Steinsland C, Fridstrøm L, Madslien A, Minken H. The climate, economic and equity effects of fuel tax, road toll and commuter tax credit.

Transport Policy. 72 (December), 2018, 225-241. 0967-070X

Transport Policy
Available online 24 May 2018
In Press, Corrected Proof

The climate, economic and equity effects of fuel tax, road toll and commuter tax credit

Christian Steinsland, Lasse Fridstrøm, Anne Madslien, Harald Minken

Institute of Transport Economics (TØI), Gaustadalléen 21, NO-0349 Oslo, Norway

Received 30 August 2016, Revised 6 April 2018, Accepted 28 April 2018, Available online 24 May 2018.

Show less

https://doi.org/10.1016/j.tranpol.2018.04.019 Get rights and content

Highlights

- Increased fuel tax could be welfare enhancing in view of external costs of road use and the marginal cost of public funds.
- The same applies to a revocation of the commuter tax credit.
- But both of these policy options are distinctly regressive, as measured by their impact in low vs. high income zones.

Abstract

State-of-the-art travel demand models for Norway have been run with the aim of revealing the equity effects of selected policy measures for greenhouse gas abatement. The Oslo Intercity Regional Model, comprising roughly 43 per cent of Norway's five million population, was used to study short distance trips in southeastern Norway, i. e. in and around the capital city of Oslo. The NTM6 model for domestic, long distance travel was used to analyze domestic trips longer than 70 km one way. Both of these are network models of travel demand, predicting car ownership, trip frequency, destination choice, mode choice and route choice under user specified input assumptions.

The following three policy options have been studied: (i) tripled toll rates and ferry fares everywhere in Norway, (ii) a NOK 0.20 (= € 0.024) per vehicle km road charge or equivalently higher fuel tax, and (iii) abolishment of the commuter tax credit, which in 2014 amounted to roughly € 0.05 per km for long-distance commuters. By design, these three policy options give rise to similar reductions in CO_2 emissions from travel.

While option (i) turns out to be highly inefficient, options (ii) and (iii) appear, in a partial travel demand analysis, to be welfare increasing even before CO_2 abatement benefits. However, when the policy options are ordered according to their equity effects, the ranking becomes completely reversed. The abolishment of the commuter tax credit appears to hit people in low income neighbourhoods five to fifteen times harder than those living in high income zones. The fuel tax increase gives rise to corresponding inequity ratios between three and seven. The main explanation is that residents of remote, low income areas generally sustain longer commutes, and also to a larger extent depend on their cars for commuting than do workers in densely populated urban or suburban districts.

Keywords

Efficiency; Distribution; Greenhouse gas; Fuel tax; Toll; Tax credit

1. Introduction

Policy measures to reduce the climate and environmental impact of transport are being considered world-wide. One major concern relates to the equity effect of the respective measures in question. Will the measures affect different segments of the population in unfair or unreasonable ways? How large is their economic cost or benefit? The aim of this paper is to shed light on these issues, in the context of certain fiscal instruments as applicable in Norway.

Equity effects may be measured along a number of different dimensions. Most commonly, the focus is on (changes in) the *income* distribution. Other dimensions may, however, also be of interest in a political context. These dimensions include *age, gender,* and *type of household*.

For quantitative assessment one needs a quantitative behavioural model. In this paper, two different models have been used:

- The Oslo Intercity Regional Model for short trips in south-eastern Norway
- The NTM6 model for long-distance domestic travel in Norway

Three different types of policy instruments have been studied: (A) increased fuel tax or kilometre charge, (B) higher toll rates and ferry fares, and (C) abolishment of the commuter tax credit.

As our main criterion for benefit assessment, we use the relative changes in consumer surplus as calculated for various policy measures, travel distances and population segments. A simplified method of calculation, based on the so-called rule-of-a-half, is applied. Results are interpretable as policy effects as of 2014.

In Section 2, we explain some of the tax rules bearing on automobile use in Norway. In Section 3, our modelling apparatus is described. Section 4 sets out the main principles of applied equity analysis. Results are shown in Section 5. A discussion is offered in Section 6, while conclusions are drawn in Section 7.

2. Taxes on automobile[1] use in Norway

2.1. Fuel tax

In Norway as of 2014, petrol was subject to a ‘road use’ tax amounting to NOK[2] 4.87 per litre, a ‘CO_2’ tax of NOK 0.93 per litre, and a general value added tax (VAT) of 25 per cent, calculated on the retail price including the road use and CO_2 taxes. Diesel was subject to corresponding tax rates of NOK 3.82, NOK 0.62 and 25 per cent VAT. Needless to say, one NOK of ‘road use’ tax has the exact same behavioural and distributional effect as one NOK of ‘CO_2’ tax, regardless of how the two are labelled.

Biodiesel was in 2014 subject to a ‘road use’ tax of NOK 1.91 per litre. No ‘CO_2’ tax was levied on biofuel. Since October 2015, the ‘road use’ tax on biodiesel has been abolished.

In our model simulations, we shall examine the case where the fuel cost per car km as of 2014 increases by NOK 0.20 (= € 0.024). Given the average fuel mileage of the Norwegian passenger car fleet (about 30 mpg[3]), this corresponds to a fuel price increase of about 20 per cent, or an almost 40 per cent increase in the fuel tax rate.

There is no kilometre charge in effect for Norway. However, our simulated fuel price increase corresponds to a flat NOK 0.20 per km road charge, as implemented, e. g., through a satellite based surveillance system like the one considered for the Netherlands (Meurs et al., 2013).

2.2. Ferries and toll roads

As of January 2014, some 60 toll cordons or toll collection points were in operation in Norway. With few exceptions, the toll rates are time invariant, their purpose being road funding rather than congestion charging. The rates per passenger car passing vary from NOK 11 to NOK 150.

In many cases, toll collection is used as a means to fund bridges and subsea tunnels that replace previous ferry crossings. Yet there are still some 120 ferry crossings left in the Norwegian road network. In this study, we simulate a 200 per cent increase in all toll rates and ferry fares, i.e. tripled rates.

2.3. Commuter tax credit

As of 2014, commuters were allowed to deduct their travel expenses on their tax declaration, at a rate of NOK 1.50 per km in excess of 10 000 km annual travel distance between home and workplace, up to 50 000 km. Between 50 000 and 75 000 km the rate was NOK 0.70. The 50 000 km threshold corresponds to an about 44 km daily round trip through a 230-day working year. As of 2014, the NOK 1.50 per km deduction translates into a NOK 0.42 per km tax credit, the marginal applicable tax rate being 28 per cent.[4]

The deduction is given no matter what mode of travel is actually used, and without any need to document travel expenses, as long as the home address and the job address are sufficiently far apart. If preferred, the taxpayer is free to use his private car, in which case the tax credit is typically sufficient to cover just about half his petrol or diesel cost. For battery electric vehicle users, the tax credit is more than sufficient to offset the entire energy cost.

