Kaushal, Kevin R.; Yonezawa, Hidemichi

Book

Increasing the CO2 tax towards 2030 : impacts on the Norwegian economy and CO2 emissions

Statistisk sentralbyrå
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Increasing the CO_2 tax towards 2030

Impacts on the Norwegian economy and CO_2 emissions

TALL SOM FORTELLER

Kevin R. Kaushal and Hidemichi Yonezawa

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Preface

In this report we study the effects of the increased CO_2 tax under non-ETS. Specifically, it reaches NOK 2 000 per tonne of CO_2 in 2030. We apply the SNOW-NO model (Statistics Norway's World model – Norway), which is a numerical general equilibrium model where Norway is modelled as a small, open economy that trades with the rest of the world at given world market prices.

The project is financed by the Ministry of Finance.

Statistics Norway, 26 September 2022

Linda Nøstbakken

Abstract

In this report we study the effects of the increased CO_2 tax under non-ETS (specifically, reaching NOK 2 000 per tonne of CO_2 in 2030). We apply the SNOW-NO model (Statistics Norway's World model – Norway), which is a numerical general equilibrium model where Norway is modelled as a small, open economy, while the rest of the world is reduced to imports and exports. The model represents the Norwegian economy, with 46 producing sectors and various household and public consumption sectors.

The analysis examines long-run macroeconomic impacts. We assess the macroeconomic impacts relative to a long-run projection where current policies in 2022 are extended to 2030. Our results show that the macroeconomic impact of a NOK 2 000 CO_2 tax on the non ETS sectors in 2030 is modest. However, the CO_2 emissions could be reduced by approximately 9 percent in the non-ETS sectors compared to the reference scenario with the current level of CO_2 tax in 2022. The effect would be smaller if the road transport related sectors are exempted or partly excluded from this increase of the CO_2 tax.

Whether we transfer the extra revenues from the CO_2 tax through lump-sum to the household or through reduced labour income tax rate matters. The latter reflects an efficiency improvement for the economy due to the existing labour income tax.

Sammendrag

Denne rapporten studerer effektene av en økt CO_2-avgift i de ikke-kvotepliktige sektorene (som vil nå 2 000 kroner per tonn CO_2 i 2030). Vi bruker SNOW-NO-modellen (Statistisk sentralbyrås verdensmodell – Norge), som er en numerisk generell likevektsmodell der Norge er modellert som en liten åpen økonomi, mens resten av verden er representert ved import til og eksport fra Norge. Modellen representerer norsk økonomi, med 46 produserende sektorer og ulike husholdnings- og offentlige konsumsektorer.

Analysen vurderer de langsiktige makroøkonomiske konsekvensene. De makroøkonomiske virkningene måles i forhold til en økonomisk framskrivning hvor all gjeldende politikk antas å bli forlenget til 2030. Våre resultater viser at den makroøkonomiske effekten av en CO_2-avgift på 2 000 kroner i ikke-kvotepliktige sektorer i 2030 er beskjedne. Imidlertid vil CO_2-utslippene kunne reduseres med omtrent 9 prosent i ikke-kvotepliktige sektorer sammenlignet med et referansescenario med dagens nivå på CO_2-avgift i 2022. Effekten vil være mer moderat dersom veitransport sektorene fritas eller delvis ekskluderes fra økningen i CO_2-avgiften.

Hvorvidt vi overfører de ekstra skatteinntektene fra CO_2-avgiften gjennom et engangsbeløp til husholdningene eller som redusert skattesats på arbeidsinntekt, har stor betydning for de makroøkonomiske effektene. Sistnevnte alternativ reflekterer en effektivitetsforbedring for økonomien på grunn av den eksisterende skatten på arbeidsinntekt.

Contents

1. Introduction

The Norwegian climate policy targets towards 2030 are specified separately for the emission sources covered by the emission trading system (ETS) of the EU and those not covered (non-ETS) (Fæhn et al, 2020). The purpose of the project is to study the effect of increasing a CO_2 tax in the non-ETS sectors, reaching NOK 2 000 per tonne of CO_2 in 2030. The CO_2 tax will impact the Norwegian macroeconomy, industrial pattern and greenhouse gas emissions.

