Discussion Papers
Statistics Norway
Research department
No. 743
May 2013

Statistics Norway

Statistisk sentralbyrå

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Are tax exemptions for electric cars an efficient climate policy measure?

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Abstract:
This study finds that the welfare gain, excluding environmental effects, generated by increasing the Norwegian tax rate on purchase of electric cars from 8 to 37 percent amounts to approximately 5500-6500 NOK (or 680-820 euro) per ton increase in GHG emissions in the long run. Substantial tax exemptions implies that reallocation from electric cars towards petrol and diesel powered cars generates a tax revenue gain of more than 40 billion NOK, which amounts to almost 10 percent of government consumption in 2007.

Keywords: Taxation, Electric cars, CO_2 emissions

JEL classification: Q54, R48, H23

Acknowledgements: I wish to thank Erling Holmøy, Mads Greaker and Knut Einar Rosendahl for valuable discussions and comments on earlier drafts.

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ISSN 0809-733X
Print: Statistics Norway

Sammendrag

I Norge selges det flere elbiler per innbygger enn noe annet land i verden. En av årsakene er de gode vilkårene forbundet med kjøp og bruk av elbiler, kombinert med høye skattesatser på kjøp av konvensjonelle biler og drivstoff. Denne studien kvantifiserer samfunnsøkonomiske gevinster forbundet med å delvis fjerne de gunstige skatterabattene forbundet med kjøp av elbiler, og finner at en økning i dagens Norske skatt på å kjøpe/ eie en elbil fra 8 prosent til 37 prosent gir en velferdsgevinst på omlag 5500-6500 Norske kroner per tonn økning i utslippet av karbondioksid gasser på lang sikt. Anslaget forutsetter at elbiler drives av elektrisitet som ikke gir utslipp av klimagasser. Velferdsgevinsten blir betytlig høyere hvis det forutsettes at produksjon av elektrisitet fører til utslipp av klimagasser. Anslaget inkluderer ikke eventuelle gevinster forbundet med forbedringer i miljøet. Anslag på gevinsten av å redusere utslippet av klimagasser med et tonn variere fra 34 til 780 NOK ifølge US Environmental Protection Agency. Den gunstige beskatningen av elbiler i Norge er derfor et svært kostbart tiltak for å få ned utslippet av klimagasser. Reformen innebærer også at skatteinntektene til staten øker med over 40 mrd per år på lang sikt i faste 2005-priser. Årsaken er at husholdningene i større grad velger høyt beskattede bensin og diesel biler fremfor lavt beskattede elbiler. Velferdsgevinstene forbundet med å øke skatten på kjøp av elbiler til 84 prosent, som var gjennomsnittlig skattesats på kjøp av diesel biler i 2007, utgjør omlag 4500-4800 kroner per tonn økning i utslippet av karbondioksid gasser på lang sikt. Analysen fokus er på de langsiktige effektene av endringer i beskatning av elbiler. Studien ekskluderer momenter som er relevant for elbilens rolle i dagens samfunn. I analysen antas det blant annet at eksisterende gunstige ordninger forbundet med bruk av elbiler, som kjøring i kollektivfeltet, gratis parkering og lading, samt fritak fra å betale bompenger, fases ut. Studien forsøker ikke å belyse de kortsiktige effektene av endret beskatning av elbiler.

1. Introduction

Governments in several countries have introduced tax exemptions for purchase of electric cars, see the European Automobile Manufacturers' Association (2010). Such tax exemptions contribute to lower green house gas (GHG) emissions by distorting consumers' choice between electric and conventional cars. This study shed light on this trade off by quantifying the welfare impact of such distortions, and by comparing this welfare impact with estimates of the social cost of carbon.

The literature on optimal environmental taxation show that taxes should be levied on goods that generate external damage, see Sandmo (1975), and several studies argue that tax rates should be set equal to the social marginal damage, see Bovenberg (1999) and Jacobs and de Mooij (2011). Hence, tax rates equivalent to externalities connected to greenhouse gas emissions and other local external effects connected to consumption of petrol and diesel, see Parry (2007b), is optimal according to this literature. General climate policy measures are however expected to have a modest impact on the transition towards more climate friendly cars, see Devogelaer and Gusbin (2010). Several countries have however choosen to implement tax exemptions for electric cars to boost the transition towards electric cars. Two studies find that this transition towards electric and plug-in hybrid cars leads to substantial reductions in GHG emissions, and that abatement costs are competitive. Pasaoglu et al. (2012) show that biofuel blends, hybrid cars, electric cars and fuel cell vehicles can decrease future well to wheel GHG emissions within the EU by 35 to 57 percent. The cost increase for vehicle owners can become acceptable as technological advances through learning reduces costs. Thiel et al. (2010) show that electrification of the vehicle fleet offer significant possibilities to reduce GHG emissions when adequate policies decarbonise the electricity generation[1]. The initial cost is substantial, but can decrease in later periods to very competitive CO2 abatement costs. These abatement costs are calculated by comparing the cost of electricity powered cars with the cost of conventional cars. This method, however, ignore welfare costs attached to preferences for attributes like maximum range and charging/ refueling time, which differ between electric and convensional cars. Substantial Norwegian tax exemptions and benefits for electric cars, combined with a modest market share for electric cars, suggest that such differences are important to consumers. The method also neglects to consider how tax exemptions and other policy insentives influence the welfare costs associated with distortions in consumers' choice between electric and conventional cars. Ignoring welfare costs directly linked with such policy instruments limits these studies from conducting convincing analysis of welfare impacts of tax exemptions and other policy incentives for electric cars.

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[1] Hawkins et al. (2012) and Econ (2008) also show that a decarbonisation of the electricity generation is required to acheive emission reductions.