In 2014, 420 107 taxpayers, about one out of nine, had annual commuting costs higher than NOK 15 000 and were hence eligible for the commuter tax credit. Their mean annual deduction was NOK 15 434. As averaged over all 3 637 788 taxpayers, the deduction was NOK 1782 (Table 2.1). In this study, we examine the effect of abolishing the commuter tax credit, as proposed recently by the 'green tax commission' (NOU 2015:15).

Table 2.1. Tax statistics for 2014. Source: Statistics Norway (Statistikkbanken).

	Affected persons 17 and older (number)	Aggregate amount (mNOK)	Average amount among eligible (NOK)	Average amount among all taxpayers (NOK)
Positive gross income	4 059 909	1 730 103	426 143	475 592
Commuter costs above kNOK 15	420 107	6484	15 434	1782
Positive income tax payable	3 637 788	433 843	119 260	119 260

3. Modelling apparatus

State-of-the-art travel demand models exist for short distance trips within several Norwegian regions, as well as for long distance travel nationwide. The model system consists of one model for long distance trips, NTM6, and five regional models (RTM) for short distance trips. Together these models cover all domestic trips in Norway. By definition, long distance trips are longer than 70 km one way.

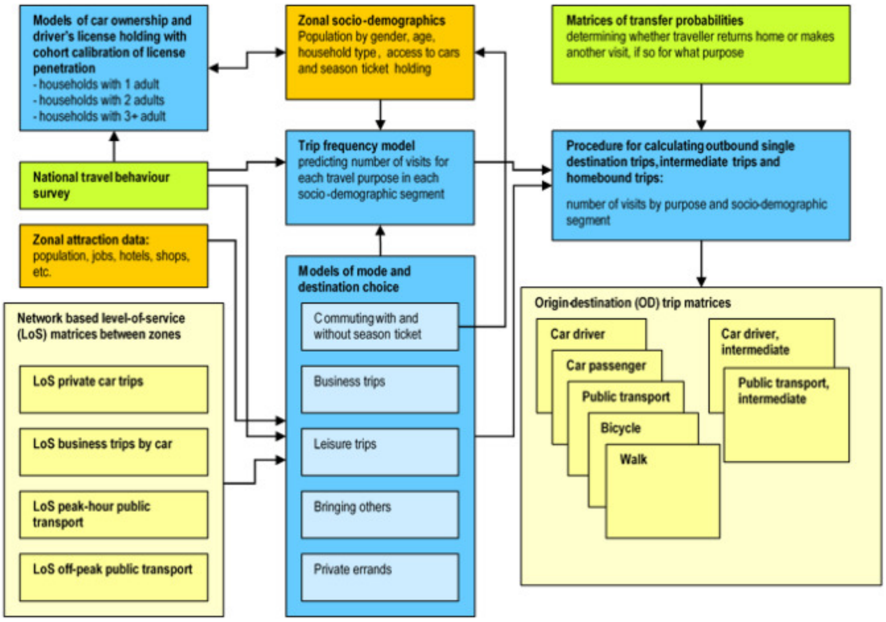
Travel demand as predicted by the models is conditioned by household car ownership and driver's license holding and by the location of residences, jobs and other nodes of attraction. The models predict travel demand response in terms of trip frequency, destination choice, mode choice and route choice, all of these being endogenously determined by the relative generalised costs of the respective travel options. The generalised costs are composed of out-of-pocket expenditure as well as of in-vehicle time, waiting time, transfer time and access/egress time, the monetary value of which have been estimated through micro-econometric analysis of data from the national travel behaviour survey.

The models do not distinguish between different types of automobiles. There is one representative per kilometre rate of out-of-pocket expenditure applicable to all car trips, covering fuel, tyres, maintenance and other variable costs. Thus the models cannot technically distinguish between a hypothetical NOK 0.20 kilometre charge and a corresponding increase in the average fuel cost.

3.1. Regional network models of short distance travel demand

The short distance model system predicts travel demand between pairs of geographic zones. In general, these zones are defined so as to coincide with the census districts known as 'basic statistical units', of which there are some 14 000 nationwide, with an average population of approximately 350.

First estimated in 2003/2004 on survey data from 2001 (Denstadli and Hjorthol, 2002), the system includes submodels for *car availability*, *trip frequency*, simultaneous *mode and destination choice*, *route choice*, and a procedure splitting trips between regular return trips and trips with two errands/visits before returning home (Rekdal et al., 2013; Madslien et al., 2005). A simplified flowchart is presented in Fig. 3.1.



Download high-res image (871KB) Download full-size image

Fig. 3.1. Information flows in the regional Norwegian travel demand models for short-haul trips. Source: Madslien et al. (2005).

The model system produces travel demand matrices for.

- Five regular travel purposes (commute, business, leisure, bring others, and private errands)
- For trips with a combined travel purpose, three separate legs: (i) outbound, (ii) intermediate, and (iii) homebound
- Five travel modes (car driver, car passenger, public transport, bicycle and walk).

In its first generation, the model system did not take account of congestion. It has since been reestimated so as to separate trips into four distinct travel time periods per day. The introduction of congestion implies that the model system must be run in iteration between travel demand and travel times/costs in congested areas. This is time consuming, so a split between four time periods is normally used only for smaller urban submodels, while the larger regional models are normally run with only one or two time periods (peak/off-peak).

For each zone, the demographic data underlying the model system partitions the resident population into a cross-tabulation of twenty 5-year age groups, two genders and three household categories (one adult aged 18+, two adults, three or more adults). In addition, every socio-demographic group in a zone is subdivided into five car availability segments, capturing unequal opportunities for travelling by car. A distinction is made between households with (i) neither car nor driver's license, (ii) car but no driver's license, (iii) driver's license but no car, (iv) fewer cars than driver's licenses, (v) at least as many cars as driver's licenses.

