil fuel, is reduced in commercial buildings in the reform scenario. This change of technology contributes to lower emissions of green house gasses. The use of pellets boilers and heat pumps is increased, and a small amount of solar hot water heaters is introduced from 2030.

In non-ferrous metal manufacturing there is slightly more district heating in the early periods of the reform scenario. The LNG burners are also replaced by electric boilers. In the later periods, prior to 2050, there are some investments in thermal conservation. No additional investments are made in iron and steel manufacturing in the reform scenario compared to the reference scenario. The additional cost thus only reflects the increase in the electricity prices because of investments in increased electricity generation.

The CO_2 emissions from the paper and paper product sector are zero in both scenarios in the selected periods and thus the difference is zero. However, small investments in energy efficiency and increased use of bio energy boilers are made in the middle periods, and this is reflected in the increased marginal cost. The use of district heat from waste district heat plants is reduced. Other manufacturing industries employ more district heating in the intermediate periods. The capacity of LNG burners is reduced and replaced by bio boilers in the early periods.

The total present value cost increase within the MARKAL model amounts to 10,4 bill NOK, and the total reduction of CO2 emissions amounts to 1,6 mill ton in 2020 and 6,2 mill ton in 2050.

The third step of the linking procedure consists of implementing the tax reform scenario into the MSG6-model. We implement the following components of the 300 NAT reform:

i) *CO2 tax component:* The uniform CO2 tax is increased from 150 to 300 NOK/ton, and the international quota price of 150 NOK/ton is fixed at the reference scenario level.

ii) *Technology choice component:* The CO2 tax increase stimulates industries in the MARKAL model to adapt new cleaner technologies that are more costly. These cost increases are incorporated into the MSG6 model as drops in the productivity.

iii) *The emission reduction component:* The emission reductions are incorporated into the MSG6 model.

iv) *The tax revenue recycling component:* The extra revenue generated by the CO2 tax reform is recycled by an endogenous uniform percentage cut in the payroll tax rate.

CO2 tax component

The increase of the uniform GHG emission tax from 150 to 300 NOK/ton leads to a price increase of emission intensive goods and services. The major price change faced by households is a price increase of heating oil and petrol of approximately 5-10 percent, see table 3.2 and 3.3. There is also a modest price increase of boat transport, mainly due to the input of fossil fuel to produce boat transport services. Other consumer good prices are basically unaffected. The representative consumer adapts to these price changes by lowering their consumption of petrol and oils by approximately 2-3 percent, se table 3.2 and 3.3. There is also a substantial reduction in purchase of private cars and transport equipment. The reduction in households' consumption of heating oil is between 1,5 and 2 percent, and substitution towards heating based on electricity leads to an increase in households' consumption of electricity. These adjustments in households' consumption lead to a reduction of GHG emissions which amounts to approximately 20 percent of the emission reduction generated by scale and substitution effects.

The increase of the uniform GHG emission tax also generates an increase in factor prices of emission intensive input factors. The price increase first of all hurts the emission intensive sectors of the economy. Within the MSG6 model these sector are; Production of oil, Production of Metals, Land transport, Production of Chemical commodities, the Agricultural sector and Other private service production. The production volume within the agricultural sector and the Production of oil are exogenous within the MSG6 model. There are also modest substitution possibilities within these two sectors of the MSG6 model. Hence, the effect of the tax increase is marginal within these sectors. Approximately 30-40 percent of the total emission reduction generated by scale and substitution effects takes place within Production of Metals. There are also substantial reductions of emissions within Production of Chemical commodities. Both these sectors export a substantial share of their production at fixed world market prices. The price taking behaviour combined with modest decreasing returns to scale (due to a scale elasticity of 0,83) generates a substantial down scaling of production, and hence emissions, as a result of the cost increase generated by the tax increase on emissions. The production of Metals drop by 4,7 percent in 2020, and 5,9 percent in 2050. There are also substantial emission reductions within Land transport and domestic sea transport due to the tax increase. These emission reductions are generated by both substitution from land and boat transport towards less polluting forms of transport, and by down scaling of transport in general. The cost increase generated by the tax increase is shifted on to consumer prices as firms are engaged in mark-up pricing within the domestic market. Hence, these scale and substitution effects are to a large extent determined by demand elasticities.

The effects described above leads to general equilibrium effects within the Norwegian economy. The drop in export of Metal and chemical products contributes to generate a negative trade balance. The import impulses created by the tax increase are modest. A current account deficit contributes to push the equilibrium wage rate downwards. The resulting cost reduction is of course larger within the labour intensive sectors. The cost reduction and price taking behaviour within the export market leads to an expansion of export production. The cost reduction is shifted on to prices in the domestic market as firms engage in mark-up pricing within this market. A drop in domestic prices leads to substitution from imports towards domestic goods. Both the expansion of export, and the reduced import, contributes to restore the balance in the current account. A drop in the real wage contributes ceterius paribus to a drop in the supply of labour. A lower supply of labour contributes to lower GDP, and the demand for real capital drops.