The present study contributes to the literature by quantifying the welfare gain per ton increase in GHG emissions of reducing the current favourable tax exemptions levied on electric cars in Norway. The analyses consider several aspects likely to influence the welfare gain of reducing these exemptions. Tax exemptions on electric cars are in many cases levied on purchase of the car, see the European Automobile Manufacturers' Association (2010), and by taxing consumption of electricity more leniently than consumption of petrol and diesel, see Eurostat (2007). Both these tax wedges are likely to distort consumers' choice between electric and conventional cars as individuals take account of the tax on fuels when they buy a car, see Heldal et al. (2009). The present study considers both of these tax exemptions. Electric cars are also likely to become closer substitutes to petrol and diesel powered cars in the future. Taxing close substitutes with different rates is likely to generate substantial welfare costs according to Hatta and Haltiwanger (1986). Such taxation creates considerable distortions as consumers substitute towards the low tax good. This substitution effect also contributes to reduce tax revenue generated as the tax base of the high tax good is reduced. The present study analyses how these features affect the welfare gain of reducing tax exemptions levied on electric cars in Norway. A tax increase on purchase of electric cars is implemented into a model framework where cars which run on different types of fuels are treated as strong substitutes, see Bjertnæs et al. (2011). The Norwegian case is interesting because Norway is the only country in the world with a sizable stock of electric cars relative to the population even though the market share for electric cars is modest[2]. Heavy taxation of petrol and diesel powered cars combined with favourable taxation/ treatment of electric cars, see Econ (2009), Rasmussen (2011) and Bjertnæs et al. (2011), have contributed to place Norway in the lead of the transition towards electric cars. This has made it possible to calibrate the model to this stock of electric cars, with current tax exemptions implemented.

A baseline policy scenario is analysed where increased consumption of fuels contributes to increase emissions, while electric cars generate zero emissions. Computer simulations unveils that the welfare gain of increasing the tax rate on purchase of electric cars from 8 to 37 percent amounts to approximately 5500-6500 NOK per ton increase in GHG emissions when initial percentage tax rates are; 167 on petrol, 119 on diesel, 52 on electricity, 93 on petrol cars, 37 on plug-in hybrid cars, and 84 on diesel cars. All tax rates are unchanged in all future periods, and lump-sum transfers are adjusted to satisfy the government budget constraint. This welfare gain amounts to almost 1 percent of current (2007) GDP, while the increase in the emission of GHG's is less than 10 percent of current (2007)

[2]The number of electric cars per inhabitant in Norway is substantially larger than the number of electric car per inhabitant in any other country in the world. The market share of electric cars in Norway, however, only amounts to 2.8 percent while the market share in Western Europe equals 0.2 percent according to AID/ Industry Sources.

emissions[3]. The substantial tax wedge implies that reallocation from climate friendly cars towards petrol and diesel powered cars generates a tax revenue gain of more than 40 billion NOK each year in the long run, which amounts to almost 10 percent of government consumption in 2007. The welfare gain of increasing the tax rate on purchase of electric cars from 8 to 84 percent, amounts to approximately 4500-4800 NOK. The welfare gain per ton is somewhat more modest in this case as the reform lowers the distorting tax wedge between conventional and electric cars even more in this case. These welfare gains increases substantially when electric cars are assumed to run on electricity produced with the current emission intensive European mix. The social cost of carbon reported by the US Environmental Protection Agency range from 34 to 780 NOK per ton. Hence, welfare gains per ton increase in emissions by fare exceed the social cost of carbon.

The study further discusses how results are affected when crude assumptions in the baseline scenario are altered. The baseline scenario excludes emissions connected to extraction and refining of fossil fuels as well as emissions connected to production of electricity and cars. This assumption is appropriate because these production sectors are included in the current European quota trading system, EU ETS. Unilateral emission reductions within these sectors would only generate equivalent increases in other sectors within the EU ETS. The Norwegian transport sector is not included in the EU ETS. Hence, unilateral policy directed towards this sector is not hampered by these leakage problems. Emissions connected to production of cars and energy should however be taken into consideration if the EU ETS is terminated. The increase in emissions generated by removing tax exemptions for electric cars is reduced (increased) if emissions originating from production of electric cars and electricity are higher (lower) than emissions originating from production of conventional cars and fuels. Hence, this contributes to increase (reduce) the welfare gain per ton increase in emissions. Emissions connected to production of electricity might be reduced by energy policy that stimulates production of cleaner energy. Such energy policy may however also be costly for the society.

The study also conducts several sensitivity tests where uncertain parameter values are altered. Model simulatins show that changes in the substitution elasticity between cars and changes in the future stock of electric cars have a marginal effect on the result. Simulation results also show that the size of the initial tax wedge between electric and conventional cars is crucial for the result. The model framework is not designed to study short run impacts of changes in the taxation of electric cars. Relevant short run incentives like free public parking, which often includes charging free of charge, no road tax, access to

[3] Changes in emissions from production of cars and fuels is not included

drive in the bus line, as well as relevant transport options like public transport and use of bicycle, is excluded from the model framework. Hence, short run impacts are byond the schope of this study.

The background and policy scenarios are presented in section 2. The model is presented in section 3. Results and welfare effects are analysed in section 4 and 5, respectively. Section 6 concludes.

2. Background and tax reforms

Norway is competing with France and Germany to become the third largest electric car market in the world, behind U.S. and Japan. The number of electric cars sold per inhabitant in Norway by far exceeded the number of electric cars sold per inhabitant in any other country in the world in 2011, see Green car (2012). Table 2.1 presents tax rates on purchase of cars and fuels within the Norwegian tax system. These tax rates are calculated as a percentage of the producer price, and contain all indirect taxes levied on each of the goods including VAT. Note that the current tax levied on GHG emissions on fuels is incorporated into the tax rates on consumption of petrol and diesel. The tax on GHG emission was 0,8 NOK/litre petrol in 2007, while the average consumer price of 95 octane was 11,68 NOK/ litre that year. This tax amounts to 345 NOK/ton GHG emission.