We apply Statistics Norway's SNOW-NO model, a computable general equilibrium (CGE) model of the Norwegian economy, with 46 producing sectors and various household and public consumption sectors. The study uses the model with the newly updated base year of 2018. The CO_2 tax is increased gradually from year 2023 to 2030. The analysis focuses on the impacts in 2030.

In a stylised economic model without market interventions and imperfections, the uniform CO_2 tax imposed on all relevant sources would enable any emission reduction to be achieved at the lowest possible cost. The SNOW-NO model incorporates many of the complexities that can be found in the real-world for Norwegian economy (e.g., the existing policies including various types of taxes and subsidies). We identify both the sectorial and macroeconomic impacts of such a policy in 2030 for Norway.

Fæhn et al, (2020) analysed the macroeconomic impact of an emissions target as reducing all GHG in the Norwegian non-ETS sector by 50 per cent compared to 2005, by 2030. This study focuses on the impact of CO_2 emissions. Further, as opposed to an emission target in 2030, this study analyses the impact of introducing a NOK 2 000 (in 2022 prices) CO_2 tax per ton of CO_2 in 2030. While the former study used a previous version of the SNOW-NO model, this study uses the latest version with the explicit choice of electric vehicles - in both private and commercial transportation, as well as biofuel. Finally, the emission projection we use in this study is consistent with the latest projection made by the Ministry of Finance.

Four counterfactual scenarios are studied with different assumptions for the CO_2 tax implementation. They are differentiated by two aspects: 1. The way of returning the extra revenue from the increased CO_2 tax; 2. Partial exemption of the increased CO_2 tax for road transport sectors. Specifically, two scenarios involve a lump-sum transfer to the household for the extra revenues, while in the other two scenarios the extra revenue is recycled back to households by reducing the labour tax rate. A taxation of labour income will distort the supply of labour. The higher the tax, the larger the distortion (Keane, 2011; Mertens and Ravn, 2013; Fæhn et al, 2020; Bye et al, 2021). The two "recycling" scenarios will show how recycling may counteract existing tax wedges, often called a "double dividend" in the economic literature (Goulder, 1995).

2. Framing of the analysis

We obtain a representation of how the future Norwegian economy may be affected by the NOK 2 000 CO_2 tax on non-ETS emissions by comparing scenarios where additional climate policies are implemented with a reference scenario. For all the counterfactual scenarios, the CO_2 tax gradually increases toward NOK 2 000 (in 2022 prices) from 2023 to 2030. The CO_2 tax is imposed on all the non-ETS CO_2 emissions. In a stylised economic model without market interventions and imperfections, the uniform CO_2 tax imposed on all relevant sources would enable any emission reduction to be achieved at the lowest possible cost.

This study presents five scenarios: (i) A reference scenario (REF) that is consistent with the projection made by the Ministry of Finance and used in the National Budget for 2023. This is the business-as-usual scenario, and the CO_2 tax is unchanged from 2022 onward; (ii) an increase in the CO_2 tax where the extra revenue is returned as lump-sum transfer to the households (CT); (iii) an increase in the CO_2 tax where the extra revenue is returned through reductions in the tax on labour income (CT_LAB); (iv) an increase in the CO_2 tax, except for road transport where the increase is limited to 50 pct. of the increase for other sectors, and the extra revenue is returned as lump-sum transfer to the households (CT_ROAD); and (v) a scenario where we combine (iii) and (iv) and the extra revenue is retuned as lump-sum transfer to the households (CT_ROAD_LAB).

In addition to the main counterfactual scenarios, we apply two more scenarios to test the robustness of the results. In these two scenarios, the CO_2 tax increase in road transportation is unchanged from 2022, as opposed to the other counterfactual scenarios where the CO_2 tax gradually increases from 2023 to 2030. Moreover, also here we have scenarios with both lump-sum recycling to the household and reduced labour tax rate.