Technology choice component

The technology choice component implies that the economy will introduce more costly technologies in order to reduce their CO2 emissions. The more costly technologies are implemented into the MSG6 model as a fall in the productivity of the sectors that introduces new technologies. According to the MARKAL model the most costly technological changes occurs in the power generation sector. This cost increase is implemented into the MSG6 model as a cost increase of consumers of electricity in proportion to their use of electricity. The aggregate productivity drop is equivalent to a present value cost increase of 10,4 billion NOK. The annuities of this amount are distributed across sectors according to the MARKAL calculations.

The Total Factor Productivity (TFP), i.e. the productivity of all production factors in specific private industries, is permanently reduced. The effects are basically the same as those working in the text-book model of a Small Open Economy (SOE) or the Scandinavian Model of Inflation, see also Heide et al (2004) for a more detailed description. Since export prices are given, producer real wages are determined by the productivity in the export sector. When technologies exhibit constant returns to scale, a reduction in labour productivity will be carried over to wages in its full magnitude. Furthermore, the lower revenue per produced unit due to lower productivity of all factors is carried over to wages. Technical complementarity between labour and other inputs implies that the marginal labour productivity is reduced both with lower productivity and with less input of capital and intermediates. In MSG6, this mechanism is somewhat modified by scale effects due to decreasing rather than constant returns to scale. Reduced total demand reduces imports according to the import shares. The drop in domestic prices contributes further to lower imports through substitution away from imports. In present value terms the drop in imports allows for a corresponding drop in exports, in order not to violate the intertemporal budget constraint on foreign debt. This contributes to moderate the downwards pressure on the wage rate. The contraction of export production increases the marginal productivity of all inputs due to decreasing returns to scale, which in turn modifies the effect on the wage rate compared to the productivity decrease.

The negative income effect of the drop in productivity contributes to reduce time spent on leisure, and hence, increases the supply of labour as leisure is a normal good. The real-wage decrease leads, cet. par., consumers to substitute from consumer goods towards leisure, and hence, reduce their labour supply. The drop in the consumer real wage rate has a negative effect on labour supply, since the substitution effect dominates the income effect in MSG6.

The emission reduction component

The emission reductions resulting from the new technologies are implemented by firms and households. The sum of these sector specific emission reductions of GHGs is implemented directly into the CO2 tax base and the emission quota budget of the government to simplify calculations. This reduction amounts to 2,7 percent in 2020, and 8,8 percent in 2050.

The emission reductions resulting from the new technologies contribute to lower the CO2 tax base, and hence, contribute to lower tax revenues generated by the tax reforms. On the other hand, the emission reductions also imply that the government has to buy less quotas, and hence, lower government expenses. Each ton reduction of GHGs generates a first round gain of 150 NOK to the Norwegian state. However, the cost of emission reductions for firms exceeds 150 NOK, as less costly reductions are already implemented in the reference scenario. The reduction of quota purchases also contributes to a current account surplus, which modifies the equilibrium wage rate.

The tax revenue recycling component

The tax revenue recycling component consists of adjusting the payroll tax rate to balance the government budget. The components incorporated in the 300 NAT reform scenario each have an effect on the government budget, and hence, generates a need to adjust the payroll tax rate.

The CO2 tax reform consisted of increasing the uniform GHG emission tax from 150 to 300 NOK/ton. This tax increase doubles the tax revenue levied on the post reform emissions. The tax increase, however, also leads to an emission reduction. This emission reduction contributes to reduce the tax base, and hence, shrink the tax revenue generated by the tax increase on GHG emissions. The emission reductions also contribute to lower government expenses connected to purchases of quotas. Hence, the first round effects of the CO2 tax increase on the government budget is a government budget surplus. The budget surplus is, however, moderated by shrinking of other tax bases like profits of firms, Labour supply and production. The drop in the wage rate also contributes to shrink the tax base. These effects contribute to generate a public sector deficit, although public spending is lowered as the wage rate drop. The public spending is lowered as the wage rate drops because a large amount of public spending is proportional to the wage rate.

All in all, the reform generates a public sector surplus which is recycled through a uniform cut in the payroll tax. In the steady state the payroll tax is reduced by 2.8 %. This leads to a cost reduction, especially in the labour intensive sectors, which becomes more competitive. The export from these sectors increases. The cost reduction is shifted on to domestic prices, which leads to substitution towards domestic goods and a reduction in imports. The subsequent surplus on the current account leads to an upwards pressure on the equilibrium wage rate. The wage increase contributes to increase the real wage, which stimulates the supply of labour, and hence, extends the tax bases of the economy.