Table 2.1. Present Norwegian tax rates

	Hybrid	Petrol	Diesel	Electricity	Hydrogen
Car purchase	37	93	84	8	8
Fuels		167	119	52	

Source: Statistics Norway: Energy account and National account

The tax rate on buying and owning an electricity powered car only amounts to 8 percent, while the tax rate on buying and owning petrol and diesel powered cars amounts to 93 and 84 percent, respectively. The tax rate on consumption of electricity equals 52 percent. The tax rate on petrol and diesel equals 167 and 119 percent, respectively. Favourable policy measures of electricity powered cars in the Norwegian economy includes: No tax on purchase, no VAT, reduced yearly tax, free public parking which often includes charging free of charge, no road tax, and access to drive in the bus line. Econ (2009) estimate that the value of the total subsidy wedge, including all policy incentives, in favour of electric cars relative to petrol and diesel powered cars in Norway amounts to 25-30.000 NOK/ ton CO_2. The present analyses, however, only includes favourable taxation as other policy measures are assumed to be removed as the stock of electricity powered cars is expanding.

The favourable taxation of electric cars in Norway may to some extent be designed to assist an infant electric car industry and/ or to trigger technological development of electric cars[4]. The present study does not analyse the relevance of these arguments as the main aim of the present study is the long term effect of favourable taxation. The long run aspect, however, seem to be highly relevant as environmentalists argue in favour of preserving the present favourable taxation even though the stock of electric cars expands substantially. A reference scenario is employed as a benchmark to compare two policy reform scenarios where tax favours are removed. In the reference scenario it is assumed that all tax rates are set equal to the rates of the current Norwegian tax system in all future periods, see table 2.1. Producer prices are also kept constant in all future periods. The policy reform scenarios consist of changing the tax rates levied on purchase of climate friendly cars according to table 2.2.

Table 2.2. Tax reforms

	Hybrid	Electric	Hydrogen
Reference	37	8	8
Middle	37	37	37
Uniform	84	84	84

Tax rates on purchase of electric and hydrogen powered cars are increased from 8 to 37 percent in the middle tax scenario. This scenario removes some of the favourable taxation of climate friendly cars in the Norwegian tax system. In the uniform scenario tax rates on purchase of hydrogen and electric cars are increased from 8 to 84 percent, while the tax rate on purchase of plug-in hybrid cars is increased from 37 to 84 percent. This scenario removes the favourable taxation on purchase of all climate friendly cars in the Norwegian tax system, while the current taxation of energy is unchanged. All tax rates in each scenario are kept constant in all future periods.

There are a range of external effects connected to automobiles that justifies taxation, see Parry et al. (2007a) and Econ (2003). One may speculate whether electricity powered cars will generate similar external effects as petrol and diesel powered cars. It is however hard to come up with good arguments why electricity powered cars should not generate the same external effects except for noise and emissions to air. Hence, other (external) effects like accidents, cueing, conspicuous consumption and free use of public roads is omitted from the analysis as a transition from electricity powered cars to petrol and diesel powered cars is assumed not to affect these types of externalities.

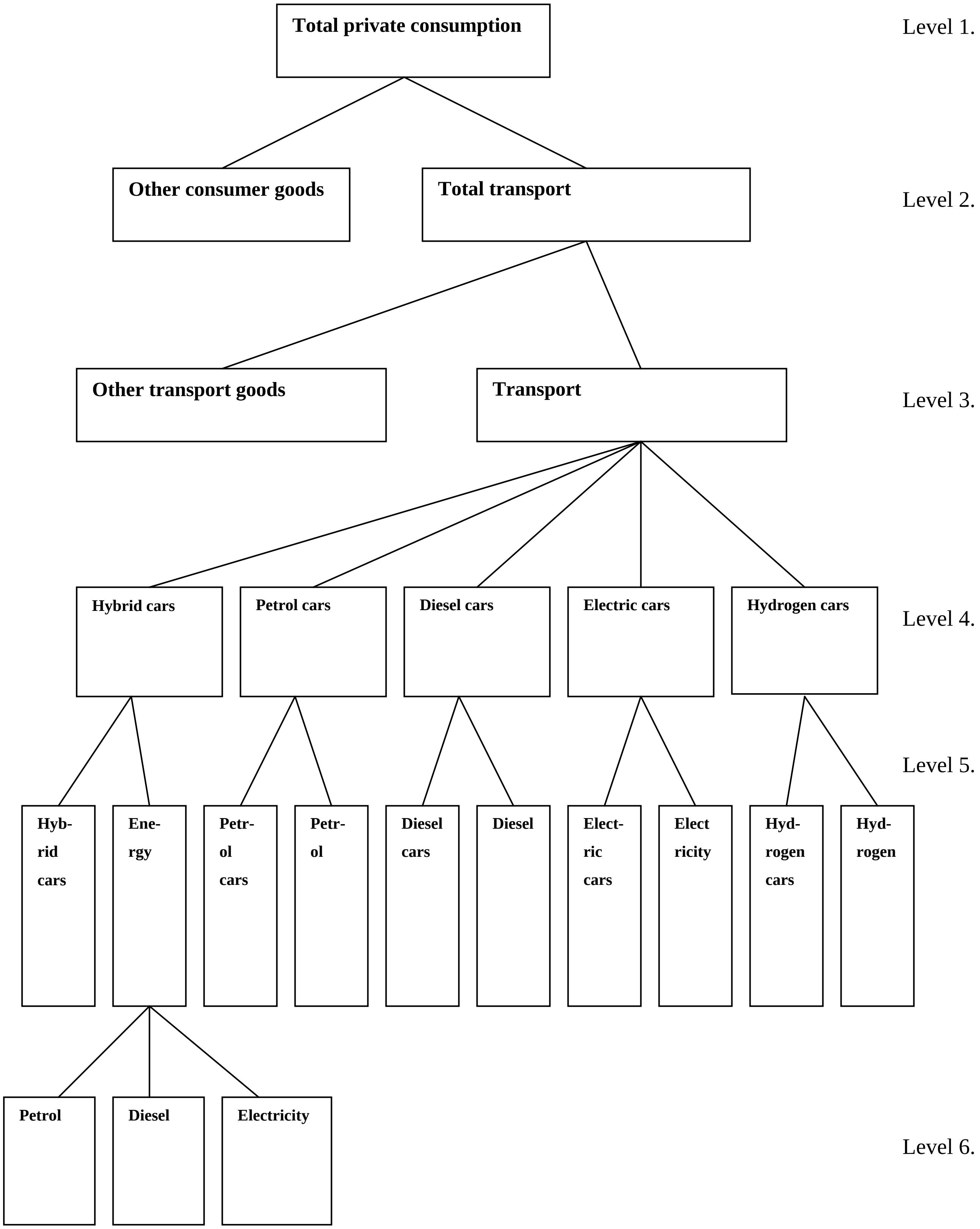
[4] Note that all Norwegian electric car manufacturers is bankrupt as of 2012.