We measure the effects of the climate policy as the differences between the REF scenario and the counterfactual scenarios. The analysis focuses on 2030 results. Note that in all the counterfactual scenarios we only consider the impacts of a unilateral CO_2 tax in Norway. Hence, the assumptions about the rest of the world are unchanged.

3. Model description – the SNOW model

The SNOW model for the Norwegian economy (SNOW-NO) is a recursive dynamic computable general equilibrium (CGE) model developed by Statistics Norway (for a detailed description, see Rosnes et al, 2019). SNOW-NO is used for simulating long-run projections by the Ministry of Finance. The model can be used to project the Norwegian economy from a calibrated base year to an equilibrium in each year ahead by choosing values of parameters. In 2021, the model was updated from a 2013 base year to 2018 and based on the National Accounts data base (by social accounting matrices) and emissions accounts from Statistics Norway. In SNOW-NO, Norway is modelled as a small open economy with extensive trade, while the rest of the world is represented only by exports and imports with Norway.

The economy in SNOW-NO consists of households, private production sectors, governmental and municipal industries and a public sector. Households and the production sectors are modelled as representative agents in the economy. The primary factors such as labour, capital and natural resources generate income for the household sector. The public sector receives all tax revenues, pays subsidies to the representative agents and transfers the net-tax revenues to the households. The recursive dynamic model keeps track of household savings and companies' investment decisions from year-to-year.

The model specifies 46 production sectors with one representative producer in each sector.[1] The representative producer in each sector minimises costs subject to a technology constraint in each period. The technologies are described by nested Constant Elasticity of Substitution (CES) functions, where combinations of capital, labour, energy and various intermediate products are input factors in production. The production technologies are modelled such that the inputs are to some extent substitutable with each other. The demand for input factors follows from the cost minimisation by the companies. For a more detailed description of the production and consumption functions, see Lindholt (2019) and Rosnes et al (2019).

Labour and capital are assumed mobile between domestic sectors. The model specifies three types of capital (building and construction; machinery and equipment; means of transport). The amount of capital flow is given in the base year and then projected in line with domestic investment, which in turn is determined by the savings of the households in each period. The households endogenously determine their time used on work or leisure. As a result, labour supply is endogenous in each period. As there is no sluggishness in the model, labour and capital can instantly move from one sector to another, e.g. to a more profitable one.

All goods and services consist of substitutable imported and domestically produced variants. The substitution elasticity defines the heterogeneity between domestically produced and imported variants. Similarly, production consists of one variant for export and one for the domestic market. The export volume of the firms is determined by exchange rates and market prices in the constant elasticity of transformation (CET) function.

World market prices are exogenously given. Factor prices and prices of domestic deliveries are all determined by the equilibrium in the domestic market. Together with a given balance of payments, the real exchange rate that is consistent with domestic consumption will be determined. All prices in the model are reported as real prices.

The GHG emissions in SNOW-NO include CO_2, methane (CH_4), nitrous oxide (N_2O) and fluorinated greenhouse gases (HFC, PFC, SF_6 and NF_3). The model also includes other emissions to air (NOx, SO_2,

[1] For details, see Appendix A

NH_3, NMVOC, PM_{10} and $PM_{2.5}$). The model represents emissions from both energy use and industrial processes. Energy-related emissions are linked in fixed proportions to the use of fossil fuels, with coefficients differentiated by the specific carbon content of the fuels. The emission coefficients are determined by base year values but can be adjusted by changing productivity parameters. Abatement of energy-related emissions can be brought about by fuel switching (including substitution of conventional fuels for biofuels), substitution of other goods for energy, or by scaling down production and/or final consumption, as well as substitution of conventional cars for electric vehicles. Abatement of process emissions by means of existing production technologies can only be brought about by reducing output.

The description of the government's climate policy instruments is relatively detailed. It includes CO_2 taxes, national and international quota systems, as well as free quotas, subsidies and compensation schemes for companies. In the present study we focus on the non-ETS emissions. For a detailed description, see Fæhn et al (2020) and Rosnes et al (2019). For the categorization of relevant sectors in this analysis, see Appendix A.

