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ENVIRONMENT WORKING PAPER N° 178

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Abstract

In addition to a longstanding CO_2 component in fuel taxes, Norway has used two main policy instruments to decarbonise its car fleet. A CO_2 differentiated registration tax gives strong and continuous incentives to buy cars with lower registered CO_2 intensity (or higher fuel efficiency). Moreover, generous tax incentives, including registration tax and VAT exemptions, are applied to zero-emission cars, and have given Norway the highest electric vehicle sales in the world. This paper analyses effects of the two instruments (the vehicle registration tax and tax exemption) using an excellent and detailed data set. These instruments are powerful and costly, applied at levels ten times EU ETS quota prices or more. In addition, user costs are influenced by fuel taxes and tolls, and lower urban tolls apply to zero-emission vehicles. The paper estimates an elasticity of -0.8, meaning that a 10% increase in the CO_2 intensity price reduces the emission intensity of the representative car by 8%. It is estimated that the registration tax also delivers improvements in other externalities, the largest effects being air pollution (in percent) and congestion (in monetary value). Alongside the reforms, overall tax revenues from cars and fuels have been reduced considerably, mostly due to declining fuel tax proceeds and the generous tax exemptions for zero-emission vehicles. Besides, vehicle taxation has become more regressive, since urban and suburban households have benefited most from low- and zero-emission vehicles, and these on average have higher incomes. These two effects can be repaired, if desirable, most simply by streamlining the treatment of zero-emission vehicles to be technology neutral, and charging VAT from all cars.

Résumé

La taxe norvégienne d'immatriculation des véhicules automobiles différenciée en fonction des émissions de CO_2

Si la réduction des émissions de CO_2 dans le secteur des transports peut être encouragée uniquement par l'instauration de quotas d'émission négociables et le prélèvement de taxes sur les carburants ou les émissions, de nombreux pays misent également sur les normes de consommation de carburant, les systèmes de bonus-malus automobile ou des instruments similaires pour les faire baisser en ne jouant que sur les ventes de nouveaux véhicules. En Norvège, une mesure énergique fondée sur ce mécanisme a été intégrée en 2007 à la taxe d'immatriculation, sur la base du taux officiel d'émission de CO_2 par véhicule, exprimé en grammes par véhicule-kilomètre. Les véhicules à émission zéro sont de plus exonérés de la taxe d'immatriculation depuis 1990 et de la TVA depuis 2001.

Le présent document analyse l'évolution de la composition du parc de véhicules neufs suite à l'introduction et à l'ajustement de la taxe d'immatriculation différenciée en fonction des émissions de CO_2, ainsi que le lien entre la croissance de la part des véhicules électriques et l'exonération de la taxe d'immatriculation dont ils font l'objet. Cette analyse vient enrichir l'étude de 2018 de Yan et Eskeland en s'intéressant à la place des véhicules électriques, ainsi qu'à d'autres impacts du secteur des transports sur l'environnement - pollution atmosphérique, accidents, bruit et embouteillages, en utilisant des hypothèses standard pour en évaluer les conséquences à l'échelle nationale.

La taxe d'immatriculation a les mêmes incidences sur la pollution de l'air et sur les émissions de CO_2, car la première comme les secondes réagissent à l'augmentation du nombre de véhicules économes en carburant qui en découlent. Si l'on constate localement une augmentation des émissions de polluants atmosphériques imputable au passage de l'essence au diesel, la baisse des émissions due à l'amélioration de l'efficacité énergétique et à la hausse du nombre de véhicules électriques viennent la compenser. La réponse est plus modérée pour les embouteillages, les accidents et le bruit (modélisés de façon très simplifiée), qui ne varient pas selon la composition du parc de véhicules achetés.

Sur le plan budgétaire, on constate une perte nette de recettes pour l'ensemble du parc automobile, la diminution des recettes des taxes sur les carburants et de la taxe d'immatriculation prélevées sur les voitures à faibles émissions étant supérieure au surcroît de recettes provenant des voitures à fortes émissions. Le produit de la taxe sur les carburants par véhicule diminue à mesure que les voitures deviennent plus sobres, tandis que les recettes fiscales nettes sur les véhicules sont susceptibles d'augmenter avec la hausse des taux d'imposition applicables selon l'intensité des émissions de CO_2. Un système de bonus-malus (conjuguant subventions pour les véhicules à faibles émissions et taxes pour ceux à fortes émissions) a été mis en place après 2009. Parallèlement, la mise en circulation des véhicules à émission zéro, qui ont bénéficié de généreuses exonérations, a entraîné une baisse des recettes totales provenant des véhicules routiers légers et des taxes sur les carburants correspondantes.

La sensibilité au prix de l'intensité d'émission de CO_2 des véhicules neufs vendus est à la fois le levier d'action sur lequel repose la taxe d'immatriculation différenciée en fonction des émissions de CO_2 de la Norvège et le principal objet de cette étude. Si l'on tient compte de la hausse du nombre de véhicules à

émission zéro, l'élasticité moyenne de l'intensité de carbone par rapport au prix du CO_2 intégré dans la taxe d'immatriculation ressort à -0.8. Il s'agit d'une sensibilité très importante : une augmentation de prix de 10 % fait chuter de 8 % le taux d'émission moyen d'un véhicule représentatif (« synthétique »). L'élasticité-prix n'est toutefois pas suffisante pour qu'une hausse des prix du CO_2, envisagée isolément, permette de générer des recettes supplémentaires. Ces calculs ne portent que sur les émissions d'échappement, conformément au principe territorial, applicable à un système électrique à émissions plafonnées, comme celui de l'Europe dans le cadre du SEQE, ou à un système électrique sans émission, comme celui de la Norvège, si on le considère séparément. Ils n'intègrent aucune analyse du cycle de vie des véhicules ou des pièces les composant.

La réduction des émissions directes de carbone induites par la taxe différenciée selon les émissions de CO_2 représente manifestement un coût. Les taux de cette taxe (qui vient s'ajouter aux taxes sur les émissions de carbone et autres taxes sur les carburants) sont très supérieurs aux prix jugés adaptés aux objectifs ou aux coûts sociaux des émissions de carbone, et par conséquent beaucoup plus élevés également que les prix actuels des quotas au sein du SEQE (de l'ordre de 20 ou 30 EUR par tonne de CO_2). La présente analyse coûts-avantages tient compte de l'impact de la taxe sur la qualité de l'air et d'autres biens publics, d'où une estimation plus élevée des avantages totaux. Néanmoins, ce n'est pas suffisant pour considérer que les coûts sont modestes. Cela tient notamment au fait que ces autres biens publics doivent faire, et font, l'objet d'autres d'instruments d'action directs, comme les péages cordon mis en place pour réguler le trafic dans les zones urbaines, les taxes sur les carburants ou encore les subventions aux transports publics. À supposer, donc, que les effets connexes des taxes sur les émissions de CO_2 soient bénéfiques, il ne s'agit pas nécessairement d'avantages *nets*. Ainsi, si un péage de congestion permet de réguler correctement le trafic, les avantages nets d'une réduction des embouteillages induite par d'autres instruments (*via* la vente de nouveaux véhicules) peuvent être nuls ou presque, même si la réduction des embouteillages est conséquente.

La prise en compte des conséquences budgétaires ne change pas beaucoup la donne. Les répercussions sur les recettes fiscales peuvent être modulées si l'on pousse l'analyse plus loin. En particulier, la baisse assez significative des recettes dans le secteur des véhicules routiers ces dernières années s'expliquent principalement par les généreuses exonérations accordées aux véhicules à émission zéro (dont, pour moitié environ, les exonérations de TVA). Si elles sont jugées importantes, elles peuvent être compensées indépendamment de l'équilibre au sein du parc de véhicules MCI, entre véhicules MCI et véhicules à émission zéro, ou encore entre les instruments visant la vente de véhicules neufs, d'une part, et leur utilisation sur les routes norvégiennes, d'autre part. De l'avis des auteurs, l'application de la TVA aux véhicules à émission zéro constituerait une première étape judicieuse pour atténuer la récente érosion des recettes provenant du secteur routier. C'est également ce qui ressort des débats sur l'action à mener en Norvège. Cette mesure envisagée isolément réduirait le soutien en faveur des véhicules électriques, mais ce n'est pas nécessairement une mauvaise chose. Ainsi, en termes d'effets redistributifs, l'expérience acquise depuis 2007 met en évidence un mécanisme compensateur créé par l'exonération des véhicules électriques, qui sont devenus abordables. Or, ce sont en majeure partie les habitants des villes et des banlieues qui en bénéficient. Si rien ne permet d'affirmer que la fiscalité des véhicules doit contribuer à la progressivité du système fiscal, on constate un certain recul de la progressivité de l'impôt dans ce domaine.

La stratégie de la Norvège, qui consiste à recourir à la taxe d'immatriculation pour rendre son parc de véhicules plus vert, en augmentant la part des véhicules MCI plus sobres en carburant et des véhicules à émission zéro, n'est pas conventionnelle. Elle se traduit par une augmentation des ventes de véhicules à émission zéro, qui représentent aujourd'hui plus de la moitié des achats de véhicules neufs, et par un parc de véhicules MCI beaucoup plus économes en carburant. Les incidences de cette taxe sont importantes parce que l'intensité d'émission de CO_2 est imposée de façon continue et directe, et parce que le prix implicite du CO_2 est élevé. Certaines faiblesses qu'aurait cette stratégie si elle devait être mise en œuvre de façon isolée ne sont pas si graves dans la pratique, dans la mesure où la Norvège recourt également aux taxes sur les carburants, aux subventions aux transports publics et aux péages cordon différenciés selon les heures et les catégories de véhicules. Par ailleurs, s'il est difficile de justifier cette politique eu égard au coût implicite élevé des émissions de CO_2, on peut arguer qu'une impulsion doit être donnée aux constructeurs automobiles et qu'ils pourront ainsi proposer une réduction des émissions à moindre coût à l'avenir.

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1 Introduction and broad outline

1.1 Motivation and Summary

While CO_2 emission reductions from transport can be stimulated merely through tradable emission quotas or a tax levied on fuels or emissions, such as fuel taxes or carbon taxes, policy instruments in many countries also include fuel economy standards, bonus-malus taxes or similar instruments that aim to reduce emissions from vehicle fleets over time through new vehicle purchases. Together with a wider range of policy instruments such as road pricing, public transport, and infrastructure provision policies, these policies work to reduce emissions along diverse dimensions of 'avoid and shift', and a broader analysis of all potential and applied instruments is beyond the scope of this study. In Norway, a forceful instrument working through this channel is the CO_2-differentiated vehicle registration tax that was introduced in 20071. Zero-emission vehicles has been exempted from the registration tax since 1990 and exempted from VAT since 2001.

This paper analyses how the composition of new vehicle sales has developed with the introduction and adjustments of the CO_2-differentiated registration tax. In this study, a part of the rising share of electric vehicles in Norway is associated with their exemptions from the registration tax. Using a larger data set than in Yan and Eskeland (2018[1]), the estimated demand elasticity is very similar. Previous empirical research on this tax in Norway was conducted using a difference-in-difference approach (Ciccone, 2018[2]), and studied changes in CO_2 intensity (and the shares of diesel cars and high-emission cars) by treating the introduction of the tax in 2007 as a one-time uniform incident for all vehicles.

The analysis by Yan and Eskeland (2018[1]) is here expanded with re-estimation on a larger dataset, and includes assessments of other environmental impacts – air pollutants, accidents, noise and congestion. This analysis uses standard assumptions for nationwide consequences. The findings are that the emission consequences of the vehicle tax on air pollution are similar to those for CO_2 emissions, since both of which are driven by a response in direction of less fuel-intensive vehicles. The increased emissions of local air pollutants that are caused by purchase shifts from gasoline cars to diesel cars are smaller than the reduced emissions from improvements in fuel efficiency within these vehicle groups. For congestion, accidents and noise, the response is blunted and more moderate, since these are in this simplistic analysis not affected by the details of the composition of vehicles purchased.

Moving to fiscal implications, a net revenue loss for all cars consists of a loss through fuel tax revenues, lower revenues of the vehicle registration tax on low-emission cars, and higher revenues collected on high-emission cars. Fuel taxes per car decline as cars become more fuel efficient, while net vehicle tax revenues may rise with the increasing tax rates on CO_2 intensity. After 2009, the introduction of a feebate structure (subsidies for low-emission cars, taxes for high-emission cars) for the CO_2-differentiated struck some balance on the vehicle tax revenues. In parallel, as zero-emission vehicles receive generous tax

[1] Before 2007, the vehicle registration tax consisted of three elements: weight, engine power, and engine size which was replaced vehicle's official CO_2 intensity. Since then, the CO_2-differentiated tax has been rising every year, while other parts of the registration tax have been stable or slightly reduced. The changes in the CO_2-differentiated tax account for the majority of the changes in the registration tax.

exemptions, including zero value added tax, revenues from road vehicles in total decline with their accelerated sales.