3. The model

The decision to purchase a car constitutes a discrete choice where households and individuals choose between cars with a range of different attributes and prices. Households with heterogeneous preferences for attributes connected with cars which run on different types of fuel lead to differences in the willingness to pay for these cars. Falling aggregate demand functions can be constructed by sorting households according to willingness to pay. Such demand functions can be exploited to calculate the sum of consumer surplus across a number of consumers, see Varian (1999). These demand functions and consumer surpluses are analogous to demand functions and consumer surpluses which can be derived from a single consumer that maximizes utility. Hence, the choice of cars is constructed by assuming that a representative consumer with preferences for each type of car maximize utility with respect to purchase of each type of car and fuel, see Bjertnæs et al. (2011). The model contains five different types of cars which are powered by different types of fuels: Plug-in hybrid, petrol, diesel, electric and hydrogen cars. The different types of cars and fuels are incorporated into a nested CES (constant elasticity of substitution) -utility function. The representative consumer behaves as if prices including tax rates are exogenous. The consumer price of each consumer good equals a fixed producer price plus the tax rate levied on that good. The CES-utility function is illustrated in figure 3.1.

The utility function consists of six levels. Level 1 consists of total private consumption, which includes total expenditures on private transport and all other consumer goods. Level 2 consists of private households total expenditures for private transport. This level includes other expenditures like maintenance and spare parts as well as expenditures for private transport. These two components constitute level 3. Level 4 consists of expenditures for each of the five types of cars. Expenditures for each type of car, level 5, consists of a service flow from that stock of cars, and expenditures on fuels for that type of car. Level 6 consists of different types of fuels used for plug-in hybrid cars. The CES-utility function is chosen to be able to study different types of tax changes levied on purchase of different types of cars and fuels. The substitution elasticity between fuels employed for hybrid cars are zero to simplify the model. Assuming zero substitution between the service flow and use of fuel for each type of car implies that there are no tax distortions between buying and using a car in this model.

Figure 3.1. The CES-utility function



There is considerable uncertainty connected to the future elasticity of substitution between types of cars. Empirical studies are not likely to remove this uncertainty because the quality of future types of cars is unobservable today. The resent development in purchase of petrol and diesel powered cars however suggest that the substitution elasticity between types of cars is substantial. The substitution elasticity between operating expenditures for each pair of the different types of cars is assumed to increase to 8 in the long run in one scenario. Hence, differentiated tax rates generate substantial distortions in the allocation of types of cars in this model. A sensitivity test where the substitution elasticity among types of cars equals 3 is analysed to unveil whether results are sensitive to choice of substitution elasticity. The tax wedge between types of cars is determined by differences in tax rates levied on each type of car. This tax wedge consists of differences in tax rates on purchase of the car and on fuels. This modelling approach is justified by an empirical study which finds that consumers consider both prices on fuels and cars when they decide which type of car to buy, see Heldal et al. (2009). The substitution elasticity between other operating expenditures and total operating expenditures is assumed to be 0,4. The model does not incorporate substitution towards public transport and/ or walking and bicycling. Such substitution effects may alleviate substitution towards petrol and diesel cars as the tax on climate friendly cars are increased. The sensitivity test with lower substitution elasticity, however, unveils whether less substitution is important for the results derived. The current tax rates on purchase of petrol and diesel cars are calculated based on data from the National accounts. The tax rates on purchase of electric and hybrid cars are calculated by evaluating present tax rules and the quality of plug-in hybrid cars launched in 2011. The tax rates on fuels are calculated based on data from the energy accounts.

The budget of the representative consumer consists of a fixed income minus a direct lump-sum tax/ transfer. This after tax income finances the consumption of all consumer goods in each period. The government is assumed to consume a fixed amount of consumer goods. This consumption is financed by indirect consumer taxes and a direct lump-sum tax/ transfer. The government budget constraint is satisfied each future period by adjusting the lump-sum tax/ transfer levied on the representative consumer when tax reforms are introduced. The budget constraint of the representative consumer together with the government budget constraint implies that the fixed income of the representative consumer equals total consumption measured in producer prices. This is consistent with an economy where all income earned by the production sector is transferred to the representative consumer.

4. Policy analysis

4.1. The reference scenario

The reference scenario is constructed by calibrating total private consumption, other consumer goods and total expenditures on private transport to aggregates from National account, 2005. Expenditure on private transport is decomposed into purchase of cars and fuels for each type of car. A smooth development in purchase of petrol and diesel cars is implemented to improve the dynamic aspect of the model[5]. The development in the stock of electric cars is implemented by assessing relevant statistics and studies containing information about the future development. Total expenditures on private transport is growing by 2,5 percent on average each year in the period 2001 to 2006. This growth rate is incorporated into total expenditures on transport in the reference scenario together with a zero rate of inflation. The fuel consumption of cars has gradually decreased in the past. Future decreases is incorporated by assuming a technological growth of 0,8 percent each year for all types of fuels. GHG emissions from fuels can also be reduced by mixing petrol and diesel with biofuels. This is, however, not incorporated into the model framework.