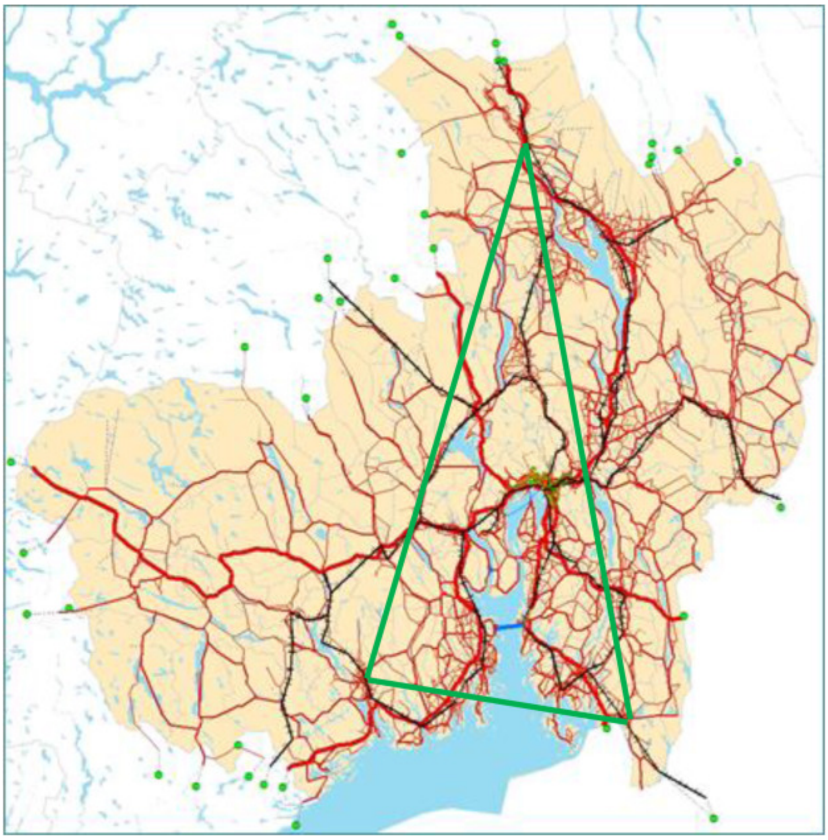
The individual access to cars is used as input in the mode/destination model for each travel purpose, along with various level-of-service data defining the generalised costs of the trips, as well as zonal data describing the attraction of competing destinations. The mode/destination models are formulated as nested logit models. Having a separate nest for those possessing season tickets (monthly passes etc.) for public transport, the model for commuting trips is a bit more complicated than the rest.

The partitioning into access-to-cars categories is based on a demand model explaining automobile ownership (or lease) as a function of gender, age, household income, presence of children, urbanization (density of jobs and population), and the logsum taken from the travel demand model for commuting trips. In model applications, households are shifted between the car availability groups in response to changes in the local levels of income and urbanization.

The trip frequency models are formulated as hurdle Poisson models (Mullahy, 1986) for each of five age groups. Important explanatory variables are gender, age, family type, type of residence, and a logsum from the corresponding mode/destination model, which implies that the travel frequency is influenced by the accessibility described in the mode/destination model, i.e. level-of-service, attractiveness of destinations, and car availability.

3.2. The Oslo Intercity Regional Model

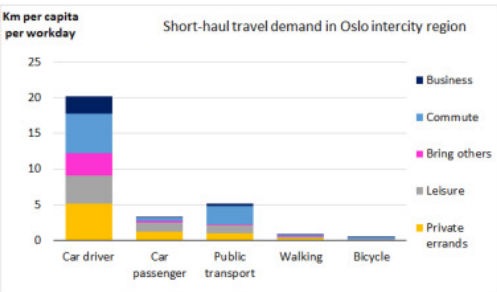
In our study, we have adapted and applied a specialized combination of two of these regional travel demand models, covering an area stretching some 100–200 km out from the capital city of Oslo – more precisely the so-called Intercity Triangle formed by the smaller cities of Skien, Lillehammer and Halden and surroundings (see triangle drawn in green in Fig. 3.2). Containing 5566 zones, the Oslo Intercity Regional Model encompasses 43 per cent of the nation's about five million resident population (Steinsland, 2009, 2011, 2014). The public transport network consists of boat, bus, railway, tramway and subway (metro) lines. For the purpose of our analyses, the model was calibrated against aggregate flow data for December 2013. Network level-of-service (LOS) data for all modes of transport were updated to 2014.



Download high-res image (1MB) Download full-size image

Fig. 3.2. Map of area covered by the Oslo Intercity Regional Model network for short distance trips. Roads in red, railroads in black, and sea routes in blue. Triangle corners indicate cities of Lillehammer, Skien and Halden.

Short-haul travel demand in the reference scenario is shown in Fig. 3.3.



Download high-res image (183KB) Download full-size image

Fig. 3.3. Benchmark short-haul person kilometres in the Oslo intercity model region, by travel purpose and mode.

Some 68 per cent of the person kilometres travelled are made by car drivers. When passengers are included, the car share is 79 per cent. Public transport (PT) has a 17 per cent share. Among commuters, the PT share is 28 per cent.

The private car accounts for 95 per cent of the CO_2 emissions from short-haul travel in the Oslo intercity region, the remaining 5 per cent being due mostly to bus/coach.

3.3. The NTM6 model

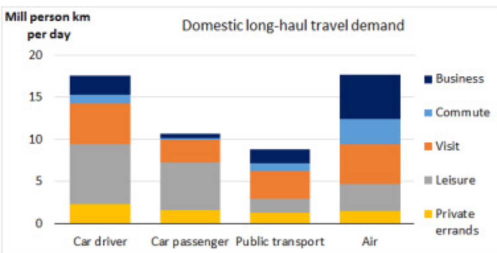
The NTM6 long distance model has much of the same structure as the short distance regional models. Containing 1428 zones, it is, however, more aggregate than the regional model system. The network is shown in Fig. 3.4. Since, for some origin-destination (OD) pairs in Norway, the shortest connection passes through Sweden and/or Finland, the network includes some border crossing links.

Download high-res image (1MB) Download full-size image

Fig. 3.4. Map of the NTM6 long distance travel demand model network. Roads in red, railroads in black, air routes in grey, and sea routes in blue.

Being based on travel behaviour data from 2009 and network data from 2013, the NTM6 model defines six different modes: car driver, car passenger, bus/coach, rail, sea and air (Rekdal et al., 2014).

Long-haul domestic travel demand in the reference scenario is shown in Fig. 3.5. Just about 50 per cent of the long-haul person kilometres are made by car (drivers and passengers). The air mode has a 32 per cent share. The public transport (PT) category comprises the bus/coach, rail and sea modes.