The quantitative effects of the reform are given in table 3.2 and 3.3 for the years 2020 and 2050 respectively. The emission of GHGs is reduced by 4,6 percent in 2020 and 11,7 percent in 2050. The larger emission reduction in 2050 is generated by slow implementation of new technologies. Approximately 75 percent of the emission reduction in 2050 is generated by implementation of new technologies. The reduction of the payroll tax has the opposite effect on the labour market compared to the CO2 tax component and technology choice component. Overall, the supply of labour increases by 0,09 percent in 2020, and decreases by 0,01 percent in 2050. The main explanation being that the cut in the payroll tax rate is larger in 2020 compared to 2050. The payroll tax rate cut also stimulates to more production and hence, to more use of energy intensive input factors. Overall, GDP decreases by 0,09 percent in 2020 and 0,1 percent in 2050.

Table 3.2 Main effects and results of the tax reforms. Year 2020.

	Level Data	Percentage deviation from 150 GLO	
Scenarios	Reference: 150 GLO	National Shift:300 NAT	Global Shift: 300 GLO
Uniform CO2 tax, NOK/ton	150	100	100
Payroll tax rate	13,8	-5,3	-5,0
International Kyoto price, NOK/ton	150	0	100
CO2 emissions, Mill tonn	59,8	-4,6	-3,7
- due to change in technology	-	-2,7	-2,7
- due to scale and substitution effects	-	-1,9	-1.0
Price, Material consumption	-	0,04	0,23
Wage rate, workers	-	0,19	0,33
Price, private consumption of petrol and oil	-	4,7	4,9
Price, private consumption of fuels	-	5,9	6,1
Production, Metal Sector, Mill NOK	66459	-4,7	-0.1
Production, Chemical Sector, Mill NOK	77849	-0.6	-0.2
Production, Road Transport, Mill NOK	136197	-0.8	-0,9
Private Consumption of Petrol and Oils, Mill NOK	37729	-1,9	-1,8
Private Consumption of fuels, Mill NOK	5197	-1.5	-1,0
GDP, Mill NOK	2404844	-0.09	-0,01
Export, Mill NOK	796602	0.09	-0,25
Import, Mill NOK	714363	-0.03	-0.18
Private Consumption, Mill NOK	1405731	0.04	0.05
Total Employment, Mill hours	3571	0,09	0.033
Utility (Aggregate of consume and leisure)	2330902	-0.01	0.012
Welfare (present value) Mill, NOK	58283636	-0.015	0.048
Welfare corrected for externality (net present value) Mill, NOK	55378354	0.010	0.047
Markal system cost, Mill NOK (present value)	5574109	0,19	0,19

3.2 The welfare effect of the 300 NAT reform

The 300 NAT reform scenario generates a drop in welfare of 0,015 percent according to the original welfare measure, and an increase in welfare of 0,01 percent when local external effects are incorporated into the welfare measure. The reduction in petrol and fuel consumption is the major explanation why our alternative welfare measure produces a welfare gain, while our original welfare measure produces a welfare loss.

The welfare effect of this reform is mainly determined by reallocation of resources between sectors, and by reallocation of time spent on leisure and on work. The CO2 tax component generates a reallocation of resources away from the metal sector, and towards other sectors. The marginal product of input factors within the metal sector is somewhat lower than that of other sectors because of favourable taxation (the payroll tax is modest due to location) and lower electricity price (due to favourable contracts which however last less than a decade). The marginal product is also lower because metal is exported at a price equal to the marginal cost, while the mark-up pricing of domestic products contributes to push up the marginal product within other sectors with more domestic production. Hence, this reallocation of resources generates a modest positive welfare effect. Similar effects are also present within production of chemical commodities. The CO2 tax component also implies that consumption of fuel and petrol is reduced. The reduction takes place both within households and within the transport sector. The current tax on petrol consumption (4,20 NOK/liter in addition to the CO2 tax and VAT) implies that the marginal utility (product) of petrol exceeds the marginal utility (product) of other goods. A reallocation from petrol towards other goods consequently leads to a welfare loss. There are also a substantial reduction in purchase of cars and private transport equipment. The current tax on purchase of new cars together with the tax on fuels constitutes a substantial tax wedge on households private transport services. The increase in the CO2 tax contributes to increase this substantial tax wedge.

The technology choice component leads to reduced consumption possibilities, which lowers the welfare. The emission reduction component implies that the government has to buy fewer quotas from abroad, and this represents a welfare gain. The net welfare effect of implementing new costly technologies to lower emissions is negative, as the cost of lower emissions exceeds the pecuniary benefits of buying fewer quotas from abroad.

All components affect the allocation of time spent on leisure and on work. Reducing the wedge between the social marginal utility of leisure and the social marginal utility generated by labor also has a welfare-enhancing effect. In the Norwegian economy, the initial wedge is substantial and consists of a marginal tax on labor income, approximating 40% on average, indirect consumer taxes (including the VAT averaging 22%, and the payroll tax, averaging about 13%), and a 5% markup in the domestic industry. The simulations show that the reform generated a modest increase in the supply of labour in the early decades and a marginal change in the long run. The difference between short and long run was mainly generated by a slightly larger wage increase in the short run. Hence, the labour market impulses contributed to increase the welfare generated by the tax reform.