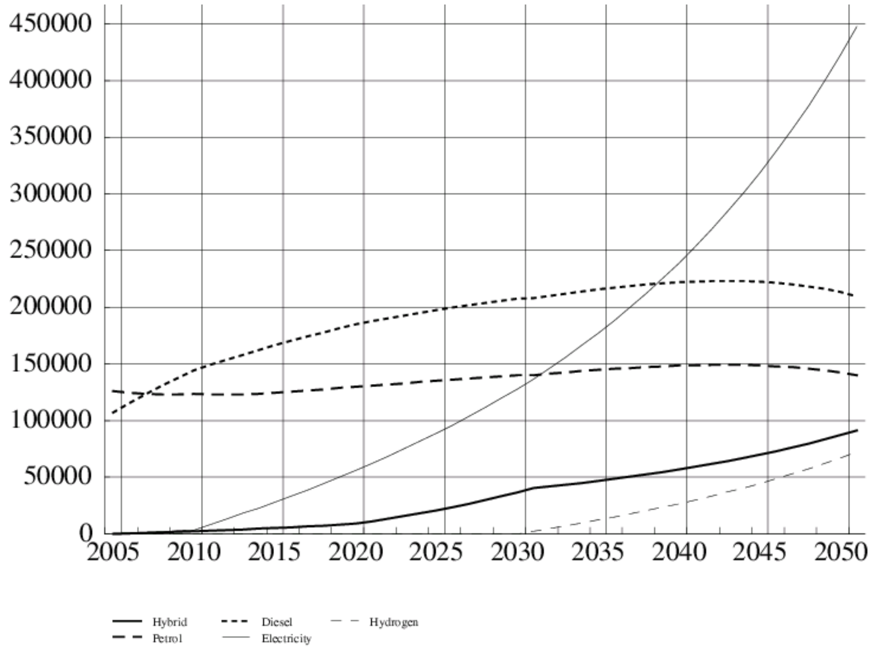
The development in the stock of each type of car is determined by the development of the CES cost-share of each type of car and the development of relative prices between cars, see appendix. The initial stock of each type of cars is determined by calibrating CES-cost-shares for each type of car. Expected technological improvements related to production and us of electric and hydrogen cars is implemented by gradually increasing CES cost-shares connected to these types of cars. CES-cost-shares of petrol and diesel cars are gradually decreased as the stock of electric and hydrogen cars is increasing, see appendix. A detailed description is given in Bjertnæs et al. (2011). Implementation of technological improvement by lowering the price of these cars does not generate a substantial stock of such cars within this model framework. Hence, the technological improvement is implemented by increasing CES cost-shares to be able to arrive at substantial stocks of electric, hybrid and hydrogen cars in the long run.

There are approximately 10.000 electricity powered cars in Norway as of 2013. Electricity powered cars is however assumed to have a substantial market share in 2050 when the current favourable taxation is preserved. Note that the development of the stock of cars in the reference scenario is generated by the assumptions imposed in the reference scenario, see Bjertnæs et al. (2011) for a more

[5] Modest deviations from National accounts are generated when dynamic aspects of the model are improved. Electric cars are not included as a separate good in Norwegian National Accounts.

detailed description of variables in the reference scenario. There are substantial uncertainties connected to these assumptions. This assumption seems to be consistent with pridictions in the literature even though the future market share of electric cars is highly uncertain. A study of Eurelectric (Eurelectric, 2007), an association representing the interests of the electricity industry in Europe, argue that plug-in hybrid vehicles can have a market share of 8 to 20 percent in 2030. ECN (2009) show that the share of light electric vehicles can reach 20 percent in 2030. Most individuals also seem to have a positive willingness to pay for cars that use alternative fuels, see Dagsvik and Liu (2009) and Caulfield et al. (2010). Devogelaer and Gusbin (2010), however, predict a smaller share of electric vehicles and plug-in hybrid vehicles in Belgium in the period 2012-2030. General climate policy measures generate a share of electric and plug-in hybrid vehicles of about 2% of the fleet in 2020, and about 5% of the fleet in 2030 in their study. The stock of each type of car is displayed in figure 4.1. This figure shows that electric cars dominate the market in 2050. The stock of electric cars is more than twice as large as the stock of any other type of car in 2050. The stock of hybrid and hydrogen cars is marginal the first periods, but expands gradually and ends up with a modest market share in 2050.

Figure 4.1. The stock of cars in the reference scenario, mill 2004-NOK

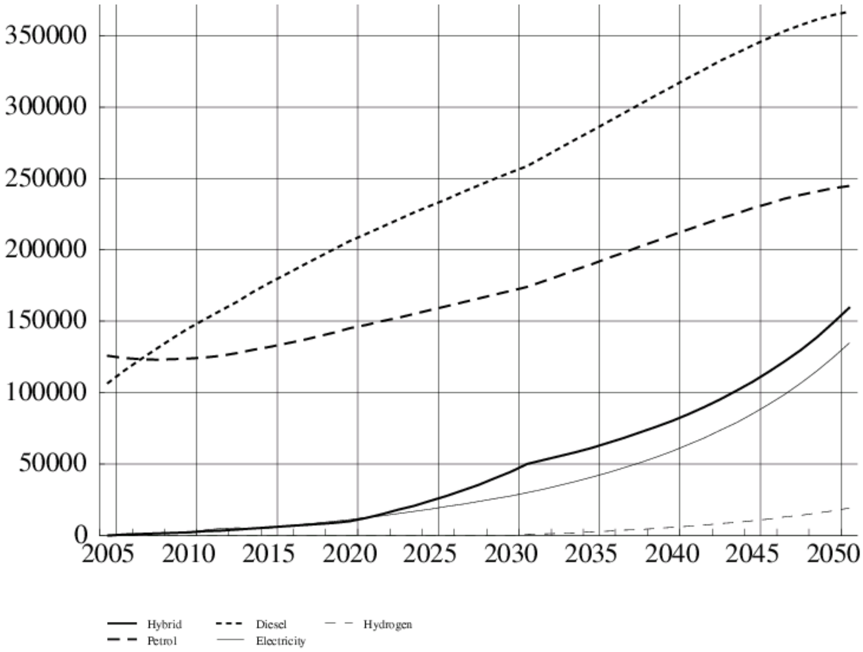


4.2. The middle scenario

Tax rates on purchase of electric and hydrogen powered cars are increased from 8 to 37 percent in the middle tax scenario. The increase in the price of electric and hydrogen cars leads to substitution away from electric and hydrogen cars. The magnitude of this effect is marginal in early periods when the