Download high-res image (167KB) Download full-size image

Fig. 3.5. Benchmark domestic person kilometres on long-haul trips, by travel purpose and mode.

3.4. An application to climate policy appraisal

To study the greenhouse gas (GHG) abatement effect of various policy options, we generate a set of potential policy scenarios and compare these to the reference (benchmark) scenario. The following scenarios have been calculated (confer Section 2):

A. A NOK 0.20 kilometre charge or equivalently increased fuel tax.

B. Tripled toll rates and ferry fares everywhere

C. Abolishment of the commuter tax credit.

Each policy measure impacts the perceived generalised cost of travelling, although in quite different ways for the various OD zone pairs and for various population subgroups. Apart from these changes to the generalised costs of travel, all model parameters are kept constant in the model runs, in accordance with their estimated or calibrated value.

Our short and long distance travel demand models predict overall trip frequency as well mode and destination choice. The trip frequency depends on accessibility as described by the logsums from the lower level nested logit model of mode and destination choice. Hence, the models take full account of any induced demand effects due to changes in the level-of-service.

Faced with increasing fuel prices, higher toll rates and ferry fares, or a revocation of the commuter tax credit it, some households may choose no longer to own a car. Even this induced demand effect is taken account of in our calculations, as car ownership rates change in response to variations in the logsum derived from the travel demand model.

By design, the three policy options are expected to yield comparable GHG abatement effects. CO_2 emissions follow from the travel demand output (origin-destination trip matrices, see lower right corner of Fig. 3.1) through the application of per person kilometre (PKM) emission rates. Although these rates vary not only by mode, but also by occupancy (Borken-Kleefeld et al., 2013; Aamaas et al., 2013), certain mode-specific average rates are used. These assumptions are set out in Table 3.1.

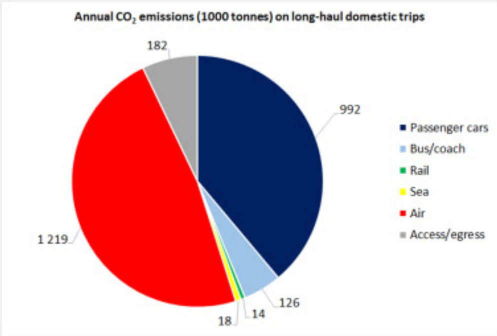
Table 3.1. Input CO_2 emission rates by mode.

Mode	gCO_2/PKM
Diesel driven trains	80
Coach/bus	92
Air	198
Speed boat	904
Ferry	621
Car driver - urban	202
Car driver - rural	149
Car passenger	0

Only direct emissions (pump-to-wheel) are accounted for. Electrically driven means of transport are assumed to generate zero emissions. This assumption can be justified, either by the fact that Norwegian electricity supply is almost 100 per cent hydropower based, or by the fact that all EEA[5] power plants are covered by the European cap-and-trade system for GHG emission allowances (EU ETS).

Greenhouse gases other than CO_2 are disregarded. The inaccuracy caused by this simplification is small, except perhaps for the air mode, where the high altitude emissions of particles and water vapour do have a significant climate impact, through the formation of contrails and cirrus clouds (Borken-Kleefeld et al., 2010).

Almost one half (48 per cent) of the CO_2 emissions on long-haul domestic trips are due to aviation (Fig. 3.6). The car as a main mode of travel accounts for about 39 per cent. The access-egress ‘mode’, which also to a large extent consists of car trips, accounts for an additional 7 per cent.



Download high-res image (162KB) Download full-size image

Fig. 3.6. Benchmark CO_2 emissions on long-haul domestic trips, by mode.

In our model simulations, public transport vehicle kilometres – and hence CO_2 emissions – are assumed to respond to demand according to Mohring's (1972) square root law of optimal supply. That is, when demand increases by *x* per cent, vehicle kilometres increase by a factor given by the square root of (100 + *x*)/100. This applies even to the air mode.

3.5. Socio-demographic segmentation

In their standard versions, the RTM and NTM6 models produce output in the form of tables showing trip generation and person kilometres travelled, by travel purpose and mode. Output is not segmented by population subgroups. However, for the purpose of equity comparisons, we want to predict travel behaviour responses within selected segments of the population.

To generate this kind of output, we have run the models separately for 22 socio-demographic groups, each time as if the selected group constitutes the entire zonal population. In so doing, certain precautions must be taken, so as to, e. g., not underestimate the congestion caused when all groups travel simultaneously on the same network. To circumvent this problem, in-vehicle travel times have been calculated from the aggregate model run and applied separately to each population subgroup and each travel purpose.

The socio-demographic segmentation used is shown in Table 3.2. There are five access-to-car categories, five household types, six age groups and two genders, the last two dimensions being fully cross-tabulated.

Table 3.2. Socio-demographic segmentation.

Code	Description
LC1	Persons without a driver's license and without car in household
LC2	Persons without a driver's license but with car in household
LC3	Persons with a driver's license but without car in household
LC4	Persons with a driver's license and with at least as many cars as licenses in household
LC5	Persons with a driver's license but with fewer cars than licenses in household
HH1	Single adults
HH2	Single adults with children
HH3	Couples
HH4	Couples with children
HH5	Households with more than two adults
F1	Females aged 13-17
F2	Females aged 18-24
F3	Females aged 25-44
F4	Females aged 45-59
F5	Females aged 60-66
F6	Females aged 67+

Code	Description
M1	Males aged 13-17
M2	Males aged 18-24
M3	Males aged 25-44
M4	Males aged 45-59
M5	Males aged 60-66
M6	Males aged 67+

4. Assessment principles

4.1. Consumer surplus changes

Assume that in the initial situation travellers by a certain mode, say by private car, perform an amount of travel denoted by v_0, at a generalised cost k_0. Imagine that under some alternative policy scenario, the cost is raised to k_1, and demand falls to v_1. The change in consumer surplus may then be roughly estimated by the well-known 'rule-of-a-half' formula

$$N = \frac{(k_1 - k_0)(v_1 + v_0)}{2}$$

To assess the welfare costs incurred by private travellers, we have resorted to this rule, which measures the change in consumer surplus as one moves up or down the demand curve. The rule applies to every single origin-destination (OD) pair in the geographic area considered. For each OD pair, the generalised cost consists of out-of-pocket expenditure (fares, fuel, toll, etc.), travel time, headway, walking distance, as well as other elements of (dis)utility perceived by the travellers. To obtain an overall estimate of the consumer surplus change one sums through all OD pairs that experience a change in generalised cost (Neuburger, 1971).