The price responsiveness in the CO_2-intensity of new vehicle sales is both the intended channel of influences of the Norwegian CO_2-differentiated registration tax, and the main objective of the research is to estimate it. When including the rise in zero emission vehicles, the estimated coefficient implies a price elasticity of the CO_2-intensity with respect to the price of CO_2 in the registration tax of -0.8 in the example of 2018. This is a very substantial price responsiveness: a price increase of 10% reduces the average emission rate for the representative ("synthetic") car by 8%. The price elasticity is small enough, however, to render a price increase on the CO_2-intensity revenue generating, when seen in isolation. These calculations involve only tailpipe emissions, in accordance with the territorial principle, relevant for an emission-capped electricity system such as Europe's under ETS, or an emission-free electricity system, such as the Norwegian one if seen in isolation. It does not include any attempt at life-cycle analysis for cars or their parts, road or rail or cities.

It is clear that the direct CO_2 reductions resulting from the CO_2-differentiated tax are costly. The CO_2-differentiated tax rates (additional to the CO_2-related and other taxation on fuels) are much higher than proposed estimates for target consistent prices or the social costs of carbon,[2] and also much higher than present European ETS quota prices. The present cost-benefit analysis (CBA) brings in air quality benefits and other public goods, and consequently raises a total benefit estimate. This is not, however, sufficient to make benefits considered low cost. One reason is that these other public goods should have and do have more direct policy instruments addressing them (examples are congestion tolls in the urban toll rings, fuel taxes, and public transport subsidies). It is therefore possible that so-called "auxiliary benefits" to these CO_2 taxes are benefits, but do not lead to overall net benefits. As an example, if for instance a congestion toll manages congestion appropriately, then the net benefits of reducing congestion with other instruments (through new vehicle sales) may be zero or close to zero, even if congestion reduction is substantial.

Including fiscal implications does not change this picture much. Revenue implications are adjustable at a higher level of analysis. In particular, the quite large revenue reductions in the road vehicle sector over recent years are mostly due to the generous exemptions for zero-emission vehicles (in which the VAT exemption contributes about half). These revenue losses – if deemed important – can be addressed in the road sector independently of the balance within ICE vehicles, the balance between ICE vehicles and zero-emission vehicles, and the balance between instruments addressing new vehicle sales and usage on Norwegian roads. In the authors' view and in the Norwegian policy debate, applying the VAT tax rate to zero-emission vehicles would be a sensible first step in moderating the recent revenue decline from the road sector. Alone, this would reduce the support for electric vehicles, but that is not necessarily undesirable.

1.2 Policy instruments, and the extended cost-benefit analysis

While policies in many variations for decarbonisation can be envisaged, a point of departure for this analysis is that decarbonisation in transport can be done in a classic first-best way with fuel or carbon taxes (or tradable CO_2 quotas) which price CO_2 emissions directly, equalised across polluters.

An important element in the Norwegian approach to vehicular emission control is to complement the CO_2 element in the fuel taxes with a CO_2-differentiated registration tax that applies to the sale of new vehicles

[2] For instance, the Carbon Pricing Leadership Coalition (2017[16]) concluded "that the explicit carbon-price level consistent with achieving the Paris temperature target is at least US$40–80/t$CO_2$ by 2020 and US$50–100/t$CO_2$ by 2030, provided a supportive policy environment is in place". van Essen et al. (2019[10]) stated that the central value for the short-and-medium-run costs (up to 2030) is EUR_{2016} 100 per tonne of CO_2 equivalent, and EUR_{2016} 269 per tonne of CO_2 for the long-run costs (up to 2060).

(and in a depreciated form also to imported used vehicles). This element of the registration tax aims to change the composition of the vehicle stock in a CO_2-leaner direction through new vehicle purchases.

The tax base for the registration tax is a measure of CO_2 intensity for each vehicle type (grams of CO_2 per vehicle km) that results from European Union efforts to test and estimate “on the road emissions” (New European Driving Cycle, NEDC). Over time, studies have shown the NEDC values to be increasingly inadequate in representing “on the road” performance (Helmers et al., 2019[3]). Thus, an improved procedure (WLTP) has been introduced in Europe since 2017.[3] The current study and the tax policy instruments in Norway have been based on measures from NEDC in the years of the study, including 2018.

From the point of view of policy instruments, it is worth noticing that in the eyes of EU and other pertinent authorities, imperfect measurements for parameters such as fuel economy and emission intensities are found, at this instance, worth improving (the authors of this study share this view). However, the weaknesses in such measures, as well as their costs, also highlight the importance of complementary policy instruments to reduce fuel consumption and CO_2 emissions, such as fuel taxes, which do not share these weaknesses. For emissions of air pollutants, emission testing procedures are more essential, since for many air pollutants, fuel consumption is much less adequate as a proxy.

This study extends the analysis of the policy by Yan and Eskeland (2018[1]) through including not only the CO_2 emissions, but also other externalities (e.g. air pollution, accidents, noise and congestion), fiscal outcomes and a view towards distributional implications. In addition, by applying results on a cross-price elasticity from another study, impacts through BEV sales are included.

Apart from the introduction of CO_2-differentiated vehicle registration tax in 2007, Norwegian policy has included very generous tax exemptions and other policies to promote electric vehicle adoptions. Electric vehicle purchases have expanded from nothing through substantial, now exceeding half of new vehicle registrations in 2020. This analysis of the CO_2-differentiated registration tax focuses on impacts through internal combustion vehicles (ICE, diesel and gasoline, including their hybrids) and BEVs. The CO_2-differentiated registration tax is directed to change the composition of ICE vehicle purchases, but together with tax exemptions for electric vehicles, it brings down the emission intensity of what one may think of as a “synthetic vehicle”, representative of new vehicle sales in a given year.

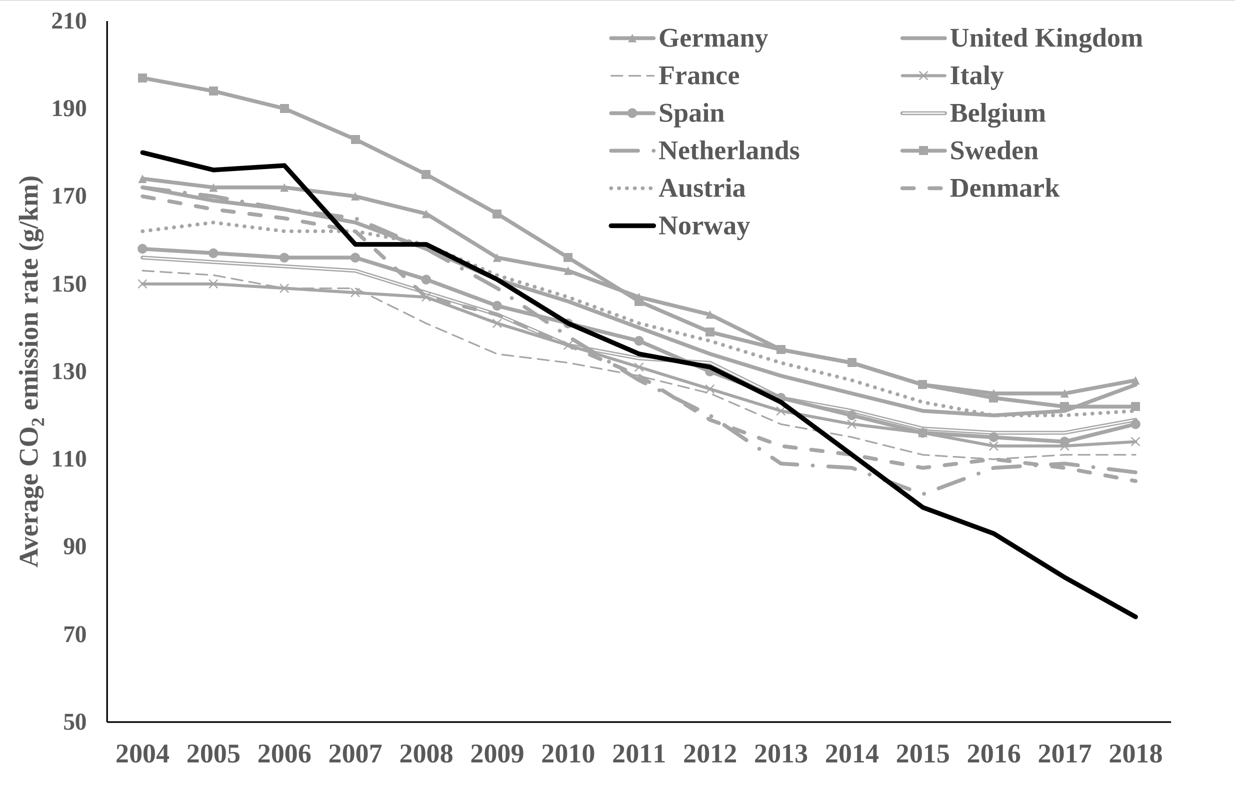
The average CO_2 intensity (gram per vehicle km, as in the registration document) in Norwegian new vehicle purchases has been declining faster than in other European countries (Figure 1.1), despite very strong developments in personal incomes in Norway,[4] especially from 2007, when the CO_2 element was introduced. Figure 1.2 provides some descriptive background, through categories of cars sold.

[3] Helmers et al. estimate the average gap in NEDC values from “real values” to have increased from 8% to 39% between 2001 and 2017 (Helmers et al., 2019[3]). From 2017, a new and more accurate Worldwide Light Vehicles Test Procedure (WLTP) has been introduced.

[4] Norway has, also historically, had heavy and powerful vehicles in a European comparison, probably reflecting high incomes, snow, dispersed settlements, and culture involving mountain cabins, trailer hooks, weekends and skiing.

Figure 1.1. Average CO_2 emission rate of car fleets by country

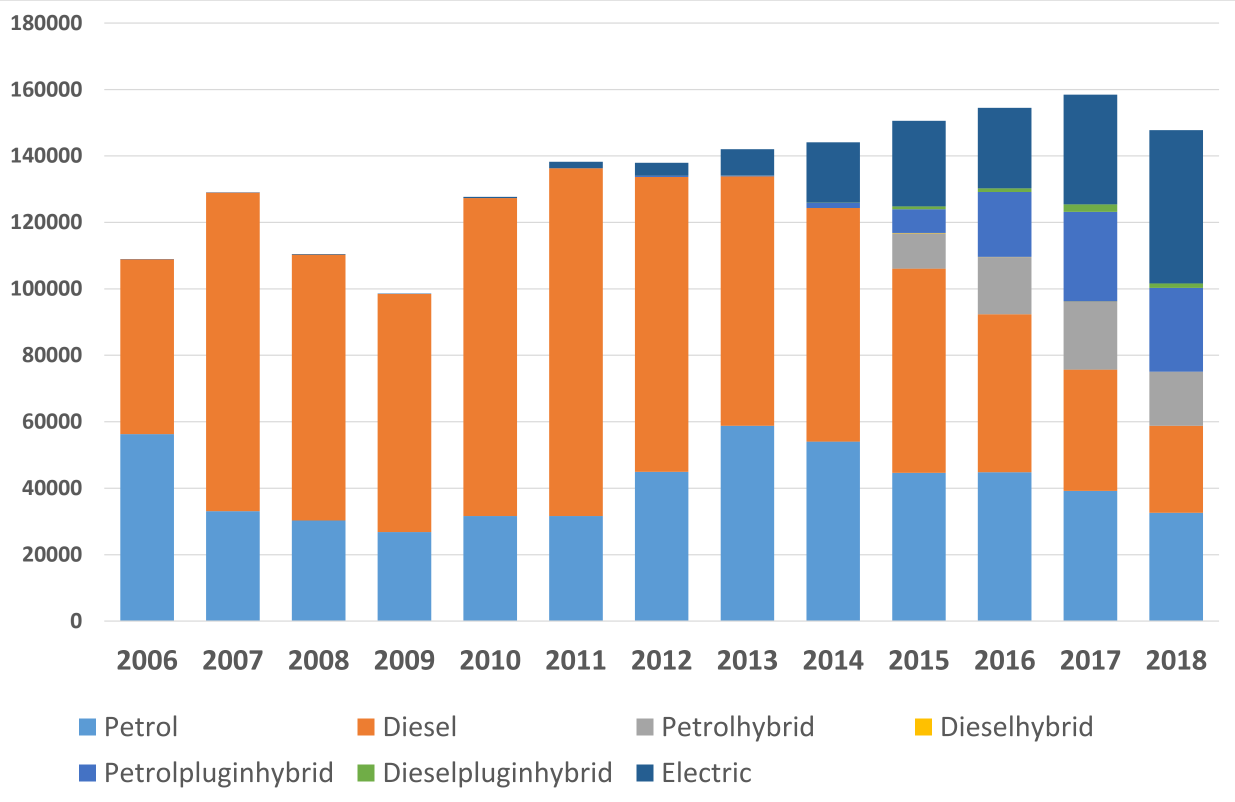
2004-2018



Source: https://theicct.org/publications/european-vehicle-market-statistics-20182019.

Figure 1.2. New passenger cars registered in Norway

2006-2018



Source: Data obtained for this report from Norwegian Road Federation.