stock of electric and hydrogen cars is marginal. The effect of this reform is, however, substantial in the long run where electric cars constitute a substantial share of the market. Results of the reform are displayed in figure 4.2. Figure 4.2 shows that petrol and diesel powered cars are dominating the market in all periods. The stock of hybrid and electricity powered cars are marginal the first periods, but expands gradually and ends up with a substantial market share in 2050. The stock of electric cars is approximately half as large as the stock of petrol cars and 1/3 of the stock of diesel cars in 2050.
A comparison of figure 4.1 and 4.2 illustrate the substitution from electric cars towards petrol and diesel powered car. The stock of hydrogen cars is also reduced.

Figure 4.2. The stock of cars in the middle scenario (37 % tax on climate friendly cars), mill 2004-NOK

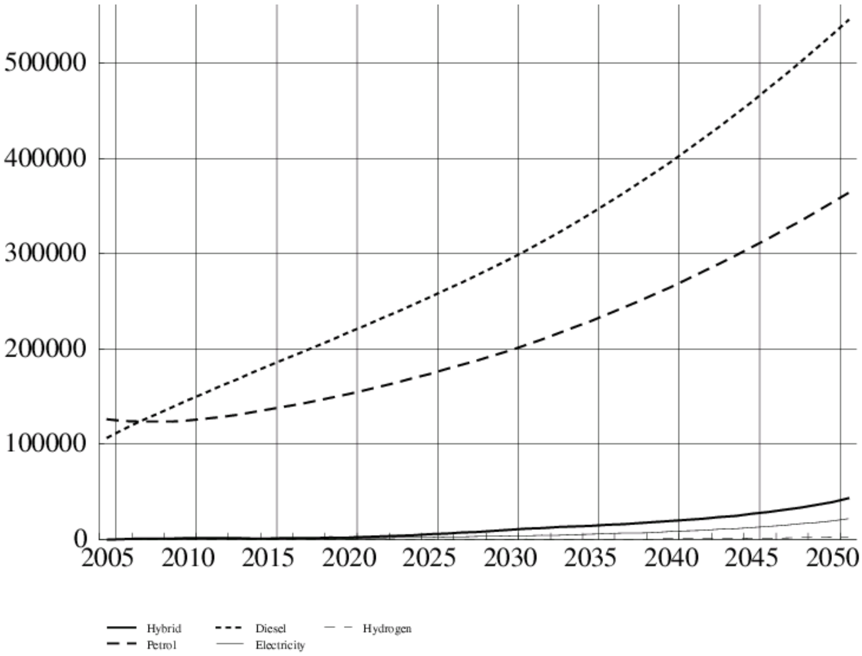


4.3. The uniform tax scenario

The tax rates on purchase of electricity and hydrogen powered cars are increased from 8 to 84 percent, while the tax rates on purchase of hybrid cars is increased from 37 to 84 percent in the uniform tax scenario[6]. The increase in the price of electric, hydrogen and hybrid cars leads to substitution away from these cars. Results of the reform are displayed in figure 4.3. This figure shows that electric, hydrogen and hybrid cars almost vanish from the market in the long run even though present taxes on fuels and electricity are unchanged. A comparison of figure 4.1 and 4.3 illustrate the substitution from electric, hybrid and hydrogen cars towards petrol and diesel powered car.

[6] The tax rate on purchase of petrol powered cars remains constant at 93 percent in the uniform scenario.

Figure 4.3. The stock of cars in the uniform tax scenario, mill 2004-NOK



4.4. Greenhouse gas emissions

The GHG emissions are directly linked to the consumption of petrol and diesel, where one litre petrol generates 2,316 kg CO_2 and one litre diesel generates 2,663 kg CO_2. Emissions of CH_4 and N_2O is also incorporated and transformed into CO_2 - equivalents. The consumption of petrol and diesel is linked to the stock of petrol, diesel and hybrid cars because there is no substitution between the services from the stock of cars and expenditures on fuels. Hence, an investigation of the development of these stocks of cars within each scenario explains the development in total emissions in each scenario. Total emissions of GHG's amounts to approximately 6,7 mill ton CO_2 equivalents in 2005. The model does not incorporate bio-fuels, and hence, tend to exaggerate the level of emission. The model also seems to predict a faster growth in GHG emission from household transport compared to the development the last twenty years. This development is however governed by drastic changes in the composition of petrol and diesel cars as well as technological progress.

The reference scenario displays a modest growth in GHG emissions in early decades which translates into a modest drop towards 2050. There is steady growth in GHG emissions in the middle scenario. The main explanation is the steady growth in income spent on private transport. The increase in emissions generated by implementing the middle scenario is modest in early decades and substantial in the long run. The reason is that a large number of electric cars are replaced with petrol and diesel powered cars in the long run, while this replacement is modest in early decades. The increase in emissions amounts to approximately 5 million ton CO_2-equivalents in 2050 when the substitution elasticity between types of cars equals 8. The increase in emission amounts to approximately 2,3 million ton when the substitution elasticity between types of cars equals 3. The uniform scenario displays an even larger growth in emissions. The reason is that almost every climate friendly car is replaced with petrol and diesel powered cars in this scenario. The increase in emissions amounts to approximately 8,8 million ton CO_2-equivalents in 2050 when the substitution elasticity between types of cars equals 8. The increase in emission amounts to approximately 5,6 million ton when the substitution elasticity between types of cars equals 3.