3.3 The 300 GLO reform

The MARKAL shift scenario when increasing the uniform CO2 tax from 150 to 300 NOK/ton is assumed to be identical to the 300 NAT reform scenario. This implies that we have considered technological alternatives to have the same price, an in particular, learning effects, whether Norway acts alone or in concert with the rest of the world. Hence, we move on to the third step of the linking procedure, which consists of implementing components of the 300 GLO reform scenario into the MSG6 shift scenario. All components in the third step of the 300 NAT reform scenario are also incorporated into the third step of the 300 GLO reform scenario. The effects of these components are described in the section containing the 300 NAT reform scenario. The 300 GLO scenario also includes three other components in addition to the components of the 300 NAT reform scenario.

i) *Kyoto price component:* The international quota price is increase from 150 to 300 NOK/ton

ii) *Oil price component:* An increase of the international quota price will reduce the global demand for fuels and oil. An estimate of the drop in the international price of crude oil is implemented.

iii) *The price of energy intensive products:* The world market price of energy intensive products is assumed to increase as quota prices increases.

Kyoto price component

The Kyoto price component consists of increasing the international price of emission quotas from 150 to 300 NOK/ton. This price increase implies that the government has to spend more on imports of emission quotas. However, the tax reform has lowered the emission of GHG’s by 8 percent in 2050. The endowment of free emission quotas was set to 90 percent of GHG emissions in the reference scenario. Consequently, a doubling of the quota price only leads to a marginal increase in public spending connected to purchases of quotas from abroad. However, a lower endowment of free emission quotas implies that the price increase of emission quotas leads to a substantial increase in public spending. This represents a terms of trade loss to the Norwegian economy. A sensitivity test shows that our welfare calculations are sensitive to endowment of free emission quotas. The welfare effect of the 300 GLO scenario becomes negative when the endowment of free emission quotas is reduced.

Oil prices component

The oil price component consists of changing the international price of oil generated by the increase in the international quota price of GHG emissions from 150 to 300 NOK/ton. The price change is found by simulating a quota price increase within the world market model labelled ”Energy Technology Perspectives" (IEA, 2008). The world price of gas was unaffected by the quota price increase within the world market model. The world price of oil, however, was unaffected until 2030, and drops substantially in the long run (22,4 percent in 2050)[3]. The drop in world demand for oil is marginal the first decades because it takes time to replace capital and equipment that rely on old technology with capital and equipment that rely on new technologies based on alternative fuel sources. The drop in demand is however substantial in the long run as capital and equipment that rely on new technologies are implemented. The drop in the world price of oil leads to a subsequent drop in the producer price of Norwegian petroleum products. The long run drop in the price of oil is implemented exogenously into the MSG6 model. Effects of a change in the world price of oil within the MSG6 model is described in more detail in Heide et al. (2004).

The major part of the Norwegian oil production is exported abroad. The Norwegian oil producers suffer a substantial loss of revenues due to the drop in the world price of oil. The major part of this loss is shifted on to the government due to a large direct ownership, and due to a substantial loss of tax revenues from oil companies (the tax on oil producers’ amounts to 78 percent of their revenues). The Norwegian extraction of oil, however, is assumed to gradually decrease towards zero in the long run, and Norway becomes a net importer of oil from 2060 and onwards. Households and firms consumption of oil based products (petrol, fuel oil etc) increases due to the long run drop in the oil price, see table 3.3. This leads to an increase in emissions in the long run. This is a major explanation why emission reductions are more modest within the global scenario. There are, however, considerable uncertainties connected to demand for oil in the long run.

The price of energy intensive products:

The higher international emission quota price leads to a cost increase of emission intensive input factors. Hence, the unit cost of production within emission intensive industries will increase. This cost increase is likely to generate an increase in world prices of emission intensive products. The price of energy intensive products component consists of increasing the world export price of energy intensive products by the same magnitude as the cost increase of energy intensive sectors within the Norwegian economy. The changes made within the MSG6 model consist of increasing the world export prices for the following sectors; chemical and mineral products (27), pulp and paper (34), industrial chemicals (37) and metals (43), by fixing the volume of export within each of these sectors to the levels in the

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[3] A forwards looking model with perfect foresight is likely to generate a drop in the world price of oil in all periods as oil is an exhaustible resource, see Dasgupta and Heal (1979).

reference scenario, and letting the export prices adjust endogenously to this volume of export. This resulted in a price increase in 2050 of approximately 0,2 percent in sector 27, 0,4 percent in sector 34, 0,7 percent in sector 37, and 2,0 percent in sector 43.