4. The Increased CO_2 tax in 2030

This section reports the main changes in macroeconomic variables and emissions of the counterfactual scenarios with increased CO_2 tax for non-ETS sectors, see Section 2.[2] In particular, we emphasize on the sectors with significant impact by the increased CO_2 tax. All the results are reported as % change from the reference scenario (REF) in year 2030.

Table 4.1 lists changes in the main macroeconomic indicators in 2030.

Table 4.1 The macroeconomic effects from the reference scenario in 2030, in percentage change

	CT	CT_LAB	CT_ROAD	CT_ROAD_LAB
Leisure	0.0	-0.2	0.0	-0.2
Private consumption	-0.4	-0.3	-0.1	0.0
Welfare	-0.3	-0.2	-0.1	0.0
GDP	-0.1	0.0	-0.1	0.0
Non-ETS CO_2 emissions	-9.3	-9.3	-4.4	-4.4
Total CO_2 emissions	-4.0	-4.0	-1.9	-1.9
Non-ETS GHG emissions	-5.7	-5.7	-2.8	-2.7
Total GHG emissions	-3.2	-3.2	-1.6	-1.5

CT is the scenario where the extra tax revenue from the CO_2 tax is returned as lump-sum transfer to the households. CT_LAB is the scenario where the extra tax revenue from the CO_2 tax is returned through reductions in the tax on labour. CT_ROAD is similar to CT, except for road related sectors where the increase is limited to 50 pct. of the increase for other sectors. Finally, CT_ROAD_LAB is the scenario where we combine CT_LAB and CT_ROAD, where the extra revenue is retuned as lump-sum transfer to the households.

The households can choose between consumption or leisure. This choice further affects the supply of labour in the economy. In general, an increase of CO_2 tax tends to lower the economic activities and thus the demand of labour, leading to the reduction of wage. Reduced wage will further increase the leisure. On the other hand, a CO_2 tax tends to reduce the capital return more than wage because the affected sectors are often capital intensive. This could in turn lead to an increase of wage, and thus less leisure. Table 4.1 suggests that the CO_2 tax with lump-sum transfer to the households has no significant effect on the leisure (CT and CT_ROAD), as these effects cancel out. If the CO_2 tax instead leads to reduce the labour tax (CT_LAB and CT_ROAD_LAB), then the labour supply is increased, and leisure goes down by 0.2% compared to the REF scenario.

The higher CO_2 tax reduces the households income leading to less consumption, since the tax distorts the combination of the consumption commodities and of production inputs (as exchange of the emission reduction). The higher CO_2 tax leads to the price increase of the refined oil products as well as the price increase of the goods and services that consume refined oil products (e.g., land transport). Thus, the substitution of these goods and services occurs and their demand goes down. For example, the substitution occurs from the internal combustion vehicles to electric vehicles, from private driving to public transport, and from transport activities to other types of consumption.

On the other hand, lower income tax rate would lead to more consumption as the labour supply (that is discouraged because of the existing labour tax) and the income are increased (CT_LAB and CT_ROAD_LAB). Table 4.1 suggests that household consumption is reduced in all the scenarios except for the CT_ROAD_LAB, where the consumption is unchanged. Moreover, the decrease in

[2] Note that the CO_2 tax in the reference scenario is unchanged from 2022 onward

consumption is less in the scenarios with an income tax decrease rather than those with a lump-sum transfer to the household.

The household's welfare consists of consumption and leisure.[3] In sum, the household's welfare decreases in all scenarios.[4] As Fæhn et al. (2020) shows, the welfare impact is improved when we reduce the tax on labour income. Since the distortion of the labour income tax (as the undersupplied labour time) is softened, the efficiency is increased. However, it is important to remember that the welfare measure here does not account for reduced emissions in the economy.