4.5. Tax revenue

Total tax revenue generated is found by adding tax revenues generated by purchase of different cars and fuels. Purchase of cars is linked to the stock of cars in the long run due to a steady growth in stocks of cars. Purchase of fuels is also linked to the stock of cars as explained above. Hence, tax rates and the development in the different stocks of cars are sufficient to explain the development in total tax revenue generated.

Tax revenue generated by taxation of energy and cars which exceeds revenue generated in the “reference scenario” is transferred lump-sum to the representative consumer. The lump-sum transfers are marginal in the short run and substantial in the long run in both the middle scenario and the uniform scenario. The reason is that a substantial stock of climate friendly car is replaced with petrol and diesel powered cars in the long run in these two scenarios compared with the “reference scenario”. Tax rates on petrol and diesel by far exceed the tax rates on electricity and hydrogen. The tax rate on purchase of petrol cars exceeds the tax rate on other cars in both these scenarios. Hence, this reallocation generates more tax revenue. The increase in total tax revenues in 2050 amounts to more than 40 billion NOK in both the middle and the uniform scenario when the substitution elasticity between types of cars equals 8. This gain of tax revenue amounts to approximately 8600 NOK per ton increase in GHG emissions when the middle scenario is introduced. Tax revenue generated and transferred lump-sum is even larger when the substitution elasticity between types of cars equals 3.

5. Welfare effects

The study analyses welfare effects of the entire transition to the new composition of cars. The welfare gain per ton increase in emissions is found by calculating the change in present value welfare divided by the change in accumulated emissions, where emissions in future periods are weighted with the discount rate. The present value of welfare is found by discounting the top aggregate in the CES-utillity function, total private consumption, with a five percent interest rate and summing over all future periods. Table 5.1 reports presentvalue welfare gains per ton increase in emissions as well as yearly effects from 2030 and 2050, measured in fixed 2005 prices. The welfare gain generated by implementing the “middle scenario” amounts to approximately 5500-6500 NOK per ton increase in GHG emissions. The welfare gain of implementing the “uniform scenario”, where the tax on purchase of electric cars is increased to the average tax rate of diesel powered cars, amounts to approximately 4500-4800 NOK per ton increase in emissions, see table 5.1. The welfare gain per ton is somewhat more modest in this case as the reform lowers the distorting tax wedge between conventional and electric cars even more in this case. These substantial long run changes in welfare and tax revenues are generated by changes in the stock of petrol/ diesel cars and electric cars due to each of the policy reforms. The qualitative impact of these reforms is similar even though the quantitative impacts differ. The qualitative impact of the “middle scenario” is presented below while the impact of the “uniform scenario” is omitted.

Table 5.1. Welfare gain per ton increase in GHG emissions, NOK/ ton

	Middle scenario, low elasticity	Middle scenario, high elasticity	Uniform scenario, low elasticity	Uniform scenario, high elasticity
2030	6587	5688	5577	5336
2050	7184	5983	5785	5196
Present value/ Accumulated emissions[1]	6455	5575	4798	4579

[1] Accumulated emissions equal the sum of emissions in all future periods, where emissions in future periods are weighted with the discount rate.

Implementation of the “middle scenario” implies that the tax rate on purchase of electric cars is increased from 8 to 37 percent. This leads to substitution from electric cars towards petrol and diesel powered cars. The tax rates on purchase of petrol and diesel powered cars is more than twice as large as the tax rate on electric cars. Hence, this substitution contributes to increase welfare as resources are allocated from low taxed goods to high taxed goods. The “middle scenario” also leads to decreased consumption of electricity and increased consumption of petrol and diesel as the stocks of cars changes. This reallocation of energy consumption contributes to increase the welfare gain as the tax rates on petrol and diesel by fare exceeds the tax rate on electricity. Hence, the major welfare gain of increasing the tax rate on electric cars is generated by the reallocation from electric to petrol/ diesel powered cars together with substantial tax exemptions for purchase of electric cars and heavyer taxation of petrol and diesel compared with consumption of electricity.

The simulations also unveiled a substantial gain of tax revenue generated when the “middle scenario” is introduced. The government budget is balanced by transferring these additional tax revenues lump-sum to the representative consumer in the reference scenario. Additional welfare gains could be achieved by recycling tax revenues by cutting other distorting taxes. Welfare gains connected to a more even distribution of income could be achieved by transferring money to poor households. These arguments suggest that the method used underestimates the difference in welfare between the reference scenario and the "middle scenario". This could be corrected for by multiplying the gain of revenue (8600 NOK/ ton increase of GHG emissions in 2050) by the marginal cost of public funds (MCF) minus one. Hence, the additional welfare gain per ton GHG emissions amounts to 2150 NOK when MCF equals 1.25.

Yearly welfare gains per ton increase in GHG emissions are reported to test whether results are sensitive to changes in the stock of electric cars. Yearly welfare gains in 2050 are roughly the same as yearly welfare gains reported in 2030 even though stocks of cars are very different. Hence, results are not sensitive to assumptions that generate different levels of stocks of cars. A lower substitution elasticity between types of cars contribute to reduce the reallocation from electric to conventional cars. This contributes to lower both the welfare gains and the increase in GHG emissions when reforms are introduced. Simulations show that the difference in results with high and low substitution elasticity is modest. It is however hard to explain what generates the difference.