The increase in these export prices contributes to increase the volume of export production within sector 27, 34, 37 and 43, and hence, neutralize the cost increase which contributes to lower the volume of export. The expansion of export production contributes to increase emissions of GHGs, especially within the metal industry. Both the increase in the prices of export and the increase in the volume of export contribute to generate a surplus in the current account. The balance in the current account is restored by an increase in imports, and by an upwards adjustment in the equilibrium wage rate, which shrinks export and leads to substitution from domestic goods towards imported goods.

The tax revenue recycling component (modified)

The three additional components in the 300 GLO reform scenario contribute to change the total tax revenue generated by the reform, and hence, the amount of revenue recycled back to the representative consumer in the revenue recycling component. The oil price drop contributed to lower tax revenues, as the major part of the loss connected to the price drop is shifted on to the government due to a large direct ownership, and due to a substantial loss of tax revenues from oil companies. The expansion of the energy intensive sectors due to the price increase of energy intensive export goods contributes to increase tax bases, and hence, the tax revenue recycled back to the representative consumer. The price increase of energy intensive export goods also imply that firms earn more profits, which is taxed at 28 percent, hence even more tax revenue can be recycled back to the representative consumer. The effect on the government budget of the quota price increase is marginal due to the modest purchase of quotas. The overall payroll tax rate reduction amounts to 5 percent in 2020 and only 1,3 percent in 2050. The main explanation being that the drop in the price of oil after 2030 implies that less tax revenues is recycled.

3.4 The welfare effects of the 300 GLO reform

The welfare level of the 300 GLO reform scenario is compared to the welfare level of the reference scenario. The welfare effects of this reform consists of the welfare effects generated by the four components of the 300 NAT reform scenario and the three components described above. Each component generates reallocations of resources that contribute to change the welfare. Overall, GDP increases by 0,1 percent in 2050 while there is a marginal drop in 2020. Both private consumption and the supply of labour increases, see table 3.2 and 3.3.

The long run drop in the world price of oil has substantial consequences for the Norwegian oil based economy. First, the drop leads to a terms-of-trade loss connected to export of oil. The Norwegian economy is assumed to be a substantial net exporter of oil between 2030 and 2060, even though the major part of Norwegian oil resources is extracted prior to the drop in the oil price. Hence, the drop in the oil price within this time period generates a terms of trade loss, which contributes to lower the welfare measure. However, the Norwegian economy becomes a net importer of oil after 2060, as the oil wells are assumed to run dry. Hence, the oil price drop after 2060 generates a terms of trade gain, which contributes to increase the welfare measure. The net welfare effect of the oil price component is positive. The main explanation is that the terms of trade gains connected to lower import prices of oil based products in the long run exceeds the terms of trade loss connected to loss of export revenues from export of oil. The import of oil after 2060, which is calibrated according to the present pattern of consumption, might be substantially exaggerated as future technology might lower the consumption of oil based products substantially. Hence, the net welfare effect of the oil price component is highly uncertain.

The drop in the oil price also implies that less revenue is recycled back to the representative consumer. The loss of export revenues is to a large extent shifted on to the government due to a large direct ownership, and due to a substantial loss of tax revenues from oil companies. Hence, less revenue is recycled back to the representative consumer. Less revenue recycling imply smaller cuts in the payroll tax rate, and hence, more modest welfare gains.

The world price increase of energy intensive products generates a terms of trade gain to the Norwegian economy which contributes to increase the welfare measure. This component also generates a general equilibrium wage rate increase which contributes to generate more tax revenue. However, the wage rate increase also expands public spending which to a large extent is proportional to the wage rate. Hence, the wage rate increase has a modest effect on the amount of revenue recycled back to the representative consumer. The price of energy intensive products component contributes to expand the energy intensive sectors. This reallocation of resources generates a modest welfare loss due to favourable conditions within these sectors. The study assumes that import prices are unchanged.

The welfare effect of the Kyoto price component is negative as Norway imports emission quotas which become more expensive. However, the size of these effects are modest, as the amount of quotas imported are modest due to a small difference between total emissions of GHGs and the allocation of free emission quotas. Note, however, that this welfare effect becomes substantial when the allocation of free quotas is reduced.

The percentage change in the welfare measure containing local external effects is approximately identical to the percentage change in the welfare measure without local external effects. The main reason is that there are two opposing effects. The tax increase contribute to lower petrol and fuel consumption, and hence, reduce negative local external effects connected to consumption of petrol and fuels. The drop in the world price of oil contributes to increase consumption of petrol and fuels, and hence, increase negative local external effects connected to such consumption.

Table 3.3 Main effects and results of the tax reforms. Year 2050.