In this process, the value of time entering the generalised cost functions has been set in accordance with official government guidelines for cost-benefit analysis (Statens vegvesen, 2018) rather than with the empirical values implicit in the disaggregate mode and destination choice models estimated. This ensures conformity with the standard calculation methods otherwise used in Norwegian transport appraisal.

The rule-of-a-half is an approximation suitable for changes small enough to warrant an assumption that the demand curve is a straight line over the interval considered. Some of the policy changes considered here, such as tripled toll rates and ferry fares, may not be in accordance with such an assumption. Some extra caution would be in order when outcomes pertaining to these policy options are interpreted, although even these results are unlikely to be widely off the mark. It would have been preferable to apply the more accurate method of summing up all the changes in the logsums arising at the various levels of disaggregate decisions (route, mode, destination, frequency), as originally suggested by Williams (1977). Due, however, to certain practices of aggregation, segmentation and trip chaining used in the complex modelling system shown in Fig. 3.1, such a procedure has not been feasible in practice.

4.2. Income distributional effects

4.2.1. Definitions

A tax or policy measure is said to be *regressive* if it imposes a heavier burden on low-income households than on their more affluent counterparts. In the opposite case, we refer to the tax as *progressive*.

To use this definition for practical, empirical analysis one has to decide what is to be meant by 'a heavier burden'. To make the concept operational, it has become common to compute the tax expenditure or welfare loss incurred by each household as a percentage of their current income. If this percentage is a decreasing (increasing) function of income, when households are grouped into income deciles or similar, the tax is regressive (progressive).

Although this may seem like a straightforward way of deciding on regressivity or progressivity, certain ambiguities remain. Vickrey (1947, 1949, 1987) points out that since most households adapt their level of expenditure to their lifetime income expectancy, or to some more 'permanent' income measure, rather than to a single year's earnings, it would be more appropriate to view income in a long-term perspective.

One way to circumvent this problem is simply to group households by their total annual expenditure rather than by their current income. This procedure has been used in a number of empirical studies. It turns out, however, that a given tax tends to come out as less regressive when judged along the expenditure scale than according to an income scale – see, e. g., Ahola et al. (2009) or the review article by Kosonen (2012).

4.2.2. Literature review

During the last couple of decades, a large number of studies have been made on the equity effect of environmental taxes and other fiscal instruments for market correction. Poterba (1991) starts out by referring to 'the long-standing view that excise taxes such as the gasoline tax are regressive'. He finds, however, that the outlay on petrol ('gasoline') represents a much smaller share of income in the low-income deciles than in the middle-income deciles, which – in turn – do not differ much from the high-income deciles. The petrol tax is, in other word, progressive, at least over the lower half of the income spectrum. The main reason seems to be that poor families cannot generally afford a car, hence their average petrol expenditure is quite low.

Deakin et al. (1996) found that fuel tax, congestion charges and parking charges would affect the middle income groups of California harder than the lowest income quintile, since the latter represent only 7 per cent of the vehicle miles travelled.

Santos and Catchesides (2005) find that the British petrol tax is strongly regressive when only car-owning households are considered, but when all households are taken into account, the middle income households are the most seriously affected.

Kosonen (2012) reviews a number of studies from the Nordic countries. Tuuli (2009) finds that the motor fuel budget share increases up to the sixth to eighth expenditure decile, before levelling out. This is due, mainly, to the fact that low-income families own fewer cars than households in the middle-income range. He concludes that the fuel tax is not regressive in Finland, however represents a higher burden in rural areas than in the cities. Ahola et al. (2009) find a very similar pattern for Sweden, provided that households are grouped according to expenditure rather than income. Klinge Jacobsen et al. (2001) find that, in Denmark, taxes on energy and pollution are typically neutral or mildly regressive, but the transport-related taxes (on vehicles and fuel) are clearly progressive, even when related to income, and even more so when related to expenditure. One possible explanation for this is the high Danish level of automobile taxation, which makes the car into more of a luxury good than e. g. in Sweden. Berri et al. (2014) confirm that the fuel and vehicle taxes are progressive in Denmark, but not in France or Cyprus, where the fuel tax is found to be regressive. Basing their analysis on Engel elasticities[6], Aasness and Larsen (2003) find that in Norway during 1986-94, the fuel tax was regressive.

Several studies make the important point that the final distributional effect of a tax depends crucially on if and how the tax revenue is redistributed. Studying the Stockholm congestion charging scheme, Eliasson and Mattsson (2006) state that 'if revenues are spent on public transport, this will primarily benefit low-income groups, while proportional tax cuts will naturally benefit high-income groups'. Callan et al. (2009) remarks that 'A carbon tax is regressive […]. However, if the tax revenue is used to increase social benefits and tax credits, households across the income distribution can be made better off without exhausting the total carbon tax revenue'. Bureau (2011) states that 'Carbon tax is regressive before revenue recycling', but that 'recycling additional revenues from the carbon tax either in equal amounts to each household or according to household size makes poorest households better off'. Gonzalez (2012) concludes that a carbon tax is 'regressive […] when the revenue is recycled as a manufacturing tax cut and progressive […] when it is recycled as a food subsidy'.

Now, redistributing revenue in a progressive way is perhaps easier in theory than in practice. Ahola et al. (2009) seem, however, to have pointed to a quite reliable and practicable method, in suggesting that revenue be recycled through a lower VAT rate on comestibles. This will indeed make the tax scheme more progressive, since low-income families spend a larger than average share of their budget on food.

Samakovlis et al. (2015), studying carbon taxation in Sweden, demonstrate how the equity effect of recycling will differ considerably between a lowered VAT (i) on public transport, (ii) on services in general, or (iii) an all consumer goods. They find that the geographic dimension, contrasting urban to rural communities, is at least as significant for equity as the income dimension.

4.2.3. The AFFORD study

If the tax percentage does not vary monotonously with income or expenditure, no definite conclusion can be drawn about regressivity/progressivity. How can we then proceed?

The *Lorenz curve*, due to Lorenz (1905) and described well by Kakwani (1987), constitutes a concise, formalised way of summarising the degree of income inequality between the various members of society. Relating the cumulative proportion of income units, measured on the horizontal axis, to the cumulative proportion of income received, measured the vertical axis, the curve takes the form of a straight line through the origin with slope 1 (45-degree angle) if and only if all units in the population receive the same income. In all other cases the curve is a monotonously increasing convex curve located beneath the straight line with a 45-degree angle. The lower the Lorenz curve, the more income is concentrated in the upper income brackets, and the less 'equitable' is the distribution.