The analysis of "other externalities" consists of:

- accidents
- air pollutants
- noise
- congestion.

The paper also examines:

- fiscal impacts, i.e. the revenue implications, and
- distributive impacts.

The impact of the vehicle registration tax on greenhouse gases (here CO_2 only) and air pollutants depend heavily on the composition of new car sales. The paper models accidents, noise and congestion as responding only to changes in total number of cars sold. This gross simplification (not differentiating by weight or size or fuel type, or vehicle-kilometre per year, for instance) is justified only by the fact that these are analysed as "collateral" consequences of a policy intended to reduce emissions through car sales. A CO_2-differentiated registration tax is ill suited for these other public objectives, and also not very influential.

1.3 Brief description of the car market and policy instruments in Norway

- Norway is without a car industry.
- Norway has long had high vehicle registration taxes (100% of pre-tax vehicle value and beyond). Since 2007, this tax has included in its tax base the car's CO_2 intensity (grams per vehicle kilometre).

- BEVs receive very generous tax exemptions of the registration taxes, apart from other tax exemptions (e.g. VAT, which normally is 25% on all goods and services, including ICE vehicles) and incentives.

Figure 1.3. The CO_2-differentiated vehicle registration tax in Norway

2006-2018, NOK per vehicle with different levels of CO_2 emissions

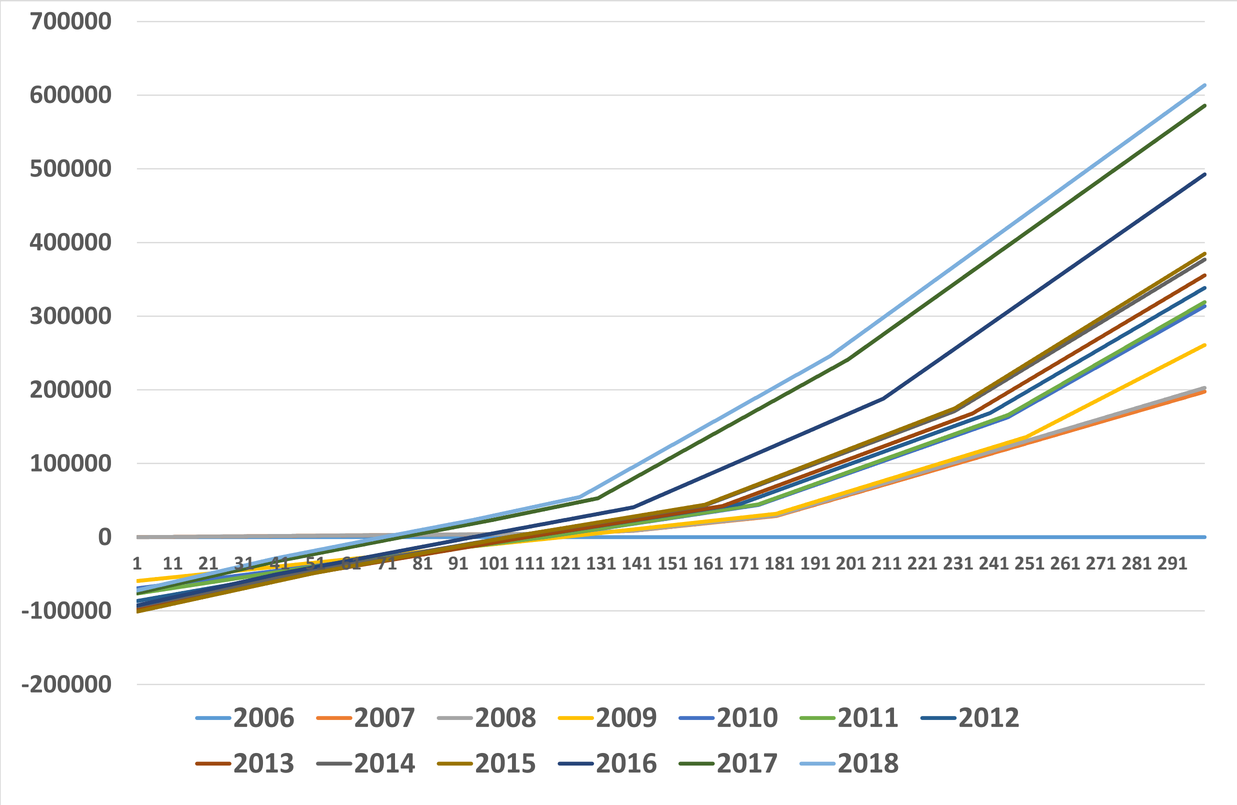


Figure 1.3 presents the schedule for the CO_2-differentiated registration tax, as it has evolved from 2006 to 2018. This tax element was introduced in 2007, and is therefore seen as flat for 2006[5]. The progressivity with respect to emission intensity is represented by the kinks on each line. In 2009, the tax was modified to a feebate structure with subsidies for fuel-efficient vehicles, maintaining its link to CO_2 intensities. The tax rates and values of cut-offs have been adjusted yearly on 1 January, with increasingly expensive carbon emissions (Relevant material is found in Yan and Eskeland (2018[1])).

The vehicle registration tax is continuous in CO_2 intensity and thus always sends a price signal for vehicles with different emission rates. This is different from the French and Irish systems, which have discontinuous jumps in tax rates between groups of vehicles representing different bands of CO_2 intensities ((Ryan et al., 2019[4]); (Teusch and Braathen, 2019[5])).

Apart from the CO_2-differentiated vehicle registration tax which accounts for major changes in the overall vehicle registration tax, current Norwegian registration taxes also include taxes based on weight and NO_x (g/vkm) in 2018, while elements formerly taxing engine power have been eliminated in 2017.

[5] There is a positive correlation between engine displacement and CO_2 emission. If the engine displacement based tax in 2006 is converted into a CO_2 emission related tax, it would not be a flat line. This issue is considered in the empirical estimation and projection.

2 Methodology

Yan and Eskeland (2018[1]) exploited the quasi-experimental reforms of Norwegian vehicle registration taxes to empirically estimate the effects of a CO_2-differentiated vehicle registration tax on private passenger car sales. In brief, the estimated tax effect shows the changes of car purchases with respect to the changes in the CO_2-differentiated vehicle registration tax. The paper by Yan and Eskeland (2018[1]) used a dataset on quarterly registration of cars by model, weight, engine power, engine size and CO_2 emission rate. To identify the tax effect on vehicle registrations, both vehicle fixed effects and model-year-quarter fixed effects were used to control for vehicle characteristics and exogenous shocks to demand and supply. In addition, Yan and Eskeland (2018[1]) analysed tax effects in different vehicle groups, and how vehicle registrations respond to taxes through vehicle prices, using instrumental variables. The paper analysed alternative regressions to validate the tax coefficient estimates, and also to be well informed of the model limitations and interpretation. New vehicle types also emerge every year, but these changes are controlled for. The estimation technology thus picks up a moderate and short-term estimate only reflecting sales changes corresponding to tax changes for vehicle types in the market. Finally, the paper compared the car sales in different segments with tax changes in the counterfactual analysis.

The study here is to make use of empirical academic research to perform ex-post assessments of environmentally related tax policies. The research by Yan and Eskeland (2018[1]) is extended in three ways. First, the time series of data for the estimation of the tax effects is extended from 2006-2012 to 2006-2018. Second, the original analysis is extended by modelling total CO_2 emissions, non-climate externalities (air pollution, congestion, noise and accident) and fiscal effects. The total external costs of the emissions and other externalities from transport are calculated to enable a social cost-benefit analysis of the CO_2-differentiated vehicle registration tax in Norway. The analysis uses inputs for external cost calculation from Yan (2018[6]), which compares emission and external costs between electric vehicles and their gasoline counterparts across European countries, including Norway.

Third, this study expands the population of new cars, including petrol cars, diesel cars and hybrid ICE vehicles, to include BEVs. A cross price elasticity, 0.36 (Fridstrøm and Østli, 2018[7]) is applied to model price responsiveness in electric vehicles purchases. In this study, the cross price of BEV is applied corresponding to the price of a representative petrol car with 27.2 mpg (198 gCO_2/km) which most BEVs replace (Xing, Leard and Li, 2019[8]). The analysis of BEVs is limited for the following reasons:

- The sale of BEVs does not affect estimated total emissions and tax revenues from the car fleet since BEVs have zero tailpipe emissions and are fully exempted from vehicle taxes.
- BEVs are exempt from the vehicle registration tax from 1990s, and EVs have had significant market shares in the new car fleet since 2011. The CO_2-differentiated vehicle registration tax influences the BEV sales indirectly through increasing taxes of corresponding gasoline or diesel substitutes on average. BEV sales are also helped by the VAT exemption and local incentives, as well as technological progress exogenous to the Norwegian registration tax system. As shown in Figure 3.1, the registration tax exemption accounts for less than 15% of the overall incentive for BEVs, while the VAT exemption contributes about 50%.

Norway influences the vehicle stock through the composition of new vehicles to affect:

- the CO2 intensity of ICE vehicles with the instrument of the study

- the balance between BEVs and ICE vehicles with various incentives for BEVs.
- the total number of new car sales through a technology-independent registration tax (or annual tax) covering all vehicles.

More generally, Norway also influences the use of vehicles through tolls, fuel taxes and public transport subsidies.

2.1 Modelling sales of new vehicles

In order to avoid restrictive assumptions about substitutability (as with segments and separability), to address omitted variables, and to identify the tax effect on vehicle sales, Yan and Eskeland (2018[1]) estimate a single-equation model. It embodies both vehicle-type fixed effects and model-year-quarter fixed effects to control for vehicle characteristics and exogenous shocks to demand and supply, such as policy pre-announcement effects, technological development, income growth and EU's vehicle-related policies.

With this empirical approach, the coefficient for the tax effect is re-estimated as 0.0134 in the present analysis. It means that a NOK 1000 (around EUR 100) tax increment for a car type reduces its sales by 1.34%. This estimate is close to the 0.0126 estimated from Yan and Eskeland (2018[1]). In the current version of study, petrol cars, diesel cars (both conventional and hybrids) and BEVs are considered. Estimation of tax impacts for BEV sales is based on a simple average cross-price elasticity of 0.42 (cross-price elasticities of BEV to gasoline car and diesel car, 0.36 and 0.48) (Fridstrøm and Østli, 2018[7]). BEVs are in the Norwegian system considered to have zero emissions. As a result, this group of (increasingly) heterogeneous car models is not charged with any registration taxes. BEVs are now starting to pay tolls in urban toll-rings, to reflect road space requirements, but these and some other policies (like access to bus lanes) are local, not national, and beyond the scope of this study. The focus on the present study is on national instruments, in part reflecting data and methodological constraints.

Following a counterfactual analysis similar to that in Yan and Eskeland (2018[1]), the present analysis estimates for every year what change in vehicle sales would be caused in a scenario for which the CO_2-differentiated vehicle registration tax is the only impetus that varies. The projection of car sales in the current year is based on the historical sales data in the previous year, shown as in Eq. (1). $\mathrm{CarSales}_{ti}^{TaxScenario}$ is the number of vehicle type *i* registered in the year *t* under the scenario of tax change. Tax_{ti} is the CO_2-differetiated vehicle registration tax for car *i*.

$$\mathrm{CarSales}_{ti}^{TaxScenario} = \mathrm{CarSales}_{t-1,i}^{HistoricalData} * (1 - 0.0134 * (Tax_{ti} - Tax_{t-1,i})) \qquad (1)$$

Next, a baseline (business-as-usual) is constructed of car sales without changes in the CO_2-differentiated vehicle registration tax, but with changes in all other non-tax factors (e.g. income). Historical car sales represent changes in the registration tax and other non-tax factors, while car sales under the tax scenario include sales effects of changes in the registration tax only. In Eq. (2), the baseline sales in the current year (e.g. 2007) is obtained by adding the difference calculated to historical car sales in the previous year (e.g. 2006).

$$\mathrm{CarSales}_{ti}^{Baseline} = \mathrm{CarSales}_{t-1,i}^{HistoricalData} + (\mathrm{CarSales}_{ti}^{HistoricalData} - \mathrm{CarSales}_{ti}^{TaxScenario}) \qquad (2)$$

This method identifies the short-term effects of one-year changes in the CO_2-differentiated vehicle registration tax on consumer purchase behaviours. The method does not capture any potential long-term effects of the tax, as through technological improvements. This may be seen as reflecting the fact that there are no car manufactures in Norway and that the Norwegian car market is small relative to the manufacturers' overall market and strategies. Therefore, long-term effects of the Norwegian CO_2-differentiated registration tax on manufacturers are very small. The treatment of Norwegians as simply making choices amongst vehicle types available "on the shelf" is – if anything – conservative about

Norway's influence. It could also be a hint that policy coordination, such as at the EU, US or a global level, would give greater responsiveness.

This analysis evaluates the tax effects on new vehicles sales, as well as their lifetime emissions. The assessment is thus not of the car stock, though over the years, the effects through the stock of vehicles, and through vehicles on the road, are fairly direct.