	Level Data	Percentage deviation from 150 GLO	
Scenarios	Reference: 150 GLO	National Shift:300 NAT	Global Shift: 300 GLO
Uniform CO2 tax, NOK/ton	150	100	100
Payroll tax rate	13.8	-2,8	-1,3
International Kyoto price, NOK/ton	150	0	100
CO2 emissions, Mill tonn	69,6	-11,7	-8,0
- due to change in technology	-	-8,8	-8,8
- due to scale and substitution effects	-	-2.9	0.8
Price, Material consumption	-	0,09	-0,14
Wage rate, workers	-	0,05	0,18
Price, private consumption of petrol and oil	-	7,6	-8,8
Price, private consumption of fuels	-	9,6	-0,6
Production, Metal Sector, Mill NOK	107708	-5,9	-0.05
Production, Chemical Sector, Mill NOK	136794	-0.53	-0.09
Production, Road Transport, Mill NOK	244226	-0.65	0.42
Private Consumption of Petrol and Oils, Mill NOK	55611	-3.05	4.05
Private Consumption of fuels, Mill NOK	6468	-1.78	0.14
GDP, Mill NOK	4176204	-0.1	0.1
Export, Mill NOK	959531	-0.95	0.01
Import, Mill NOK	1282171	-0.41	0.18
Private Consumption, Mill NOK	3189154	0.00	0.176
Total Employment, Mill hours	3764	-0.01	0.025
Utility (Aggregate of consume and leisure)	5 238 621	-0.009	0.010
Welfare (present value) Mill, NOK	58283636	-0.015	0.048
Welfare corrected for externality (net present value) Mill, NOK	55378354	0.010	0.047
Markal system cost, Mill NOK (present value)	5574109	0,19	0,19

Note: The effects of the exogenous shift are measured as percentage deviations from the reference scenario. Even if the absolute change is moderate, the percentage deviation will be very large if the reference value is small. Moreover, a positive absolute change will result in a negative percentage deviation if the reference value is negative.

4. Conclusion

This study analyses whether the strong double dividend hypothesis holds within a setting where a uniform tax on green house gas emissions is raised above the international quota price within the Norwegian economy. The study shows that the SDD hypothesis does not hold within a framework where detailed technology choices are incorporated. The main reason is that the direct cost of emission reductions exceeds the price of emission reductions. Hence, abatement technologies lower emissions at a direct cost that exceeds the price of emission reductions. Abatement technologies also contribute to lower the tax revenue recycled. Hence, the scope for cutting existing tax wedges is reduced by the technology choices. This contributes to increase the welfare cost of the reform. The SDD hypothesis, however, holds when local external effects connected to cuing and accidents etc. within the transport sector are taken into consideration. Studies which incorporate taxes designed to neutralise local external effects, but excludes such external effects from the welfare measure are likely to overestimate the welfare cost of reducing GHG emissions. The SDD hypothesis also holds when the international quota price is increased, and oil prices drop in the long run. The main reason is that Norway extracts major part of Norwegian oil resources prior to the drop in the oil price. The Norwegian economy becomes a net importer of oil after 2060, as the oil wells are assumed to run dry. Hence, the oil price drop after 2060 generates a terms of trade gain, which contributes to increase the welfare measure. Also, the price increase on energy intensive goods exported abroad generates an terms of trade gain to the Norwegian economy. The sign of the welfare effect, however, is sensitive to the amount of free emission quotas allocated to the Norwegian state.

Our results are likely to be sensitive to a number of crucial assumptions. First, we do not include adjustment costs. There are no sunk costs; all capital equipment can at any time be reallocated to other productive sectors. Second, we assume that the high carbon tax is implemented uniformly across sectors, and that all the revenue generated is used to lower the pay-roll tax. This generates a welfare enhancing double dividend effect. Introducing a uniform emission tax on top of the international quota price is the most efficient way of reducing carbon emissions from Norwegian territory further; still, the government may choose other instruments. If for instance the government chooses to subsidize instalment of carbon abatement technologies in order to obtain additional emission reductions, some or all of the positive double dividend effect may disappear. Third, in the 300 GLO scenario, import prices on goods and services that are energy intensive, directly or indirectly, do not change. This does for example apply to biofuels or other alternatives to fossil fuels that can be imported. Clearly, if import prices also are bound to increase this effect becomes weaker. It is however very difficult to predict how import prices may change. Norway imports all vehicles on Norwegian roads, and one might expect costs in this industry to rise with more stringent climate policy due to higher prices on raw materials, energy etc. On the other hand, if other countries also lower their pay-roll tax in the 300 GLO scenario, labour intensive industries may experience lower costs, and hence, the international prices on such products may decrease. The choice of welfare measure is clearly also crucial for the interpretation of the derived results. The motivation for taking the lead in emission reduction seems to be a desire to act according to some moral standard, or to guide other countries into choosing a stricter environmental standard. The aim of this study, however, is to calculate efficiency costs and gains generated by the emission reducing policies, and not to account for possible benefits of taking such a role. The study shows that country specific emission reducing policies may generate a welfare gain even when a traditional welfare measure is employed. Hence, there may be no need to introduce moral standards or other alternative motives to find support for emission reducing policies within the Norwegian economy.