The same efficiency improvement of the reduced labour income tax is applied on the impact on GDP. The scenarios with the reduced labour income tax has less of a negative impact on the GDP than the others. However, unlike the welfare impact, it is also because the negative effect falls on the reduction of leisure, which is not captured by the GDP. Table 4.1 suggest that the effect is only marginal on the GDP.

As for the economy wide emission reduction, Table 4.1 suggests that the greenhouse gas (GHG) emission reduction would be similar, whether we introduce the lump-sum transfer to the households or reduce the labour tax. In the CT_ROAD and CT_ROAD_LAB, the emission reduction is more than halved due to the CO_2 tax for road transport being limited to 50 pct. of the increase for other sectors. This is mainly due to the road transport being a major emitter in the economy.

Table 4.2 Sectorial CO_2 emission for major emitters with more than 0.05 million tonne reduction, percentage change relative to REF in 2030

	CT	CT_LAB	CT_ROAD	CT_ROAD_LAB
Land transport[1]	-12	-12	-2	-2
Gasoline and Diesel[1]	-22	-22	-5	-5
Fishery	-12	-12	-12	-12
Construction	-7	-7	-7	-7
Wholesale trade[1]	-8	-8	-2	-2

[1] Road transport related sectors where CO_2 tax increase is smaller in the CT_ROAD and CT_ROAD_LAB scenarios

Table 4.3 Activity[1] volume for the main emitters in 2030, percentage change relative to REF

	CT	CT_LAB	CT_ROAD	CT_ROAD_LAB
Land transport[1]	-0.8	-0.8	-0.2	-0.1
Gasoline and Diesel[1]	-13.3	-13.2	-3.2	-3.2
Private transport activity	-0.7	-0.6	-0.2	-0.1
Fishery	-3.2	-3.2	-3.5	-3.5
Construction	-0.2	-0.1	-0.1	0.0
Wholesale trade[1]	0.1	0.2	0.1	0.2

[1] Activity is measured in real terms (at base-year prices) and consists of production in sectors and consumption in households.
[2] Road transport related sectors where CO_2 tax increase is smaller in the CT_ROAD and CT_ROAD_LAB scenarios

The sectorial emissions and the activity levels for the major emitters between the counterfactual scenarios are reflected in the sector-wise results of Tables 4.2 and 4.3. In general, the sectors with high emission intensities tend to have larger emission reductions, such as land transport, gasoline and diesel and fishery. The result of the scenarios of a 50 pct. CO_2 tax in the road related sectors compared to the other sectors suggests that the emission reduction of the road related sectors would be less than half, while the other sectors are not affected much.

The largest emission reduction in terms of change from REF can be found in the Gasoline and Diesel to the household. For use of Gasoline and Diesel in the household, the share of biofuel increases with higher CO_2 tax. This leads to more extensive use of biofuel in private transportation and thus

[3] The welfare impact in the counterfactual scenarios is measured as the equivalent variation, and it is shown as the percentage of the welfare in the reference scenario.
[4] For the scenario CT_ROAD_LAB, while the welfare impact is negative, it is smaller than 0.1%.

the use of gasoline and diesel level decreases less than the CO_2 emission reduction. As for the private transport activity, the total volume decreases with higher CO_2 tax due to relatively the higher cost of driving from the internal combustion vehicles. Moreover, the household increase their use of public transportation in the economy.

The land transport sector reduces its emission with 12%. The change in activity level for the same sector, however, remains moderate as the sector switches over from use of fossil fuel to biodiesel. Furthermore, the CO_2 tax increase the demand of EVs in the Land transport. Overall, the activity level decreases far less than the emission reduction from the same sector.

In general, the higher CO_2 tax leads to the substitution of emission intensive goods/services for less emission intensive ones for both households and production sectors. This leads to the positive impact on activity level for the latter sectors (e.g., service sectors and wholesale trade). That is why the wholesale trade increases in terms of activity level, although the emission is reduced because of the CO_2 tax increase. The construction sector results in moderate effect, since the emission intensity is not as high as transportation or fishery sectors.