One way to summarize the information contained in the Lorenz curve is by way of the *Gini* coefficient, due to Gini (1912). Equal to twice the area between the 45-degree straight line and the Lorenz curve, the *Gini* coefficient is bounded between zero and one. The higher the *Gini* coefficient, the larger is the 'gap' between the actual and the maximally equitable distribution, and the less 'equitable' is – in a sense – the distribution at hand.

In the AFFORD project for the European Commission, Fridstrøm et al. (2000) exploited this apparatus to study the income distributional effects of marginal cost pricing of travel in the greater Oslo area. They computed changes in the Lorenz curve and in the Gini coefficient, as defined in terms of household income per consumption unit, under various first or second best marginal cost pricing packages and revenue redistribution schemes. The equity effect was shown to be strongly dependent on how the revenue from peak-load pricing and congestion charging was used. If the revenue is recycled to the taxpayers in the form of poll transfer, i. e. with an equal amount to every adult, equity was seen to improve. When no recycling takes place, or when revenue is recycled in the form of a proportional tax relief, the pricing scheme was found to be regressive.

4.2.4. A simplified modelling approach

The AFFORD exercise was possible thanks to the availability of disaggregate household income data coupled with a detailed network travel demand model. The authors of the present paper are less fortunate. The Oslo Intercity and NTM6 models do not contain income data at the individual or household level. The best proxy one can obtain is the average personal income among residents in each zone of origin, as measured at the level of the basic statistical unit (BSU). These figures are summarised in Table 4.1. In the urban areas, the BSUs have fairly small extension, typically just a few blocks. We shall henceforth refer to the BSUs as 'neighbourhoods'.

Table 4.1. Resident population and mean income in local per capita income brackets, according to the network models for short, resp. long distance trips.

Per capita income in neighbourhood (NOK 2001)						
	0–174	**175–224**	**225–274**	**275–324**	**325+**	**Total**
Oslo Intercity Regional Model						
Population aged 13 and above	148 552	776 938	662 695	265 208	199 455	2 052 848
Per cent of population	7.2	37.8	32.3	12.9	9.7	100.0
Average per capita local income	126 605	204 194	245 551	296 016	413 615	
Income ratio	1	1.61	1.94	2.34	3.27	
NTM6 Long-Distance National Model						
Population aged 13 and above	410 459	2 192 136	1 224 516	259 760	162 232	4 249 103
Per cent of population	9.7	51.6	28.8	6.1	3.8	100.0
Average per capita local income	156 774	203 140	245 143	294 343	369 738	
Income ratio	1	1.30	1.56	1.88	2.36	

Income distribution results based on this simplified approach are shown in section 5.4.1.

4.3. Other equity dimensions

Another angle under which one might want to study equity is the household structure. Are the policy effects fair to families with children, to persons living alone, or to the most crowded households?

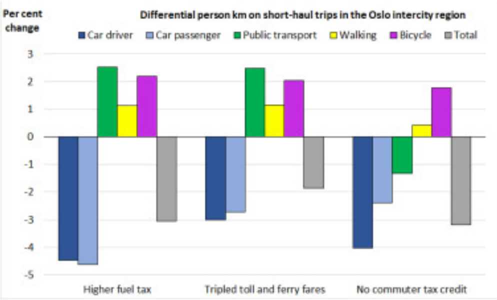
A third way to look at equity is by age and gender.

> Results along these dimensions are presented in sections 5.4.2 Effects by age and gender, 5.4.3 Effects by household structure.

5. Network modelling results

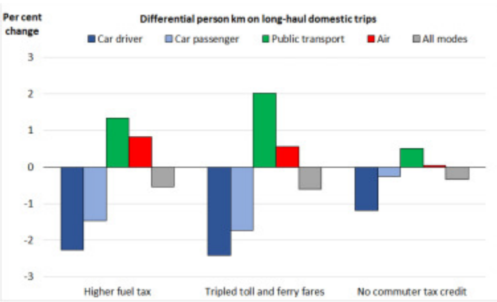
5.1. Travel demand

Fig. 5.1, Fig. 5.2 show travel demand effects of the three policy measures studied by means of short- and long-haul travel demand models.



Download high-res image (209KB) Download full-size image

Fig. 5.1. Policy impact on short-haul travel demand in Oslo intercity region. Per cent change in person km travelled, by policy measure and mode.



Download high-res image (175KB) Download full-size image

Fig. 5.2. Policy impact on long-haul domestic travel demand. Per cent change in person km travelled, by policy measure and mode.

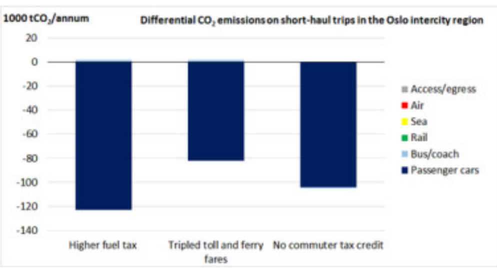
A NOK 0.20 increase in per km car travel cost, brought about by a new kilometre charge or by an escalated fuel tax, will lead to an estimated 4–5 per cent decrease in short-haul car kilometres and an about 2 per cent decrease in long-haul car travel demand. Short distance public transport demand expands by 2–3 per cent, while long distance air and public transport demand expand by around 1 per cent each. Total travel demand shrinks by an estimated 3 per cent for short-haul trips and by one half per cent for long-haul trips.

According to the model simulations, tripled toll rates and ferry fares would have comparable effects on long-haul trips, but somewhat smaller effects on short trips in the Oslo intercity region.

The abolishment of the commuter tax credit would lead to an even larger overall travel demand effect on short-haul trips than the fuel tax increase considered. This policy measure affects all modes of transport, yielding reduced demand even for short-haul public transport. At longer distances, however, air and public transport will experience slight increases in demand, as the car mode becomes comparatively less competitive.

5.2. CO_2 emissions

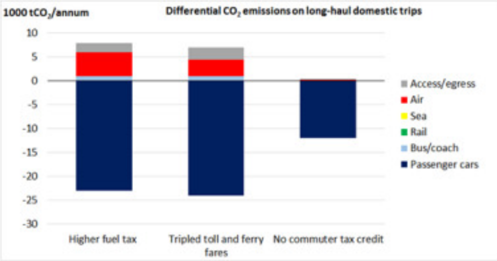
In terms of CO_2 emissions, the three policy measures have comparable effects – 80 to 120 000 tCO_2/annum – as far as short-haul trips in and around Oslo are concerned (Fig. 5.3). The relative reduction is 2.8–4.2 per cent compared to the reference scenario emissions of 2.89 million tonnes of CO_2 annually on short-haul trips.