Table 2.1 shows changes in market shares for cars grouped by CO_2 emission rates, isolating the changes induced by the CO_2-differentiated vehicle registration tax. The numbers are simulated by the estimated model, and thus eliminate the effect of all other variations than those through the changes in the tax. In 2007, the introduction of the vehicle taxes significantly reduced sales of new vehicles sales with CO_2 emission rates above 180 g/km. Since 2007, the taxes have been adjusted annually to be more stringent. After 2009, the vehicle tax was modified to a feebate form with subsidies for low emission cars, resulting by 2010 in a big sales increase for cars with CO_2 emission rates below 120 g/km. In 2016 and 2018, large increases in sales of electric cars lead to a big rise in market shares of cars under 120 g/km.

As tax rates rise for high-emission cars, the number of car groups with reduced market shares increased from the two heaviest groups out of six in 2007 (Table 2.1), to all groups except the one with the lowest CO_2 intensity in 2018. Evaluating these changes through "segments" (categories from the car industry), Yan and Eskeland (2018[1]) found that substitution within segments (small cars, say) contributed about as much to the decline in the average emission coefficients as did substitution between segments (small cars versus subcompacts, for instance). The analysis showed that high-emission segments lose market share *and* get CO_2-leaner, medium segments mostly get CO_2-leaner, while low-emission segments mostly gain market share. As Table 2.1 shows, on average over the years, the tax changes have raised the sale of vehicles with less than 120 g/km by 2% per year.

Table 2.1. Changes of car sales shares induced by the CO_2-differentiated vehicle registration tax

	2007	2008	2009	2010	2012	2014	2016	2018	Average
<120 gram CO_2 per km	1,55%	0,07%	1.23%	2,69%	0,76%	1,07%	5,01%	3,53%	2,00%
121-140 gram CO_2 per km	5,50%	0,12%	0.46%	1,31%	-0,06%	0,04%	0,04%	-1,81%	0,41%
141-160 gram CO_2 per km	5,90%	0,07%	-0.31%	-0,45%	0,15%	-0,26%	-3,02%	-1,35%	-0,36%
161-180 gram CO_2 per km	2,74%	-0,06%	-0.39%	-1,00%	-0,36%	-0,67%	-1,67%	-0,24%	-0,26%
181-200 gram CO_2 per km	-2,40%	-0,03%	-0.44%	-1,65%	-0,43%	-0,10%	-0,20%	-0,06%	-0,48%
>200 gram CO_2 per km	-13,29%	-0,17%	-0.56%	-0,90%	-0,07%	-0,08%	-0,16%	-0,06%	-1,29%

2.2 External costs of climate effects

External costs, $TotalExternalCost_t$, of climate effects are measured as the product of total CO_2 emissions (tonnes) from the new vehicle fleet and the marginal costs of CO_2 emissions (NOK/tonne), *MarginalCost*, shown in Eq. (3). Total CO_2 emissions from the fleet are calculated with the number of cars sold, $CarSales_{it}$, the annual distance travelled per car (km), $AnnualDistance_t$, CO_2 emission rate (g/km), $EmissionRate_i$, and the lifetime of a car, *lifetime*.

$$TotalExternalCost_t = (\sum_{i \in I} CarSales_{ti} * AnnualDistance_t * EmisssionRate_i * lifetime) * MarginalCost \quad (3)$$

Annual distance travelled by fuel type is assumed to be fixed over vehicle lifetimes of 12 years, so any rebound effects are excluded. Electric vehicles are assumed to have the same lifetime as petrol and diesel cars, for simplicity and data reasons. Emissions from vehicles are estimated from their lifetime distance travelled, ignoring manufacture-related emissions, in accordance with the territorial principle. The "type approval" CO_2 emission rates are used, without considering the possible inaccuracies, deterioration rates, or unknown on-road emission factors (see footnote 5 on this important issue). All emission rates and marginal external costs used in this section are presented in the Table A2 and Table A3 in the Appendix.

As for the external costs of pollutants, the social cost per tonne of CO_2 are the same for all cars, regardless of where and when emissions are released. Parry et al. (2014[9]) reports that estimates for the social cost of CO_2 span from 10 to 85 dollars per tonne of CO_2, while the present analysis uses the more recent EURO 100 per tonne from van Essen et al. (2019[10]). This estimate of the benefits of reduced emissions includes effects of global warming, such as sea level rise, biodiversity loss, water management issues, more frequent weather extremes and crop failures (van Essen et al. (2019[10])). It is possible to associate higher costs of GHG emissions, based on analysis of what it costs to achieve the Paris 1.5 degree target. The consequences for this analysis are outside the scope of this paper (but rather straightforward).

As shown in Table 2.2, total CO_2 emissions from new cars sold have been reduced due to the tax, shown by example years of 2007 when the tax was first introduced, and 2018 with the latest tax adjustment. The results for more years are in the Appendix.

The substantive changes of emissions and external costs (Table 2.3) relate to the shifts of vehicle purchases induced by the CO_2-based vehicle registration tax in three ways according to the vehicle registration data:

- Shift towards more fuel efficient cars within the same fuel category
- Shift from petrol cars to diesel cars
- Shift from conventional (petrol & diesel) cars to electric vehicles.

Within a car model, petrol cars have a higher CO_2 emission rate (g/km) than their diesel counterparts. Shifts to diesel reduce CO_2 emission, but raise local air pollution emissions, while shifts to more fuel efficient cars and electric vehicles reduce all emissions. In 2007, the first two of the three ways (above) are the main changes, while in 2018, the changes largely represent the shift to low-emission cars, especially zero emission vehicles. For the twelve years as a whole, the percentage change in total CO_2 emissions in an average year is about 11%, and it is similar for the change of climate-related external costs (Table 2.3).

Table 2.2. Lifetime emission reductions induced by the CO_2-differentiated vehicle registration tax

	2007		2018		Average (all years)	
	Changes in emissions	Rate	Changes in emissions	Rate	Changes in emissions	Rate
	Tonnes	%	Tonnes	%	Tonnes	%
CO_2	-1 538 388	-33%	-273 182	-15%	-340 062	-10.7%
NMVOC	-3 693	-47%	-655	-13%	-712	-11.0%
NO_x	-3 528	-35%	-626	-14%	-757	-10.7%
$PM_{2.5}$	-319	-25%	-57	-17%	-81	-11.1%
SO_2	-9	-28%	-2	-16%	-2	-10.9%

Table 2.3. External costs reductions induced by the CO_2-differentiated vehicle registration tax

	2007		2018		Average (all years)	
	Changes in external costs	Rate	Changes in external costs	Rate	Changes in external costs	Rate
	Million NOK	%	Million NOK	%	Million NOK	%
Climate	-1 538	-33%	-273	-15%	-340	-11%
Air pollution	-1 531	-30%	-272	-15%	-352	-11%
Accidents	-1 803	-28%	-503	-9%	-502	-8%
Congestion	-4 504	-28%	-1 256	-9%	-1 255	-8%
Noise	-623	-28%	-174	-9%	-174	-8%
Total	-9 999	-29%	-2 477	-10%	-340	-9%

2.3 External costs of air pollution

In this section, the study aims to quantify the external costs of changes in emissions of air pollutants – NO_x, SO_2, NMVOC and $PM_{2.5}$. The external cost, *TotalExternalCost$_{tj}$*, of air pollutant *j* in year *t* is measured as the product of total emissions (tonnes) from the new vehicle fleet and the marginal cost of the pollutant (NOK/tonne), *MarginalCost$_j$*, shown in Equation (4). Total emissions from the car fleet are calculated with the number of cars sold, *CarSales$_{it}$*, the annual distance travelled per car (km), *AnnualDistance$_t$*, fuel consumption (litre/km), *FuelConsumption$_i$*, emission factor (tonne/litre), *EmissionFactor$_{ij}$*, and the lifetime of a car, *lifetime*.

$$TotalExternalCost_{tj} = (\sum_{i\in I} CarSales_{it} * AnnualDistance_t * FuelConsumption_i * EmisssionFactor_{ij} * lifetime) * MarginalCost_j \quad (4)$$

Fuel consumption is converted from the CO_2 emission rate in the vehicle registration database, assuming a linear relationship between fuel consumption and CO_2 emissions. The combustion of one litre of diesel causes emission of 2640 grams CO_2, while the combustion of one litre of petrol causes emissions of 2392 grams CO_2. In terms of emissions per vehicle kilometre, the comparison is typically reversed, since diesel contains more energy per litre than gasoline.

In terms of emission factors for air pollutants, the data are obtained from the "*Norwegian Emission Inventory"* by Statistics Norway. Marginal external costs data for Norway are from van Essen et al. (2019[10]), using average values for regions and road types. Marginal costs include health effects, crop losses, material and building damage, and biodiversity loss.

Local air pollution emissions (Table 2.2) and their external costs (Table 2.3) have been reduced by the registration tax. Although increases in local air pollution could have been caused, for instance by NO_x from the shift towards diesel cars, fuel economy improvements and electrification have been sufficient that the overall effects are reduced air pollution.[6]

2.4 External costs of accidents, congestion and noise

Apart from the emissions, transport activities give rise to other externalities, such as accidents, congestions and noise. In this study, simplified calculations are carried out to estimate the external costs of accidents, congestions and noise. As shown in Equation (5), the *TotalExternalCost$_t$* is calibrated as the product of the total distance travelled (vehicle-kilometre) and the marginal cost of accidents, congestion or noise (NOK per vehicle-kilometre). This approach calculates the external costs considering the changes in vehicles sales induced by the changes in the registration tax. The composition of these sales is here modelled, simplistically, as not to have any consequence, since the types of vehicles do not matter to accidents and congestion. For noise, one might assume electric vehicles render lower noise effects than conventional cars, though this difference is smaller at high speeds. In these calculations, only the total effect through the number of vehicles are included. The external cost data for accidents, congestion and noise are from the European research by van Essen et al. (2019[10]).

$$TotalExternalCost_t = (\sum_{i\in I} CarSales_{it} * AnnualDistance_t * lifetime) * MarginalCost \quad (5)$$

Examining the physical externalities, these are brought down by the CO_2-based vehicle tax, and for climate and air pollution more than in proportion to the reduction in vehicle sales. For accidents, noise and congestion, the reduction is quite accurately in proportion to the effect on total vehicle sales. Such externalities are best combatted by other specific policies (such as noise barriers, tolls and road user charges, infrastructure changes), all of which are employed in Norway but not a subject of this study. Based on simple principles, they are better addressed by instruments affecting vehicle use than vehicle sales and ownership.

[6] These estimates relate to the effects of national policy instruments working through car sales reflecting detailed differences in emission coefficients and assumed constant driving per vehicle.

3 Fiscal costs and Welfare

3.1 Fiscal costs

Apart from vehicle taxes, there are two fuel-related taxes in Norway – a road usage tax and a carbon tax. Both these taxes differ according to fuel type (petrol and diesel) and rise over the sample years, 2006 through 2018. Total revenues from the vehicle registration tax and fuel taxes are calculated as in Equation (6) and (7).

$$TotalVehicleTax_t = \sum_{i \in I} CarSales_{it} * Tax_{it} \tag{6}$$

$$TotalFuelTax_t = \sum_{i \in I} CarSales_{it} * Fuelconsumption_i * AnnualDistance_t * (RoadTax_{it} + CarbonTax_{it}) * lifetime \tag{7}$$

Table 3.1 shows the changes in revenues induced by the CO_2 differentiated registration tax, and these were reduced in most years (see also Table A.7). This is due to a combined effect of more fuel-efficient vehicles, reduced vehicle sales and increased road usage and carbon tax rates. The fuel tax revenues are reduced despite rising fuel tax rates as well as rising distances (due to shift to diesel cars).

Due to the implementation and rise of the CO_2-differentiated vehicle registration tax, cars become less CO_2-intensive. However, with an elasticity of the emission rate to taxes lower than one in absolute value, the revenues from the CO_2-differentiated registration tax rises (Table 3.1).