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Appendix: Exogenous estimates of the reference scenario

The reference scenario is a growth path for the Norwegian economy from 2004 to 2100. Most exogenous estimates in the reference scenario are drawn from the baseline scenario in the Long Term Program (LTP) for Norway; see the Norwegian Ministry of Finance (2001) for a detailed documentation.[4] Exogenous factors primarily include policy variables, world market assumptions, population growth, technological change, and the development of the exogenously determined industries, the most important being the public sector and the offshore oil and gas production. Policy variables are kept at their (real) 2004 levels. World market prices increase 1.3% yearly. A Hicks-neutral technological change of 1.3% annually is assumed in the private industries; in the public sector, the rate is 0.5%. Norwegian income depends heavily on oil and gas exploitation. To a large extent, the former natural resource wealth will be turned into financial assets to ensure that Norway has a substantial currency income flow in the future.

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[4] The model version used in the LTP deviates from ours.

Table A1: Nongovernment production activities in MSG-6

Agriculture
Forestry
Fishing
Breeding of Fish
Manufacture of Fish Products
Manufacture of Meat and Dairy Products
Production of Grain, Vegetables, Fruit, Oils, etc.
Production of Beverages and Tobacco
Manufacture of Textiles, Apparel, and Footwear
Manufacture of Furniture and Fixtures
Production of Chemical and Mineral Products, incl. Mining and Quarrying
Printing and Publishing
Manufacture of Pulp and Paper Articles
Manufacture of Industrial Chemicals
Gasoline Refining
Diesel Fuel Refining
Heating Fuels, Paraffin, etc. Refining
Manufacture of Metals
Manufacture of Metal Products, Machinery, and Equipment
Hired Work and Repairs
Building of Ships
Manufacture and repair of oil drilling rigs and ships, oil production platforms etc.
Construction, excl. Oil Well Drilling
Ocean Transport – Foreign
Finance and Insurance Servicing
Crude Oil Exploration
Natural Gas Exploration
Servicing in Oil and Gas Exploration
Pipeline Transport of Oil and Gas
Production of Electricity
Power Net Renting
Sales and Distribution of Electricity
Car and Other Land Transportation
Air Transport
Railroads and Electrical Commuters
Ocean Transport – Domestic
Post and Tele Communication
Wholesale and Retail Trade
Dwelling Servicing
Other Private Servicing

Figur A1. The structure of the utility function of the representative consumer in the MSG6 model