Lastly, while the refined oil sector is one of the ETS sectors, the impact on this sector is worth mentioning. The reduced demand for fossil fuel, as a result of the CO_2 tax increase in non-ETS sectors, leads to a fall in both the production and emission by 5 %. Unlike the non-ETS sectors, the CO_2 tax in the refined oil sector is not increased, and instead, the lower demand causes the reduction of both production level and emissions in a similar manner. When the road related sectors are partly exempted from the CO_2 tax increase, the effect on emissions and activity level is approximately halved. One caveat of the emission reduction of refined oil sector is that since non-small share is exported to the rest of the world, emission reduction in Norway can lead to the increase in emission elsewhere (which is known as carbon leakage).

5. Sensitivity analysis

Initially, we presented the scenarios with a CO_2 tax increase toward NOK 2 000 in the road related sectors in 2030 (CT and CT_LAB), and scenarios with a 50 pct. CO_2 tax in the road related sectors (CT_ROAD and CT_ROAD_LAB). To test the robustness of the results, we perform a sensitivity analysis where road related sectors have zero growth in the CO_2 tax from 2022. The sensitivity analysis is performed with the assumption of (i) lump-sum recycling transfer to the household of the CO_2 tax revenues (CT_ROAD_ZERO) and (ii) revenue recycling through reduced labour tax (CT_ROAD_ZERO_LAB). All results are presented as percentage change from the reference (REF) scenario in 2030. The main results are listed in Table 5.1 to 5.3.

Table 5.1 The macroeconomic effects from the reference scenario in 2030, in percentage change

	CT_ROAD_ZERO	CT_ROAD_ZERO_LAB
Leisure	0.0	-0.1
Private consumption	0.0	0.1
Welfare	0.0	0.0
Non-ETS CO_2 emissions	-3.1	-3.0
Total CO_2 emissions	-1.3	-1.3
Non-ETS GHG emissions	-2.0	-1.9
Total GHG emissions	-1.1	-1.1

As expected, the impact on the macroeconomic indicator are limited when we assume no growth in the CO_2 tax for road related sectors. For leisure and private consumption, the effect is roughly half of the main counterfactual scenarios. The overall result on GDP and welfare is close to zero in both scenarios. The impact on emissions are smaller than in the main counterfactual scenarios, and less than half of CT and CT_LAB.

For the scenario CT_ROAD_ZERO_LAB, the welfare impact is slightly positive, although it is very close to zero (i.e., 0.01%). This is because the transportation fuels are taxed by both CO_2 tax and road usage tax, although the transportation fuels and other fuels have the same climate impact per CO_2 emissions. In other words, the exemption of road transport in the CO_2 tax increase leads to more uniform emission taxation, which contributes to some efficiency improvement. This effect is also observed in the case of shifting the emission reduction from non-ETS to ETS sectors in EU in a numerical simulation model in Abrell et al. (2019). However, as Santos et al. (2010) describes, road transport has other negative externalities (e.g., local pollutions and congestion) than climate impact, and thus the double taxation can be justified from those aspects.

Table 5.2 Sectorial CO_2 emission for major emitters with more than 0.05 million tonne reduction, percentage change relative to REF in 2030

	CT_ROAD_ZERO	CT_ROAD_ZERO_LAB
Fishery	-12	-12
Construction	-7	-7

Table 5.3 Activity volume for the main emitters in 2030, percentage change relative to REF

	CT_ROAD_ZERO	CT_ROAD_ZERO_LAB
Land transport[1]	-0.1	0.0
Private transport activity	0.0	0.1
Fishery	-3.5	-3.5
Construction	-0.1	0.0
Wholesale trade[1]	0.1	0.2

[1] Road related sectors where CO_2 tax increase is smaller in the CT_ROAD and CT_ROAD_LAB scenarios

As for the sectorial changes, Table 5.2 and 5.3 show that all the road related sectors have only small to marginal impact compared to the REF scenario. The emission reduction in the road related sectors are zero in both the sensitivity scenarios and the private transport activity actually increases in the CT_ROAD_ZERO_LAB scenario. As for the other activity levels, only land transport and wholesale trade have significant changes. The latter still benefits of its relative low emission-intensity, resulting in a positive change. As for fishery and constructions, the change in activity is quite similar to the main results from CT_ROAD and CT_ROAD_LAB.