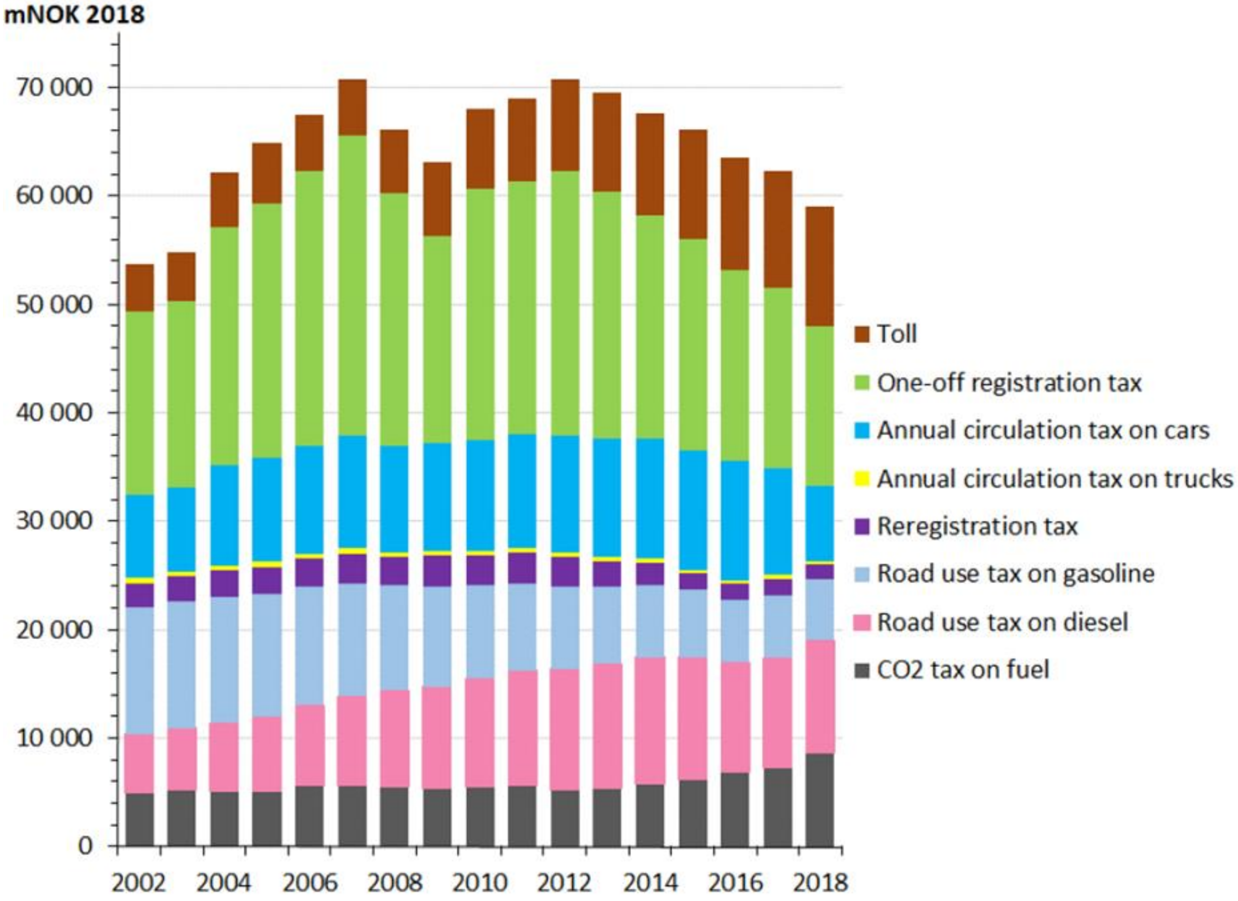
Table 3.1. Revenue changes due to changes in the CO_2-differentiated vehicle registration tax

	2007		2018		Average (all years)	
	Tax changes	Rate	Tax changes	Rate	Tax changes	Rate
	Million NOK	%	Million NOK	%	Million NOK	%
Changes in total fuel tax revenue	-2 614	-35%	-561	-13%	-533	-8%
Changes in CO_2-differentiated registration tax revenue	1 130	60%	25	1%	277	13%
Changes in total car number	-50 971	-28%	-14 211	-9%	-14 199	-8%

Leaving aside the simulated counterfactual simulations allows a broader descriptive picture over the years of revenue changes (Table 3.1, from Fridstrøm (2019[11])). The rising tax on CO_2-intensity in the Norwegian registration tax – alongside with the exemptions for electric vehicles and their rising role – has over time reduced the fiscal revenues from vehicles in Norway. Revenues from taxes on registration, annual circulation and fuel taxes have delivered declining revenue from 2012 onwards. Figure 3.1 describes how car sales by type has changed over the years. An early rise in diesel vehicles has been halted, as sales of zero-emission vehicles accelerated from 2012. Figure 3.2 displays the revenue losses associated with zero-emission vehicles in the year 2017. The VAT exemption is about half of the total.

Figure 3.1. Fiscal revenue from Norwegian motor vehicle taxes

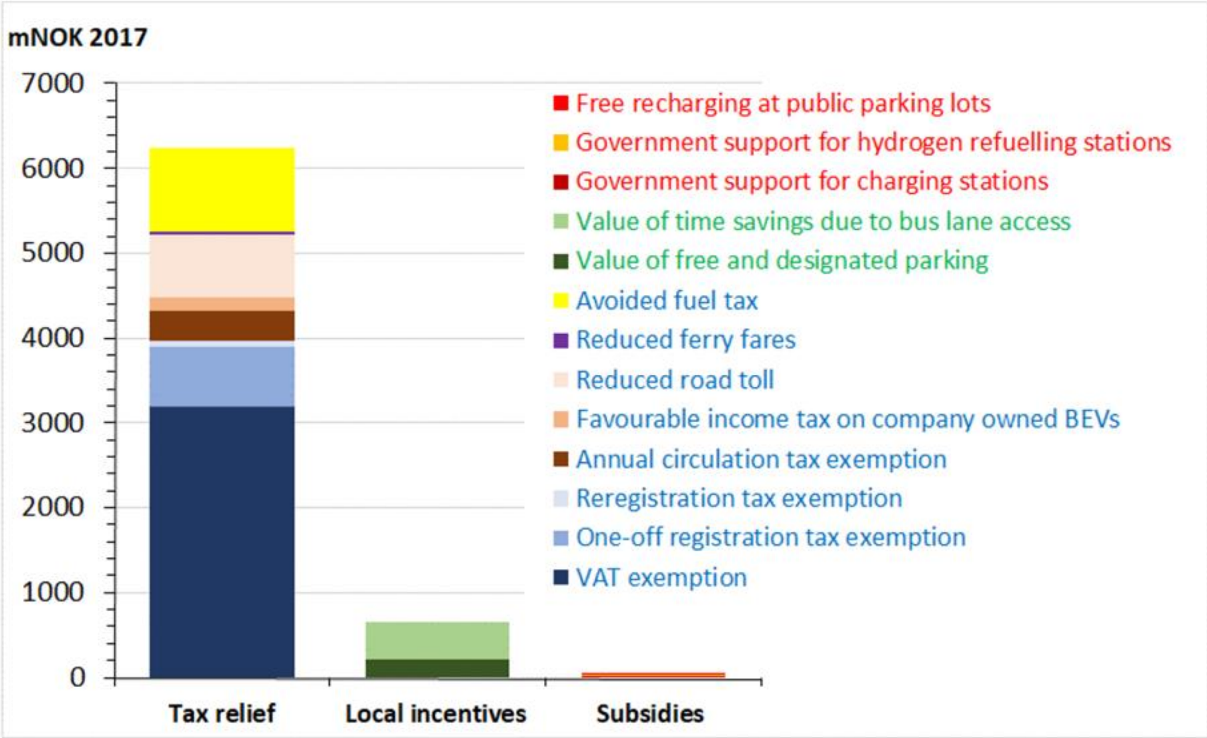
Million NOK_{2018}, Corrected for inflation



Note: NOK 1 equalled USD 0.1225 and EUR 0.1053 as of 1 July 2018.
Source: Friedstrøm (2019[11])

A loss in VAT – zero-emission cars are exempted from VAT – adds to the shown revenue reductions.Figure 3.2 displays, in terms of revenue impact, the national fiscal incentives for zero-emission vehicles in 2017.

Figure 3.2. Zero emission vehicle tax breaks, subsidies and local incentives



Note: NOK 1 equalled USD 0.1225 and EUR 0.1053 as of 1 July 2018.
Source: Friedstrøm (2019[11])

The falling revenues, thus, have to do with combined responses and technological developments, more or less as follows.

- Many of the qualities that earlier were provided only by internal combustion vehicles (ICE) (size, comfort, capacity, power, speed, range, security) are increasingly available also in electric vehicles. The rising share of electric vehicles in Norway, has been a major contributor to the revenue loss.
- Changes in other characteristics (weight, displacement) taxed in the registration taxes have also yielded revenue losses. Hybridisation has been rewarded in the tax formula through high presumptive emission reductions, especially for heavy vehicles, such as SUVs and luxury cars. Moreover, as ICE cars become less CO_2-intensive, they use less fuel per vehicle kilometre.
- While fuel tax rates have not been rising much, the uses of tolls have been, in general suppressing demand and collecting revenue, more in central areas (around Oslo, Bergen, Stavanger and Trondheim) than peripheral. Rising CO_2-differentiated registration taxes should over time be complemented by rising fuel tax rates and tolls to manage a rebound in vehicle use. This has happened, but through tolls only. Tolls are imposed at more locations, start being rush-hour differentiated, and are collected for electric vehicles too, though at lower rates. Toll revenues are used not only for roads, but also for low-emission transport modes, such as bus and rail.

It is clear that from a top down fiscal perspective, it would be simple to neutralise the decline in tax revenues from the vehicle sector in Norway. (An analysis of general optimal tax structure is beyond the scope of this study.) It has been an objective to reduce carbon emissions through the composition of the new vehicles – towards electric vehicles and towards less carbon-intensive vehicles more generally. Nevertheless, the “missing revenues”, from both responses, but particularly from the sale of electric vehicles, could and can be replaced by taxing all vehicles (at registration as new, or annually), or by higher user- and environmental levies, such as fuel taxes and tolls.

Since it would by no means be difficult to attain the objectives of reduced emissions without losing revenue nor progressivity, it would be hard to justify associating a shadow price on government revenue to the strategy itself.[7] Recommendations of applying a marginal cost of public funds equal to one are represented in the literature (Teusch and Braathen, 2019[5])), but the present study highlights more specific concerns. To illustrate, the registration tax itself has proceeds rising in the tax rate, but cuts proceeds from fuel taxation. Both tax instruments are motivated more by reducing CO_2 through fuel consumption than by raising revenue, but raising fuel taxes further may be constrained by other concerns, such as distributive concerns (see below) and an open border with Sweden. Nevertheless, an application of a penalty for revenue loss would highlight the costs of the registration tax further, say by adding an additional 20% of the revenue loss.

3.2 Welfare implications: a representative household

The estimated demand model describes how individuals (or households) respond to changes in the CO_2-differentiated registration tax. With rising rates over the years, this tax, continuous in the CO_2 intensity, rewards buyers for all sacrifices they can make to accept a low-emission vehicle. In principle, it also rewards vehicle makers to find ways to reduce CO_2 intensity in ways acceptable to buyers, whether through reforming the drive train, fuels and ignition technology, or by sacrificing space, weight, power or something else.

An important way to think about this induced change is that it encourages – in an optimal combination – efforts, sacrifices and creativity – from buyers and sellers, both of which are heterogeneous, have private information, and settle on a wide range of different vehicles. So the products bought and driving on Norwegian roads emitting to a global atmosphere are heterogeneous. From the point of view of the climate, only the average CO_2 intensity – weighted by sales and driving – matters. Similarly, from the point of view of international treaties, emissions from vehicles in Norway are Norway's responsibility. This is called the territorial principle. In this study, the CO_2-differentiated registration tax influences that average intensity through new vehicle sales, within a context that comprises a wider range of instruments – fuel taxes, tolls, public transport subsidies – that also influence driving, vehicle retirement, etc.

Figure 3.3 demonstrates welfare analysis in a simple "representative household" model, with consumer surplus as a welfare measure. The figure may be thought of as representing vehicles heterogeneous in many dimensions, here sorted and displayed in one of them, by the CO_2 intensity of a representative vehicle.

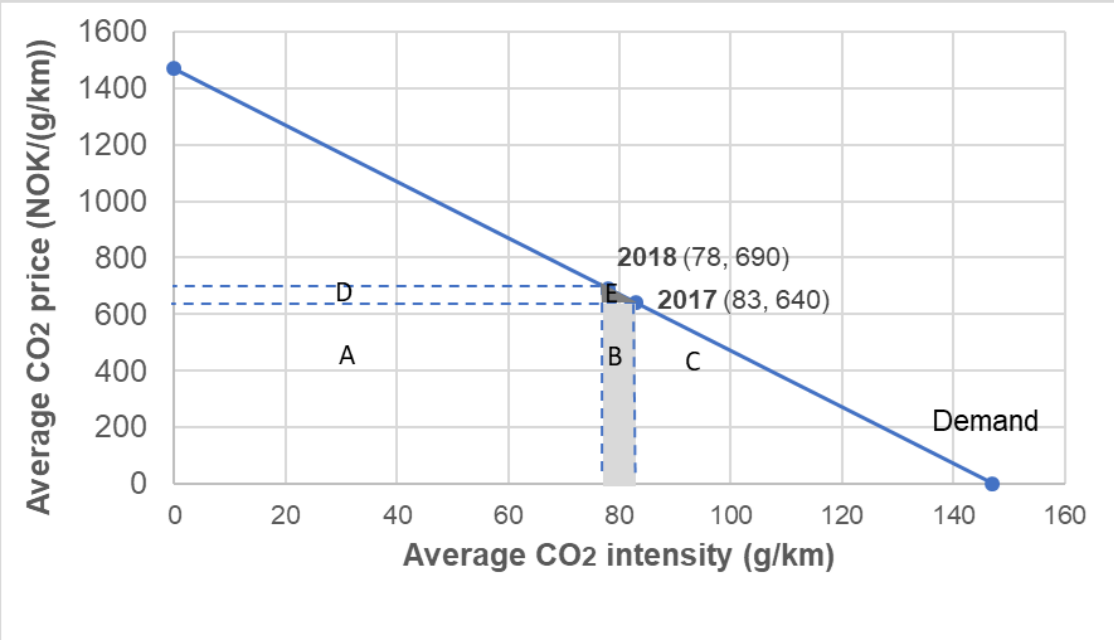
In the consumer's choice of car characteristics (in a bundle called "a car", or car type), the figure represents from left to right along the axis of CO_2 grams per vehicle kilometre, the car qualities that can be provided with the help of higher CO_2 intensity. These may be qualities that are positively associated with

- Weight or size (say: safety, passenger or cargo capacity)
- Horsepower or displacement (such as acceleration, speed)
- Comfort (such as space, climate control, sound).