Electric cars require clean electricity to remain a low emission vehicle even though electric cars are more energy efficient, see Thiel et al. (2010) and Econ (2008). Close to 100 percent of the Norwegian production of electricity consists of clean hydro power. The Norwegian electricity grid is however connected with the European electricity grid, where electricity is produced with a mix of polluting and non-polluting power plants. Emission reductions connected to a transition to electric cars become more modest when the source of electricity consists of this European mix, and the EU ETS is abolished. Hawkins et al. (2012) employ a life cycle approach which include production of cars and fuels and find that electric vehicle powered by the present European mix generates a 10 to 30 percent decrease in global warming potential compared to conventional diesel and gasoline vehicles when vehicle lifetime exceeds 150.000 km[7]. Hence, welfare gains per ton increase in GHG emissions attached to each reform analysed in this study will increase as the increase in emissions is reduced. Implementing results from Hawkins et al. (2012) generates a welfare gain between 18.000 and 65.000 NOK per ton increase in GHG emissions due to an increase in the tax rate on purchase of electric cars from 8 to 37 percent. The welfare gain of implementing the "uniform" scenario with this European mix amounts to 15.000 to 48.000 NOK per ton.

[7] The upper estimate is more relevant for petrol powered cars while the lower estimate is more relevant for diesel powered cars.

6. Conclusion

This study shows that the welfare gain, excluding environmental effects, generated by increasing the tax rate on purchase of electric cars from 8 to 37 percent amounts to approximately 5500-6500 NOK per ton increase in GHG emissions in the long run when electric cars run on electricity that do not generate emission of GHG's. Substantial tax exemptions also implies that reallocation from electric cars towards petrol and diesel powered cars generates a tax revenue gain of more than 40 billion NOK per year in the long run. The welfare gain per ton increase in emissions amounts to approximately 4500-4800 NOK when the tax on purchase of electric cars are increased to the average tax rate of diesel powered cars. The main explanation for these substantial welfare effects is that electric cars are exempted from revenue rising taxes as well as taxes justified by local external effects like accidents and cueing, while purchase of conventional cars and fuel is heavily taxed. These welfare gains increases substantially when electric cars are assumed to run on electricity produced with the current emission intensive European mix.

A number of relevant factors are omitted. First, reallocations of cars from electric to petrol/ diesel powered cars are likely to increase emissions of NOx and some other gasses. This reallocation is also likely to increase negative external effects connected to noise. These effects are not incorporated into the welfare measure. Hence, the welfare gain of increasing the tax rate on purchase of electric cars is likely to be overestimated when such effects are excluded. Second, the transition from electric cars towards petrol and diesel cars would generate a more modest increase in GHG emissions when some of the fossil fuel is replaced with biofuel. It is however also more expensive to manufacture some forms of biofuels compared to fossil fuels. Hence, the net welfare impact is ambiguous. Third, consumption of petrol and diesel in Norway may generate a reduction in consumption of petrol and diesel in other countries due to a world market with an increasing supply curve. This effect would reduce the increase in emissions connected to a transition to petrol and diesel powered cars in Norway. The welfare gain per ton increase in emissions consequently increases. Fourth, substitution away from electric cars may prevent technological development connected to electric cars which constitutes positive external effects. The Norwegian market for cars is however small compared to the rest of the world. Hence, it is not likely that Norwegian policy influence R&D decisions of large multinational cars manufacturers. Fifth, the future design and existence of an international quota market for GHG emissions may reduce the relevance of results derived in this study. Sixth, the future stock of electric and hybrid cars are highly uncertain. A radical change in technology in favour of one type of car may also reduce the relevance of this study.

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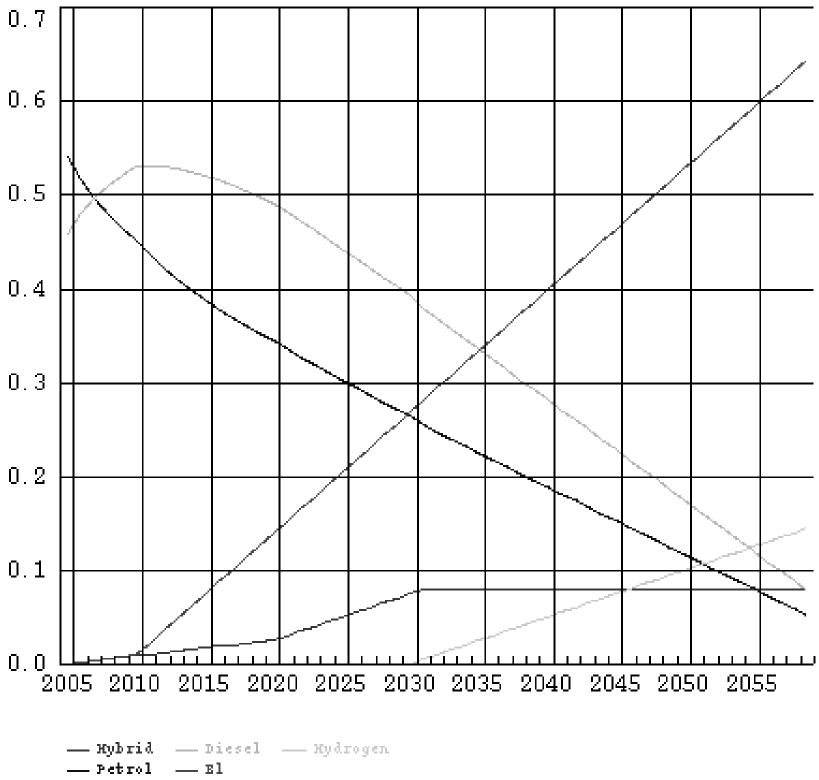
Appendix A

Operating expenditures of electric cars is given by

(1A) expel = omel *((pcel / pcall) ** (1-sigall)) *expall.

Equation (1A) shows that operating expenditures of electric cars, expel, equals the CES-cost-share of electric cars, omel, multiplied by an expression which includes the price of operating expenditures of electric cars, pcel, divided by the price aggeregate of operating expenditures of all cars, pcall. The impact of a relative price change is determined by the substitution elasticity between types of cars, sigall. This expression is multiplied with operating expenditures for all cars, expall. Note that operating expenditures of electric cars equals the CES-cost-share of electric cars multiplied with operating expenditures of all cars when pcel/pcall equals unity.

CES-cost-share of types of cars in all periods



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ISSN 0809-733X

Statistisk sentralbyrå
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Design: Siri Boquist