6. Concluding remarks

In this study we have analysed a CO_2 tax of NOK 2 000 per tonne of CO_2 in 2030, and its impact on the Norwegian economy and emissions. The CO_2 tax increase is compared to a reference scenario consistent with the projection made by the Ministry of Finance, where the CO_2 tax is unchanged from 2022 onward. The Norwegian climate policy targets towards 2030 are specified separately for the emission sources covered by the emission trading system (ETS) of the EU and those not covered (non-ETS). The CO_2 tax is imposed on all the non-ETS CO_2 emissions. The CO_2 tax will impact the Norwegian macroeconomy, industrial pattern and greenhouse gas emissions. We apply Statistics Norway's SNOW model, a computable general equilibrium (CGE) model of the Norwegian economy, with 46 producing sectors and various household and public consumption sectors.

We compare four main counterfactual scenarios with the reference scenario that is consistent with the projection made by the Ministry of Finance. We assume that the extra revenue from the CO_2 tax is returned as a lump-sum transfer to the households in two of the scenarios. For the remaining two, we assume revenue recycling through reduced labour tax rate. Two of the scenarios assume a 50 per cent CO_2 tax in the road related sectors, i.e., a CO_2 tax of NOK 1 000 per tonne of CO_2.

The macroeconomic impact of such a CO_2 tax is moderate. Specifically, we examine them by comparing the GDP, leisure/labour supply, private consumption and welfare with the reference scenario. For the Norwegian emissions, we find that a CO_2 tax of NOK 2 000 could reduce the emission by more than 9 per cent in 2030, compared to the reference scenario. If the road related sectors are partly exempted, the CO_2 emission reduction would be approximately halved.

The sectorial effect of the CO_2 tax suggests that the households consumption of gasoline and diesel and the production of land transport would be the major emission reduction contributors, with up to 17 per cent emission reduction compared to the reference 2030. However, the impact on private transport activity and the land transport sector would be modest because of more extensive use of electric vehicles and biofuel. By partly exempting these sectors, the effect becomes smaller.

Another finding in this analysis is that existing tax distortions have an impact on the social costs of climate policies (Fæhn et al, 2020; Bye et al, 2021). In particular, the scenarios with recycling of the CO_2 tax revenue through reduced labour tax rate would have less negative impact on the economy. By counteracting other existing tax wedges, our findings suggest that this revenue recycling method could be an efficiency improvement to the economy as well. However, the emission reductions are not the same in the scenarios with lower CO_2 tax increase in the road related sectors. In other words, lower CO_2 tax gives lower emission reductions and hence the efficiency is not comparable.

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Appendix A: Classification of relevant sectors in SNOW

Table A1 Categorization of relevant sectors in SNOW-NO

Description	Sectors (see Rosnes et al., 2019)
Road related sectors	Land transport nec (not elsewhere classified); consumption of petrol and diesel; wholesale trade;
Other household consumption	Paraffin and heating oil; furnishings & household equipment and routine household maintenance; gas; fuel wood & coal etc.
Rest of non-ETS sectors	Agriculture; forestry; fishing; minerals nec; water; business services nec; defence; public administration (central) education, health, etc; recreational and other services; communications; private education, health, etc; insurance; financial services nec; dwellings; vegetable oils and fats; food products nec; beverages and tobacco products; metal products; dairy products; textiles, wearing apparel; leather products; wood products; motor vehicles and parts; manufactures nec; transport equipment nec; machinery and equipment, incl. electronic equipment; fuel wood, coal etc; construction; gas manufacture, distribution; waste (public); waste (private); water transport;
ETS sectors	Crude oil and gas; refined oil products & chemicals industry; non-metal minerals; iron and steel; non-ferrous metals; paper products, publishing; air transport; electricity

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