Download high-res image (171KB) Download full-size image

Fig. 5.3. Policy impact on short-haul trips in Oslo intercity region. Absolute changes in CO_2 emissions, by policy measure and mode.

On longer distances, the commuter tax credit reform is seen to have only half as large an impact on emissions from private cars as the other two strategies (Fig. 5.4). However, since tripled toll and ferry fares as well as increased fuel tax shift travel demand from cars to the air and bus/coach modes, generating increased emissions from these, the overall CO_2 impact on long-haul trips is of the same order of magnitude – 12 to 17 000 tCO_2/annum, or 0.5 to 0.7 per cent down from 2.55 million tonnes annually – in all three policy scenarios.

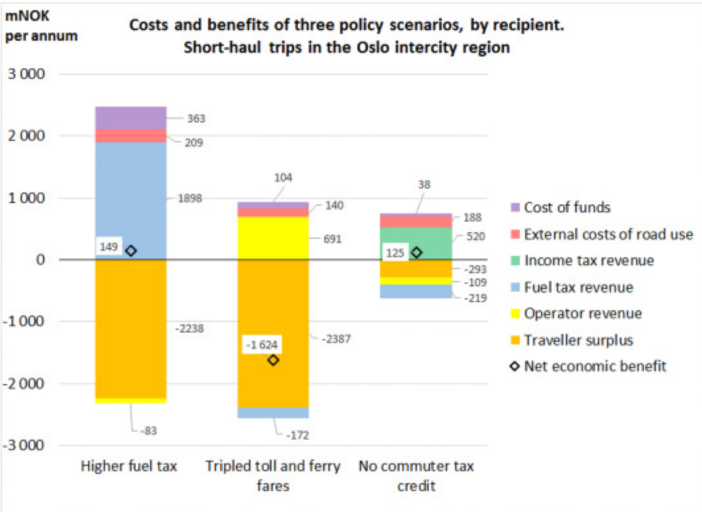


Download high-res image (161KB) Download full-size image

Fig. 5.4. Policy impact on long-haul domestic trips. Absolute changes in CO_2 emissions, by policy measure and mode.

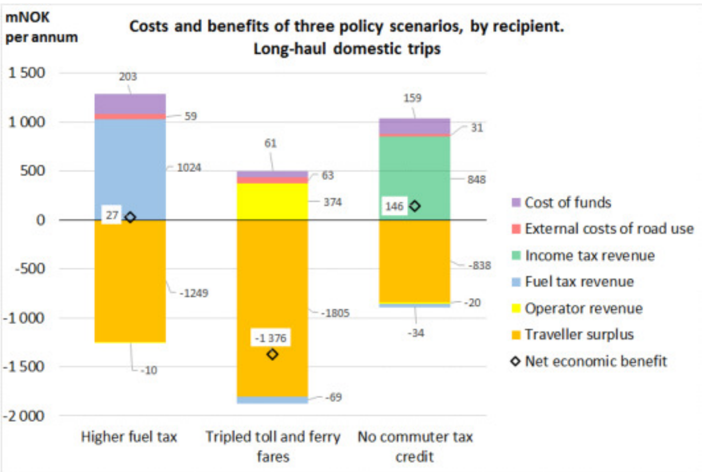
5.3. Economic costs and benefits

Certain costs and benefits arising under the three policy scenarios are shown in Fig. 5.5, Fig. 5.6.



Download high-res image (418KB) Download full-size image

Fig. 5.5. Differential costs and benefits calculated for short-haul trips in the Oslo intercity region, under three policy scenarios.



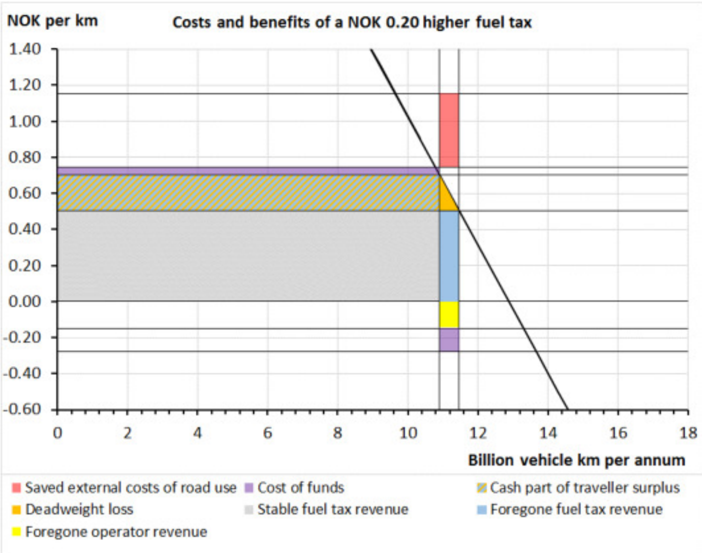
Download high-res image (419KB) Download full-size image

Fig. 5.6. Differential costs and benefits calculated for domestic long-haul trips, under three policy scenarios.

The increased fuel tax option comes out with a positive net annual economic *benefit* of NOK 149 million in the short-haul Oslo intercity market, and at NOK 27 million in the long-haul domestic market. The abolished commuter tax credit also comes out as socially profitable, with net annual *benefits* of NOK 125 and 146 million, respectively, in the two markets. Tripling the toll rates and ferry fares is, however, strongly unprofitable, with net annual *costs* of NOK 1624 and 1376 million.

The net economic benefit, as calculated here, is the sum of six elements: the traveller surplus change, the differential external cost of road use, the changes in public revenue from fuel tax, income tax, toll and ferry fares, and the economic value attached to additional public revenue[7] (the 'cost of funds').

In Fig. 5.7, we present a diagram for the short-haul market, where all of the revenue flows in the increased fuel tax scenario have been drawn to scale, with colour codes corresponding to those of Fig. 5.5, Fig. 5.6. Since we are not concerned with the absolute level of welfare in the initial situation, only with the *changes* brought about by the policy measure in question, the zero point on the vertical axis of Fig. 5.7 can be set arbitrarily, without loss of generality. We have set it at the point corresponding to a zero fuel tax. Hence the grey area shown represents the fuel tax revenue obtained by applying the 'old' fuel tax rate to the 'new' travel demand, in other words the fuel tax revenue previously collected from the road users that remain in the market after the policy intervention. We refer to this as 'stable fuel tax revenue'.