[7] Redistributive objectives and progressivity as political topics have not been off the agenda in Norway in these years. Examples are that the inheritance tax has been abolished, wealth and property taxes have been defended and collects significant revenue, while they have been reformed to give middle class people greater breaks, collecting more from the wealthier. Direct progressivity in taxation in Norway is mostly through (these and) the income tax. Solid contributions from the middle class are assured through the revenue importance of the value added tax at 25% on general consumption, but not giving any direct progressivity.

Such qualities may to some extent also be provided without raising the CO_2 intensity. This model simply conveys the idea that something of value to the buyer is – at the margin – most cheaply or easily provided with the help of additional CO_2-intensity in the car purchase. Otherwise, the car would have a lower CO_2-intensity. Though people buy different cars, the model is best thought of through a representative car: a sales-weighted average of all car types sold.

Figure 3.3. A representative car



Note: Average values are used for a representative car in 2017 (historical data, baseline) and 2018 (baseline plus 2018 tax change only). This implies an elasticity of CO_2 emission rate to CO_2 price, -0.77.

The policy experiment displayed here is an increase in the average CO_2 price[8] from on NOK 640 in 2017 per gram per vehicle kilometre to on average NOK 690 per gram in 2018. The downward sloping line represents consumers' marginal willingness to pay for qualities provided with additional CO_2, and has been drawn with a price elasticity of -0.77, so that the CO_2-price increase of 8% causes a CO_2-intensity reduction for the representative car of 6%. This (in absolute value) high estimated price elasticity reflects inclusion of zero-emission vehicles in car sales, and thus in the representative car's emissions. When buyers reduce the emission-intensity of the representative car by 5 grams/vkm, they sacrifice a combination of some qualities they would have liked to see in a car, and some way of delivering those qualities with less CO_2, but at a higher production cost.

If a tax schedule (Figure 1.3) is represented by the average CO_2 price (Figure 3.3), the tax increase reduces government revenue with the area D-B, reduces consumer welfare with the area D+E, and – if government revenue is valued equally with the household's – results in a net welfare loss (keeping environmental and climate consequences out of the picture, presently) of E+B. If the tax increase is made in very small steps, an area like E+B approaches the rectangle B, and the marginal welfare cost per unit of CO_2 reductions (B divided by its horizontal width, which is the CO_2 reduction) approaches the value of the tax itself. As a

[8] What we call an average CO_2 price is calculated as the sales-weighted average of each slope shown in figure 1.3.

consequence, at t=640 NOK/g, the marginal welfare cost of additional CO_2 reductions with the help of the registration tax is 640.

The curve simplifies, but makes a subtle point: A household's willingness-to-pay for vehicular characteristics associated with CO_2 intensity is a very tangible currency. Households are not only ready to pay this tax, but are equally (and alternatively) willing to make other sacrifices, and do so: vehicles are bought which embody other features, technologies and materials, to deliver those quality dimensions that CO_2 intensity would otherwise have delivered. A consequence, thus, is the purchase of cars that are costlier not only in Norway, but also at factory gate in the manufacturing country, such as Germany, the United States, Korea or Japan (see, inter alia, Fridstrøm (2019[11])). In this analysis, change in producer surplus is ignored, as under perfectly competitive behaviour and elastic supply. From a Norwegian policy maker perspective, with no car-makers domestically, focusing on consumer surplus can find its justification.

The estimates reflects that demand for CO_2 intensity is insensitive enough that an increase in the carbon tax raises revenue in the sense that B is larger than D. However, the broader revenues collected from cars and road use (Fridstrøm (2019[11])) have been declining over these years, first with the introduction of the CO_2 element in the registration tax from 2007, and later and more forcefully as electric car sales accelerated from 2012. Figure 3.3 reflects an increased sale of BEVs in a fairly CO_2-slim (80 grams per vehicle km) representative vehicle, and also in a fairly responsive emission-intensity price elasticity (-0.77).

A simplistic aspect of the above analysis is a "representative car-owning household". This abstraction of a household is confronted with changes in relative prices that raise the costs of buying a less fuel-efficient vehicle, but is not thrown out of car ownership. The policy is costly, and in a larger, more realistic population of households, especially costly for households who drive little and are at the margin of car ownership. These would otherwise buy a cheap and highly fuel-consuming car. Norway's combination of tolls, fuel and registration taxes is revenue raising, and so is the registration tax if seen in isolation (even with its bonus-malus form). This combination thus would have the potential to redirect revenue (from car taxes to fuel taxes) to facilitate car ownership while keeping aggregate fuel consumption constant. The point made in Levinson (2019[12]), that fuel efficiency standards raise the costs of cars in a regressive way thus applies also to Norway's differentiated registration taxes, but somewhat less harshly: by raising the bonus-part of the bonus-malus structure, cars could be more affordable while equally less carbon intensive, so car taxation could be less regressive, but then less revenue raising.[9] This type of questions and concerns are illuminated in the following section.

3.3 Distributional considerations

The reforms in the registration tax have redirected the road tax structure towards "efficiency oriented objectives", such as to reflect CO_2 emissions (grams per vehicle kilometre), road damage, congestion and air pollution (NO_x). This development has reduced the weight on vehicle characteristics associated with luxury, especially as the exemptions given for small hybrid batteries reduced the taxation for many heavy and powerful vehicles, such as SUVs. Tesla's model S is therefore not the only powerful luxury car that has become less expensive.

Neither the revenue loss nor the apparent reduction in progressivity were necessarily given as consequences of the new (post 2006) objectives regarding emissions. Progressivity could be re-strengthened by elements taxing factory-gate car prices, as it was used prior to the reform. At the same time, the increase in tolls collected, especially in urban and suburban areas, have been challenged on

[9] A 2020 proposal (by the Labour Party Vice Chair, Hadja Tajik) would make car taxation (including the combination of car taxes and fuel taxes) both less regressive and raise revenue: to introduce VAT for the expensive end of zero-emission cars (at around Euros 70k factory gate prices).

equity grounds (tough on low-income urban families with children). In urban areas, a good share of toll revenues are now used to strengthen public transport, in part compensating for this.

A simple model of household preferences for quality characteristics in cars is presented as follows:

$$u^h = u^h(c, q, k),$$

where household *h* cares about quality dimensions *c* associated with CO_2 intensity (as in Figure 3.3), some other quality dimensions *q*, and vehicle kilometres *k*, where the latter can be mostly in tolled areas or mostly in non-tolled areas (e.g. rural).

The corresponding indirect utility function is the solution to the household's maximisation problem within constraints such as income I^h and time, which may be written as

$$v^v = v^h(t_c, t_q, t_t, t_f, t_e),$$

where the five tax rates are taxing, respectively, the CO_2 intensity in cars (as in Figure 3.3), other qualities in the car, tolls (*t*), fuels (*f*), and electricity (*e*).

The optimisation assumed in this formulation gives the following result when asking what welfare costs are borne by household *h* when each of the tax rates are raised. Using the CO_2-differentiated tax as an example:

$$\frac{\frac{\partial v^h}{\partial t_c/t_c}}{\frac{\partial v^h}{\partial I^h/I^h}} = -\frac{t_c c^h}{I^h},$$

the left hand side asks what is household *h*'s marginal change in welfare when the tax rate on CO_2 intensity rises by one percent, expressed relative to the effect of a one percent change in income. The answer, on the right hand side, is the cost share of this CO_2 intensity in household *h*'s income, or total budget. Thus, the households most hurt by this tax are the ones who – for their income group, buy vehicles of relatively high CO_2-intensity. As an illustration through an urban to rural split, if urban households are less in need of ICE vehicles, of driving range, of cargo capacity or horsepower, then a tax rate increase on carbon-intensity will be relatively costly for rural households in similar income brackets. Similarly, along the income or wealth dimension, households are sacrificing welfare in proportion to their income or wealth if carbon-intensity (and the number of cars) has an income elasticity of one, and more than in proportion if carbon-intensity and number of cars is a luxury good. An important caveat on the number of cars and income may be that if rural households are very much in need of at least one car, then any car taxation may have important regressive consequences for rural households. In the United States, where reliance on fuel efficiency standards rather than fuel taxes has puzzled economists, the question of their relative regressivity has been the focus of a longstanding debate. Levinson (2019[12]), in a recent contribution, highlights that fuel efficiency standards function like a tax on inefficiency. This perspective makes instruments raising the fixed costs of vehicle ownership more regressive than fuel taxes, but regressivity holds in general as long as cars and their use are often found to be normal goods, not luxuries.

Figure 3.4. Average CO_2-intensities in new car sales by county and income level

2006, 2007 and 2018

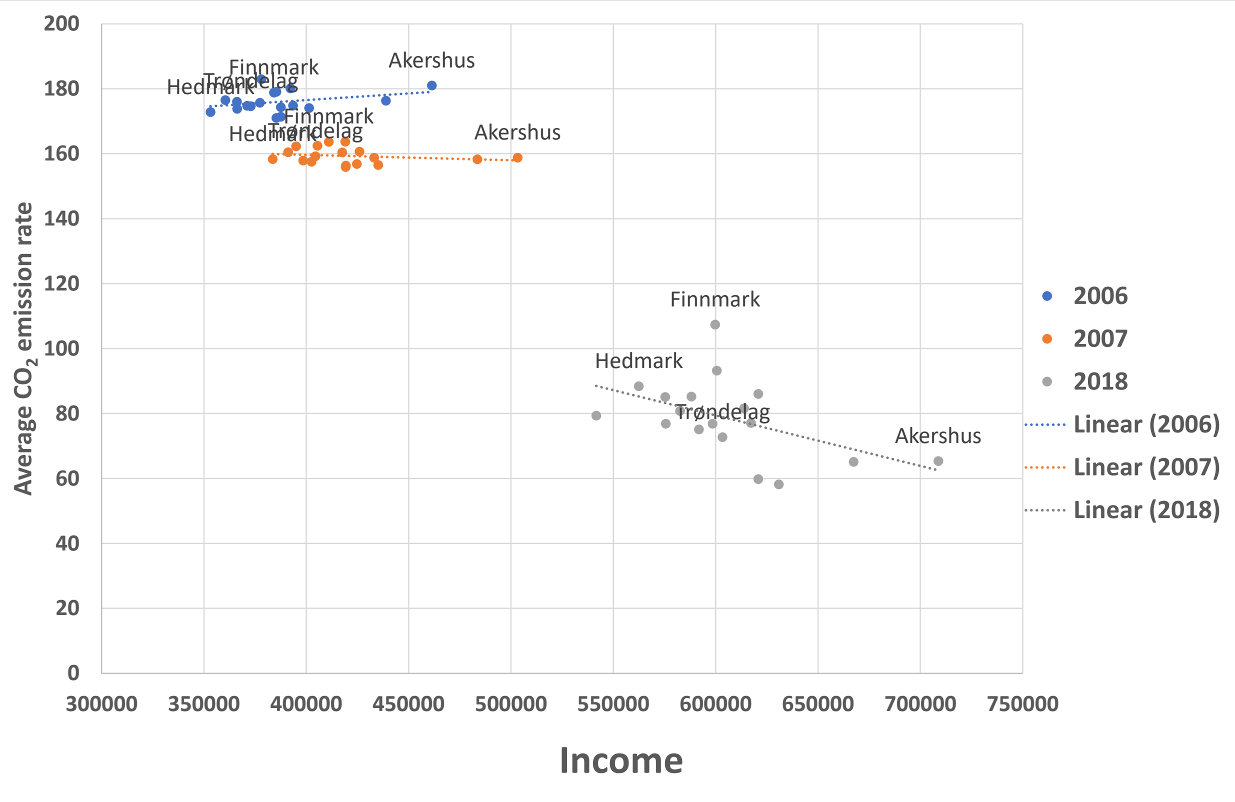


Figure 3.4 describes historical average emission intensities and income data at the county level. As representatives for rural counties, Finnmark and Hedmark, in the arctic and interior, respectively, have lower income, while Akershus is an urban/suburban county with higher incomes. As one can see, CO_2-intensities in new car sales are – as bases for a tax - in the outset (2006) about the same for Akershus as for Finnmark and Hedmark. As such, CO_2-intensity is a regressive tax base: on a per car basis not taxing wealthy county residents more than poorer county residents. By 2018, average CO_2-intensities in new car sales within counties have about halved (descriptively, not simulated), compared to 2006 or 2007. However, one can see that the residents of a wealthier county (Akershus) have to a greater extent been able to take advantage of the less carbon-intensive cars on offer. The linear 2018 regression line, cutting through Hedmark at 90 g/km and Akershus at 65 g/km, illustrates a general tendency when comparing CO_2 intensities in new car sales on a county level basis. It is thus fair to say that a tax on CO_2 intensity in new car sales alone is regressive, and over these years increasingly so. This picture would be somewhat modified by including number of cars sold per household: richer households buy more vehicles, but likely less than in proportion to their higher income. Car taxes, when levied on CO_2-intensities, thus likely are by and large regressive, and more so as the reform has progressed. A recent study, (Fevang et al., 2020[13]), finds that households buying electric cars in Norway are more likely to live in central areas, have children, as well as higher incomes and education, suggestion that a good portion of the patterns displayed here by counties have to do with the electric vehicles.