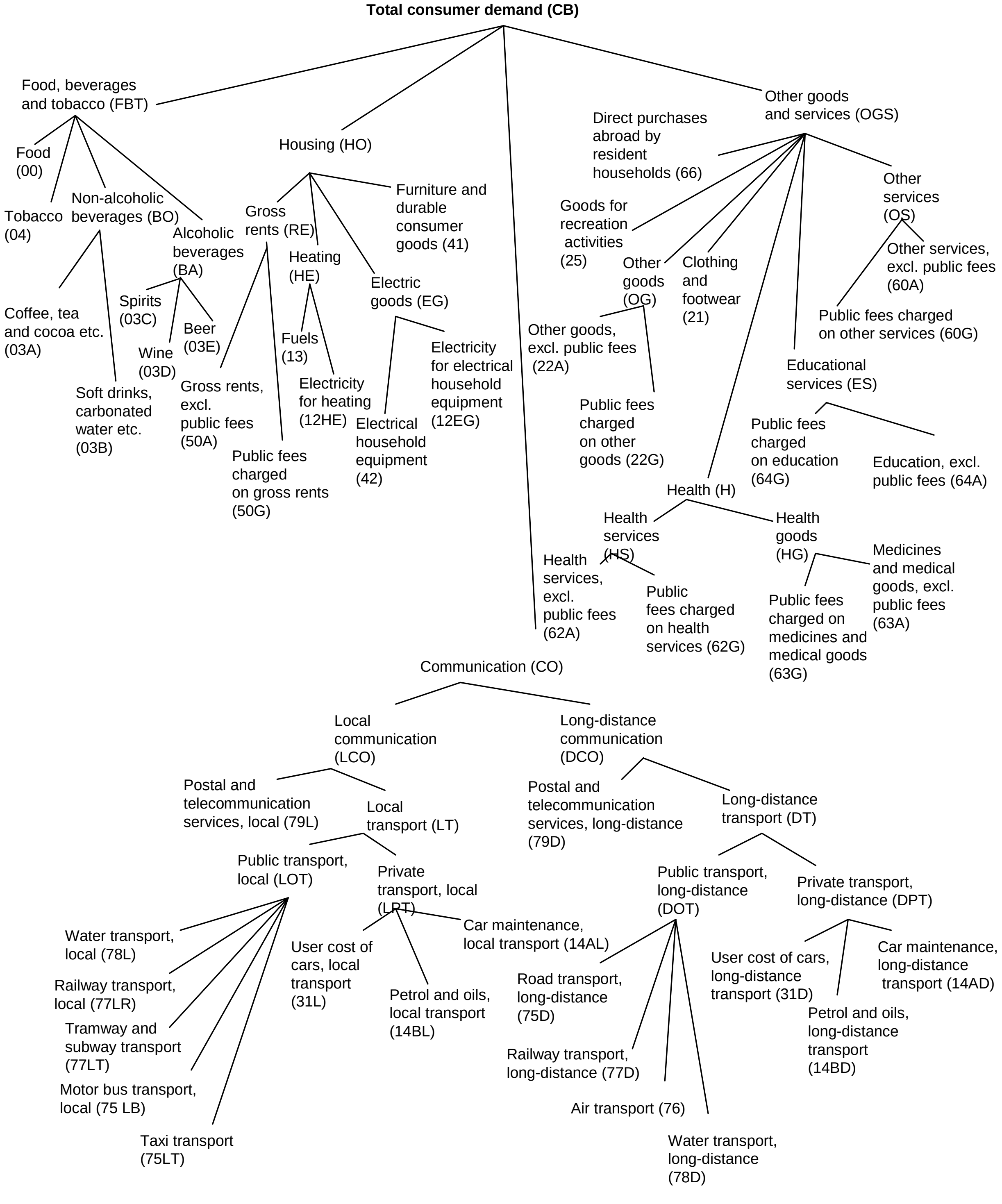
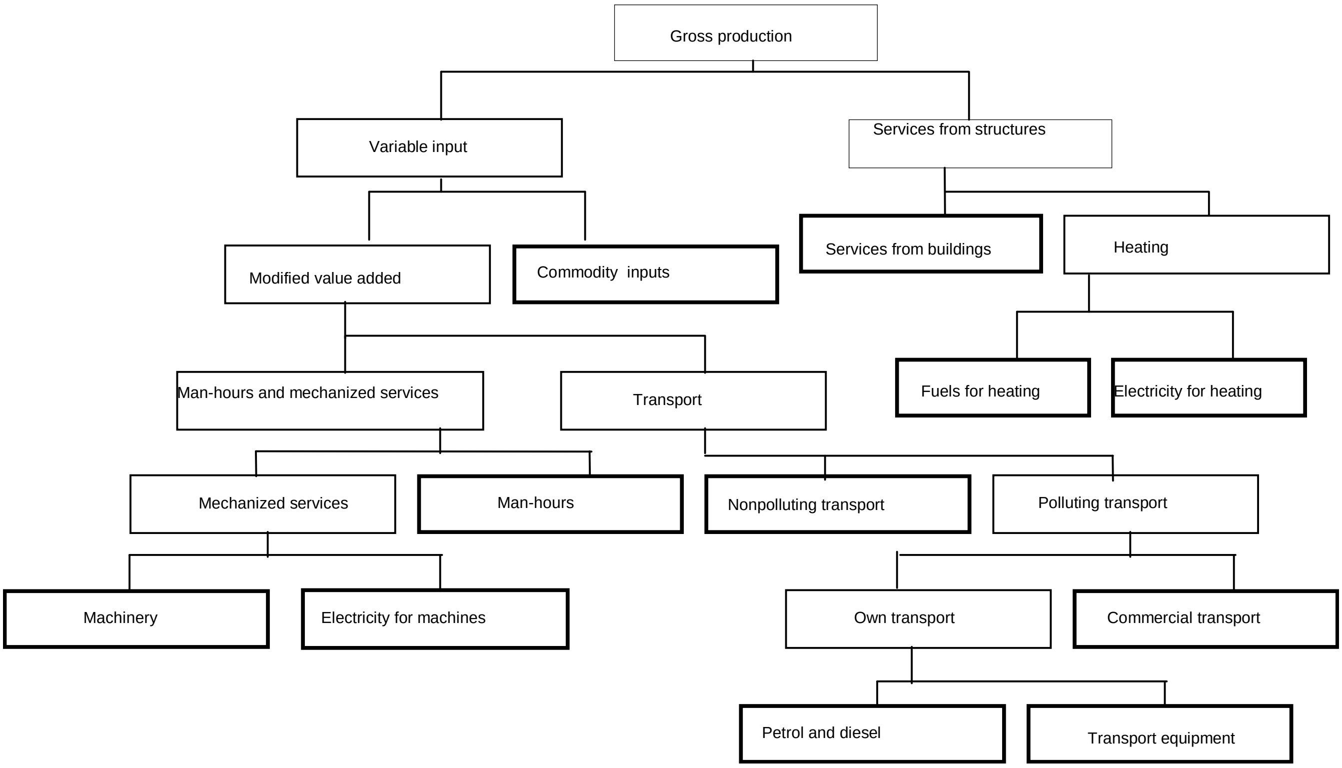


Figure A2: The separable factor use structure of the firms in MSG-6



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ISSN 0809-733X

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