Similar expressions will be found for the other taxes, displayed here for the fuel tax and the urban toll, respectively:

$$\frac{\frac{\partial v^h}{\partial\, t_f/t_f}}{\frac{\partial v^h}{\partial\, I^h/I^h}} = -\frac{t_f f^h}{I^h}$$

$$\frac{\frac{\partial v^h}{\partial\, t_t/t_t}}{\frac{\partial v^h}{\partial\, I^h/I^h}} = -\frac{t_t t^h}{I^h}$$

Here, similarly, if rural households are (or have been) more dependent on ICE vehicles, and on driving range, then the fuel tax rise ∂t_f is costly for them, relative to the urban toll rate increase (and vice versa). There are efficiency reasons to treat the urban tolls and the fuel tax differently, of course. Both work to suppress demand for driving for a given vehicle. The former is desirable on efficiency grounds if urban congestion and air quality objectives are important (see below), while t_f is preferred if national or global concerns, such as greenhouse gas emissions, are important. Both are important for efficiency reasons if roads are underbuilt in the sense that managing demand reduces congestion. Distributional concerns may – absent better distributional policy instruments – modify this in the direction of more emphasis on tolls.

The expressions above – and Figure 3.4 - consist of Engel curves (the figure though at county and per vehicle data), and thus rate distributional impacts according to income elasticities: or necessities, normal goods and luxury goods. If there are plausible stylised facts along these lines for cars, suggestions might be

- costly car characteristics rise with income more than do vehicle kilometres driven,
- wealthier households buy new cars,
- lower-income households buy used cars, and a higher share of their car costs are fuel costs.

Among middle- to low-income households

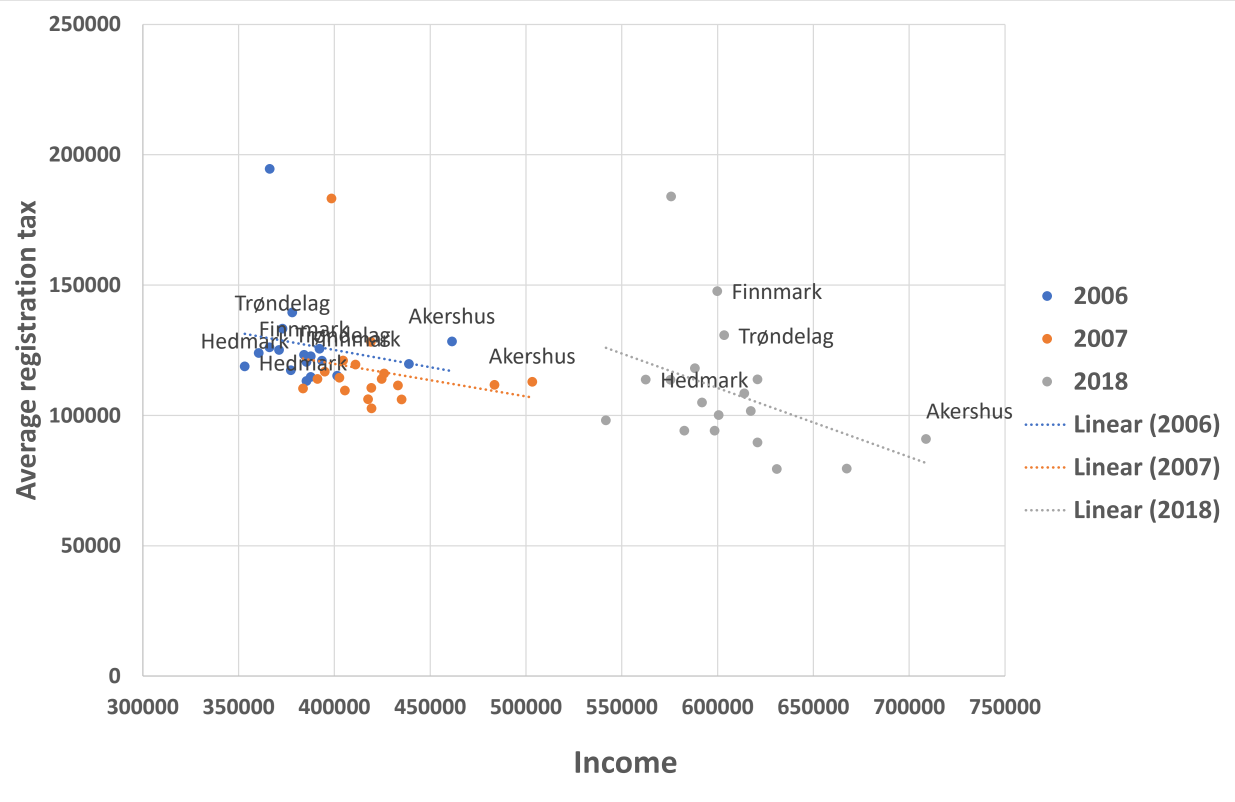
- urban households can do fairly well without a car, with public transport or a BEV,
- suburban households commute most – pkm per year – with public transport or car, perhaps electric cars
- rural households to a great extent depend on range, cars, and on fuel (see (Fevang et al., 2020[13])).

This simple picture provides the distribution-based idea in favour of car standards (such as emission standards, fuel economy standards, and CAFÉ (corporate average fuel economy standards) relative to fuel taxes. Prices in the used car market will in the long run make all used cars more expensive if the tax rate on carbon-intensity raises new car prices, but most so for carbon-intensive cars. However, low-income households will then over time find used cars with lower fuel consumption in the market, and benefit from the lower user cost at less than their full purchase cost as new. Relatively to the fuel taxes necessary to deliver equally fuel-efficient vehicles, the distributional impact from taxes on CO_2-intensity or fuel economy standards may be less regressive and thus more politically acceptable. However, as (Levinson, 2019[12]) points out, if instruments are compared on an equal revenue basis, then fuel taxes are less regressive.

Figure 3.5 demonstrates that the registration tax as such, summing the CO_2-intensity component (part of its base, Figure 3.4) and other components, also has become increasingly regressive over the years. Though the figure fails to correct for cars sold per household, the cars that meet requirements of Finnmark (poorer county, smaller towns, less dense) are by 2018 taxed about fifty percent more than cars bought in Akershus (richer county, suburban, city). A broader picture is definitely more mixed. An example is that urban tolls have increased, while fuel taxes – which would have harmed rural and peripheral counties more – have been only moderately rising.

Figure 3.5. Average vehicle registration tax[10] on new car sales by county and average income

2006, 2007 and 2018



[10] The vehicle registration tax includes CO_2-differentiated tax and other tax components based on, for instance, weight and engine power.

4 Conclusions

Norway has taxed its road sector quite heavily. On efficiency grounds based on public finance principles, taxation of fuels serves well to reduce carbon emissions and road use in general, and tolls serve well to contain road use in certain areas with special problems, such as pollution or congestion.

From 2007 onwards, the country has introduced CO_2-intensity as a base for its registration tax, together with full exemptions for electric vehicles, to discourage purchases of high-emission cars. The CO_2 differentiated registration tax works as a complement to – and alongside with – the fuel taxes that apply in Norway. The fuel taxes on automotive fuels such as diesel and gasoline contain an element labelled a CO_2 tax (NOK 1,45 and 1,26 per litre, respectively) that are around a third or a quarter of other fuel specific taxes (in lieu of road use). Value added tax (VAT) of 25% is levied on top, so fuel prices to users in Norway are about NOK 12 to 13 per litre (November 2020), typically not too different from other European countries.

This study builds on Yan and Eskeland (2018[1]), to provide implications of the CO_2-differentiated tax when broader effects, such as air pollution, congestion, accidents, government revenue and distributional effects are considered.

The CO_2-differentiated tax is well suited for a particular route to reduce greenhouse gas emissions through changing the vehicle fleet to be less carbon-intensive over time, through new car purchases.

Part of its good design is that it is:

- *quite direct*: taxing the intensity (grams per vehicle kilometre) rather than something associated, such as horse-powers, or weight, or air-conditioners;
- *continuous*: encouraging every little gram of CO_2 saved, rather than some lumpy chunks, like “light”, “medium” and “large”, or emission groups.

The CO_2-differentiated tax is for this reason quite effective.[11]

The CO_2-differentiated tax aims to influence emissions through an intermediate-term decision, namely the selection of cars that enter the fleet. Shorter-term consumer decisions of shifting to public transport modes, are to a greater extent influenced by tolls, fuel taxes and public transport fares. Longer-term developments, such as technological R&D and infrastructure provision are outside the scope of this study, but they are presumably driven by expectations, research subsidies, and perhaps also by shorter-term policy instruments such as these studied here, and observed car sales.

The decarbonisation of vehicles is costly, since the vehicle tax rates are based on CO_2 emission rate and imply thousands of NOK per tonne of CO_2. This is hundreds of Euros, as compared to the CO_2 quota price in the European emission trading system (applied to fixed, not mobile, sources), lately in the range of fifteen

[11] This measurement of CO_2 intensity as in the registration document is and has not been perfect. It has been found to be unjust, and also increasingly favourable (especially to low-emitting cars, such as hybrids, in Norway lowering their taxation). The average gap from “real values” rose from 8% to 39% between 2001 and 2017 (Helmers et al., 2019[3]). The measurements have been revised in EU from 2017 with a new and more accurate Worldwide Light Vehicles Test Procedure (WLTP), but in Norway the NEDC values have been applied throughout the sample period, 2006 through 2018. Thus, in the eyes of EU and other pertinent authorities, imperfect measurements of parameters worthy of considerable tax- and regulatory pressures, are thus also worth improving. In this study, this view is shared.

to thirty Euros per tonne. For Norwegian cars, this high vehicle tax rate works together with carbon taxes of fuels, so emission reductions in the Norwegian road sector are not cheap to the Norwegian society, even though Norwegian car buyers can buy a less CO_2-intensive car – including a zero-emission car – for their own frugal budgetary reasons. The cost of greenhouse gas mitigation that Norwegian policies allow car buyers and road users to internalise is very high by standards of the planet, and by Europe's.

A political economy interpretation of Norway's extraordinary pressure on emissions in the road sector could be i) that Norway is without a car industry, thus lacking much industry-based political resistance, ii) that Norway is without a fossil-based electricity and manufacturing sector, thus pressed at an early point to squeeze emissions out of the transport sector, and iii) that Norway draws part of its wealth from petroleum exports, perhaps embodying particular responsibilities for mitigation.

If the air quality benefits of this vehicle tax are included, it makes a costly policy seem more justifiable. A less carbon-intensive car is to a great extent also a less polluting car. (An early and costly exception to this "rule", later "corrected" is a rise in diesel vehicles. Diesel vehicles may contribute more to local air pollution than similarly CO_2 efficient gasoline vehicles). The policy is also made less costly by including such benefits as reductions in congestion, accidents and noise, but perhaps not a lot. The reason is that for these non-emission externalities, the vehicle registration tax trying to shift the *composition* of vehicle purchases in less CO_2-intensive directions really is not well targeted. More effective policies would be a flat tax on all vehicle purchases, but much better are user fees targeting congested areas for congestion, and other regulations or policies to deal with noise and accidents.

The current analysis should be seen in a broader light, as there is a CO_2-component in fuel taxes, as well as tolls, rush-hour differentiation, and air pollution policies. Since Norway and Norwegian cities also apply such policies (perhaps more so than some other countries and cities), a possibility is that while there are benefits in the ancillary reductions of externalities other than climate change, the *net* benefits of those ancillary reductions are zero. Indeed, if optimal policy is employed, this would be the expectation.

For this reason, this paper does not sum up benefits across externalities. It is worth looking at non-emission externalities, since they are large. Indeed, this and other analyses (Parry et al., 2014[14]) indicates that they can be large. For road vehicles, congestion benefits invariably loom large, in this and other studies. A similar example may be that the Clean Power Plan, which aimed to reduce CO_2-emissions from the US power sector, could be justified by air quality health benefits alone, even though its more explicit motivation was greenhouse gas mitigation (Driscoll et al., 2015[15]).

With similar motivation, this study does not examine the registration tax and the revenue reductions from car taxation in light of a shadow price of revenue. The CO_2 differentiated tax has proceeds rising in its tax rate, but reduces proceeds from road users because of larger reductions in fuel tax proceeds (over the life time of the vehicles). Nevertheless, it is patently clear that the revenue reductions can be cancelled by a combination of VAT on electric vehicles and higher general fuel, road use and vehicle taxes. Indeed, a reduced CO_2-intensity as well as progressivity with respect to wealth in road taxation could be retained. In consequence, it is not obviously justified to see reduced revenue nor reduced wealth progressivity as a consequence (nor as an unintended consequence) of the CO_2-differentiated registration tax and the exemptions for zero-emission vehicles.

Including the revenue implications also does not change the picture much. It is true that the recent developments in the registration tax and in tax exemptions for electric vehicles have reduced revenue collected in the road sector. But this obviously can be fixed within the road sector, if deemed desirable or expedient.

From a top-down public finance (welfare economic) perspective, one may examine Norwegian road taxation from the point of view of three perspectives:

1. efficiency objectives (such as managing air quality, congestion, accidents and climate change)
2. revenue (contributing to overall government revenue)

3. progressivity with respect to wealth, income, conspicuous consumption, or personal discretion.

For these three, strong normative implications for the sector as a whole are clearest for 1). There are plenty of policy instruments engaged, at high levels. With respect to climate change, Norway's personal vehicles are decarbonising (and decarbonised) ahead of most countries, and are exposed to pressures not weaker than any other nation's. There are auxiliary benefits to the instruments applied, but this study does not assess whether these are *net* benefits at present margins. With respect to these externalities (some internal to the sector, such as congestion), on the one hand, the CO_2-reductions indicate the sector is reducing its negative externalities (some of them, at least), so falling revenues is an indication that the strategies work. If a tax instrument mostly meant to collect revenue is modified to deliver some other benefits, the falling revenues from this instrument is not a measure of failure. On the other hand, as the vehicle fleet changes in composition towards lower costs of usage, needs may arise to raise such user costs, such as congestion tolls to manage road use and suspended particles in polluted cities or seasons.

With respect to 2), there are a priori arguments that the road sector should be subsidised (a sector with scale and network economies might provide negative net revenue), or taxed (a sector subject internally to congestion – or subjecting other sectors to damages – should offer revenue). In Norway, it is clear that the sector does provide net revenue, and has done so for many decades.

With respect to 3), progressivity, there is no indication in general public finance principles that progressivity with respect to wealth within road sector taxation is necessary or desirable. On the other hand, it is not hard to see that progressivity with respect to wealth, income, ability and consumption comes at a cost in the general tax system (taxes on income, wealth, inheritance, education subsidies, VAT and commodity taxes, say). Then, Norway's traditional practice of heavy taxation of new vehicle purchases may be interpreted as a desired element of progressivity. Norway has recently strengthened progressivity in the property and wealth tax, while removed the inheritance tax. As noted above, the apparent reduction of progressivity with respect to wealth in road taxation could be halted or reversed by removing the VAT exemption for zero-emission vehicles and by reintroducing a value element (i.e. factory gate vehicle price) in the base of the registration tax.

Departing from the top-down public finance perspective, it is plausible that this costly move towards less carbon-intensive cars – with the help of taxation – would not have been so palatable to car buyers without some compensating features. Such a compensating feature has been the expanding opportunities within electric vehicles, and perhaps also the overly generous tax treatment of zero-emission vehicles (electric) as well as pluggable hybrids. As shown in Figure 3.4 and Figure 3.5, richer county households have reduced their relative emission rates more than their relative registration tax revenue contributions, indicating that their reduced tax contributions in part are explained by lower-emission cars that tax changes have made attractive. In other words, to some extent they contribute more to emission reductions as they contribute less with revenue, reflecting an ability the country may be seen as trying to exploit. On the other hand, if emerging availability of zero-emission cars have made the tax reform politically acceptable to car buyers at a national level, then these cars seem to have served rural and peripheral households less, in this sense making car taxation more regressive over these years.

Other compensating features that car owners could have been offered – but quite generally have not obtained, and defensibly so – are reduced fuel taxes or tolls. Tolls for zero-emission vehicles have been zero and are still low, but general toll revenues have been rising, not only to fund roads but also funding public transport improvements in the so-called city packages, negotiated with fiscal support from the national government. The national government is not only a powerful policy maker, but also the recipient of registration tax and fuel tax revenues.

Advocates of environmental progress and public transport have thus been defending both fuel taxes and tolls, and this may have contributed to the combination of a less progressive tax collection from costly cars (the value element in the registration tax was eliminated) and the very generous tax exemptions for zero-emission vehicles, including no VAT. The Norwegian experience discussed in Norway and worldwide thus is much broader than the CO_2-differentiated registration tax and the generous incentives for zero-emission vehicles. It involves a history of high vehicle and road taxes, decades of expanding toll rings with increasing sophistication, and CO_2 taxation in fuels. The CO_2-differentiated registration tax is costly, considering charges per tonne of CO_2. It is less expensive if considering auxiliary benefits in terms of air pollution, congestion, noise and accidents, but it is certainly less well targeted to deliver this broader range of benefits, such as noise and congestion, that are commonly addressed with other policy instruments.

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Annex A. Additional data

Table A A.1. Annual vehicle distance travelled by fuel type

Average number of km driven annually per vehicle

	Petrol	Diesel	Electric	Petrol plug-in hybrid	Petrol hybrid	Diesel plug-in hybrid	Diesel hybrid
2006	12,113	18,449	7,407				
2007	12,249	19,309	7,248				
2008	11,878	19,024	6,635				
2009	11,517	18,312	7,926				
2010	11,106	17,335	6,806				
2011	10,709	16,626	6,427				
2012	10,365	16,691	7,612				
2013	9,990	16,229	5,692				
2014	9,695	15,741	7,729				
2015	9,502	15,494	11,380				
2016	9,309	15,059	11,788	9,652	12,614	13,953	20,606
2017	9,210	14,829	11,818	11,375	12,835	13,286	19,734
2018	9,034	14,527	12,171	14,352	13,572	15,437	18,665

Source: Statistics Norway.

Table A A.2. Emission rates of CO_2 and air pollutants from fuel combustion

	Year	CO_2	SO_2	NO_x	NMVOC	$PM_{2.5}$
		Tonne/tonne	Kg/tonne	Kg/tonne	Kg/tonne	Kg/tonne
Petrol	2018	3.130	0.010			
Petrol	2017	3.130	0.010			
Petrol	2016	3.130	0.010			
Petrol	2015	3.130	0.010			
Petrol	2014	3.130	0.010	4.273	6.852	0.047
Petrol	2013	3.130	0.010			
Petrol	2012	3.130	0.010	5.485	7.767	0.051
Petrol	2011	3.130	0.010	6.042	8.166	0.053
Petrol	2010	3.130	0.010	6.026	7.939	0.051
Petrol	2009	3.130	0.010	6.721	8.623	0.055
Petrol	2008	3.130	0.010	6.879	10.347	0.139
Petrol	2007	3.130	0.010	7.229	10.842	0.141
Petrol	2006	3.130	0.010	8.296	12.612	0.151
Diesel	2018	3.170				
Diesel	2017	3.170				
Diesel	2016	3.170				
Diesel	2015	3.170				
Diesel	2014	3.170	0.014	8.668	0.616	0.341
Diesel	2013	3.170	0.014			
Diesel	2012	3.170	0.015	9.093	0.692	0.393
Diesel	2011	3.170	0.015	9.083	0.729	0.455
Diesel	2010	3.170	0.015	8.660	0.729	0.494
Diesel	2009	3.170	0.029	9.360	0.843	6.15
Diesel	2008	3.170	0.028	4.514	1.013	0.808
Diesel	2007	3.170	0.024	4.910	1.101	0.922
Diesel	2006	3.170	0.028	5.903	1.381	1.264

Source: The Norwegian Emission Inventory reports[12], Statistics Norway.

Table A A.3. Marginal external costs

	Petrol	Diesel	Unit
CO_2	1,000	1,000	NOK per tonne
SO_2	149,226	149,226	NOK per tonne
NO_x	232,053	232,053	NOK per tonne
NMVOC	16,429	16,429	NOK per tonne
$PM_{2.5}$	2,040,900	2,040,900	NOK per tonne
Accidents	0.24	0.24	NOK per vkm
Congestion	0.59	0.59	NOK per vkm
Noise	0.08	0.08	NOK per vkm

Source: van Essen et al. (2019[10]).

[12] https://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/the-norwegian-emission-inventory-2016.

Table A A.4. Road usage tax and carbon tax for petrol and diesel

NOK per litre

	Road use tax		Carbon tax	
	Petrol	Diesel	Petrol	Diesel
2006	4.10	2.97	0.79	0.53
2007	4.17	3.02	0.80	0.54
2008	4.33	3.40	0.82	0.55
2009	4.46	3.50	0.84	0.57
2010	4.54	3.56	0.86	0.58
2011	4.62	3.62	0.88	0.59
2012	4.69	3.68	0.89	0.60
2013	4.78	3.75	0.91	0.61
2014	4.87	3.82	0.93	0.62
2015	4.87	3.36	0.95	1.09
2016	4.99	3.44	0.97	1.12
2017	5.19	3.80	1.04	1.20
2018	5.17	3.75	1.16	1.33

Source: National budgets[13], Norway.

[13] https://www.statsbudsjettet.no/Statsbudsjettet-2016/English/

Table A A.5. Lifetime emission reductions induced by the CO_2-differentiated vehicle registration tax

Tonnes	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
CO_2	-1,538,388	-25,758	-53,963	-374,370	-15,250	-172,240	-41,885	-180,386	-10,936	-534,481	-859,903	-273,182	-340,062
NMVOC	-3,693	-31	-78	-491	-17	-205	-50	-329	-8	-1,037	-1,950	-655	-712
NO_x	-3,528	-52	-112	-769	-31	-349	-85	-391	-21	-1,172	-1,947	-626	-757
$PM_{2.5}$	-319	-8	-16	-117	-5	-56	-14	-47	-4	-135	-189	-57	-81
SO_2	-9	0	0	-3	0	-1	0	-1	0	-3	-5	-2	-2
Percentage													
CO_2	-33%	-1%	-2%	-12%	-1%	-6%	-2%	-7%	0%	-20%	-30%	-15%	-10,7%
NMVOC	-47%	-1%	-2%	-12%	0%	-5%	-1%	-7%	0%	-16%	-27%	-13%	-11,0%
NO_x	-35%	-1%	-2%	-12%	-1%	-6%	-1%	-7%	0%	-19%	-30%	-14%	-10,7%
$PM_{2.5}$	-25%	-1%	-2%	-12%	-1%	-7%	-2%	-7%	-1%	-23%	-35%	-17%	-11,1%
SO_2	-28%	-1%	-2%	-12%	-1%	-6%	-2%	-7%	-1%	-22%	-33%	-16%	-10,9%

Table A A.6. External costs reductions induced by the CO_2-differentiated vehicle registration tax

Million NOK	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Average
Climate	-1,538	-26	-54	-374	-15	-172	-42	-180	-11	-534	-860	-273	-340
Air pollution	-1,531	-30	-61	-426	-18	-199	-48	-193	-13	-564	-871	-272	-352
Accidents	-1,803	-33	-50	-512	-20	-274	-51	-304	-9	-883	-1,586	-503	-502
Congestion	-4,504	-81	-126	-1,279	-51	-685	-127	-758	-22	-2,206	-3,960	-1,256	-1,255
Noise	-623	-11	-17	-177	-7	-95	-18	-105	-3	-305	-548	-174	-174
Percentage													
Climate	-33%	-1%	-2%	-12%	-1%	-6%	-2%	-7%	0%	-20%	-30%	-15%	-11%
Air pollution	-30%	-1%	-2%	-12%	-1%	-6%	-2%	-7%	-1%	-21%	-32%	-15%	-11%
Accidents	-28%	-1%	-1%	-10%	0%	-5%	-1%	-6%	0%	-14%	-22%	-9%	-8%
Congestion	-28%	-1%	-1%	-10%	0%	-5%	-1%	-6%	0%	-14%	-22%	-9%	-8%
Noise	-28%	-1%	-1%	-10%	0%	-5%	-1%	-6%	0%	-14%	-22%	-9%	-8%

Table A A.7. Tax changes induced by the CO_2-differentiated vehicle registration tax

Million NOK	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Average**
Fuel Tax	-2,614	356	39	-578	56	-225	21	-258	-5	-982	-1,646	-561	-533
Vehicle Tax	1,130	35	-46	341	19	338	-3	387	-10	645	468	25	277
Percentage													
Fuel Tax	-35%	9%	1%	-11%	1%	-4%	0%	-5%	0%	-17%	-26%	-13%	-8%
Vehicle Tax	60%	1%	-2%	14%	1%	14%	0%	20%	-1%	38%	11%	1%	13%