Download high-res image (686KB) Download full-size image

Fig. 5.7. Market response to a NOK 0.20 higher per km fuel tax, calculated for short-haul trips in the Oslo intercity region. Coloured areas are proportional to cost/benefit/cash flow involved.

The fuel tax, toll, ferry fares and foregone commuter tax credit represent costs perceived by the travellers and are hence included in their generalised costs. But these cost items reappear as revenue in the accounts of the public treasury. In general, the cash flows between private households and the public sector, or between different segments of the private sector, are not economic costs – only redistributive transfers. Thus, the greater part of the ochre coloured area shown in Fig. 5.5, representing traveller surplus loss, consists in a mNOK 2182 cash expenditure, which has an exact counterpart in the form of extra fuel tax revenue for the government. In the cost-benefit account, these two items cancel each other out, as suggested by the hatched, blue-and-ochre rectangle in Fig. 5.7. What is left as a real welfare economic cost is just the mNOK 56 deadweight loss, represented by the ochre triangle in Fig. 5.7. This is the benefit foregone by road users travelling less frequently or to less distant destinations than before.

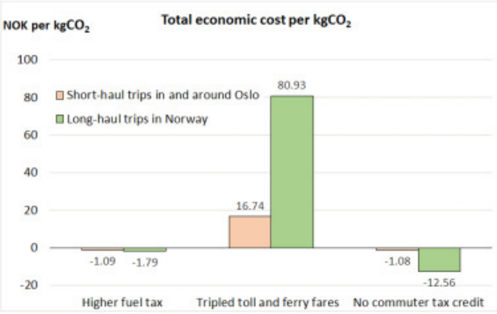
Now, in practice the additional net public revenue will not be quite as large as the hatched blue-and-ochre area, since the public treasury will lose out (i) on the fuel tax, previously collected on a larger number of vehicle kilometres travelled (mNOK 284 blue area in Fig. 5.7), and similarly (ii) on previously collected toll and ferry fares (mNOK 83 yellow area). These losses, representing a negative 'rebound effect' for the public treasury, must also be taken into account.

On the other hand, when the number of vehicle kilometres travelled goes down, so do their external costs. The size of this benefit (mNOK 209) is shown by the pink areas in Fig. 5.5, Fig. 5.6, Fig. 5.7. To calculate this benefit, we have applied average marginal external cost rates as derived by Thune-Larsen et al. (2016), amounting to around NOK 0.40 per km for passenger cars. Since not all external costs are strictly proportional to the vehicle kilometres travelled, this is an approximation.

Finally, the cost of funds are taken into account, with a premium valued at 20 per cent of the additional public revenue generated, and an equally large share of public revenue foregone on account of reduced travel demand. Thus, the mauve area in Fig. 5.5 is the balance between the upper (mNOK 436) and the lower (mNOK 73) mauve areas shown in Fig. 5.7.

One notes that the premium value of public revenue and the reduced amount of external costs are sufficient, taken together, to more than offset the deadweight loss and the reduced revenue from fuel tax, toll and ferry fares. But this conclusion hinges crucially on the assumed premium value of public funds and on the unit rate of external costs. We revert to this question in section 6.2.

While the three policy strategies considered have comparable effects in terms of CO_2 abatement (Fig. 5.3, Fig. 5.4), they are remarkably different as judged by their economic costs (Fig. 5.8).



Download high-res image (201KB) Download full-size image

Fig. 5.8. Calculated net economic cost per avoided kg CO_2 under three policy scenarios, according to the Oslo Intercity Regional Model for short-haul trips and the NTM6 model for long-haul trips.

Considered as a GHG abatement measure, abolishing the commuter tax credit has a negative economic cost – i. e. it is socially profitable even before we consider GHG abatement effects. In the long-haul domestic travel market, the estimated benefit is as high as NOK 12.56 per kgCO_2. A more moderate benefit is derived in the short-haul market – NOK 1.08 per kgCO_2.

The incremental revenue obtained by the public treasury is, however, not nearly as large as one might expect. In the short-haul market, more than half the mNOK 520 extra revenue from income tax is counterbalanced by reduced revenue from fuel tax (mNOK 219), toll and ferry fares (mNOK 109) – a most significant fiscal ‘rebound effect’. In the long-haul market, the travel demand response is much smaller, and so is also the reduction in toll and fuel tax revenue.

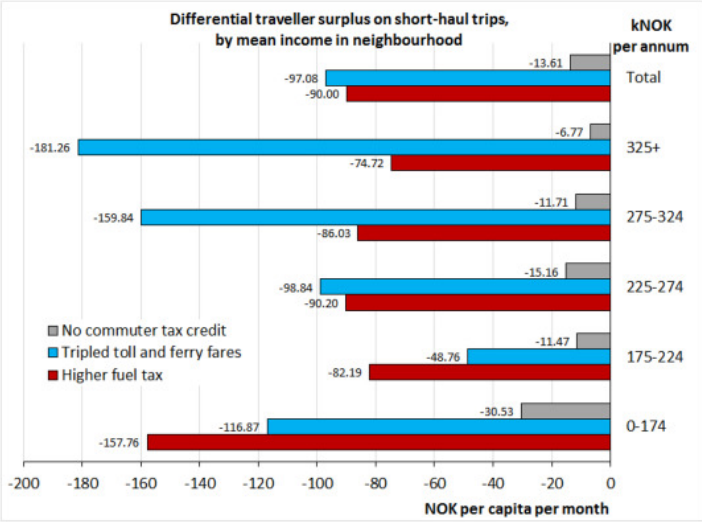
Increasing the fuel tax is also shown to be socially profitable, on account of reduced external costs and the premium value attached to public revenue. In the long-haul market, the estimated benefit is somewhat bigger (NOK 1.79 per kgCO_2) than in the short-haul market (NOK 1.09 per kgCO_2).

In this context, the tripled toll and ferry fares strategy is the odd man out, with abatement costs reaching almost NOK 81 per kgCO_2 in the long distance market and almost NOK 17 in the short distance market, corresponding to € 9600 and € 2000 per tonne CO_2, respectively. Note, however, that the increased toll rates considered have nothing to do with congestion charging or marginal cost pricing. What we have modelled is essentially a tripling of fundraising toll on highways that are already in a free-flow state of demand, i. e. without significant delays. The negative economic impact of such a strategy should come as no surprise; it was recognised already by Dupuit (1844), some 170 years ago.

5.4. Equity

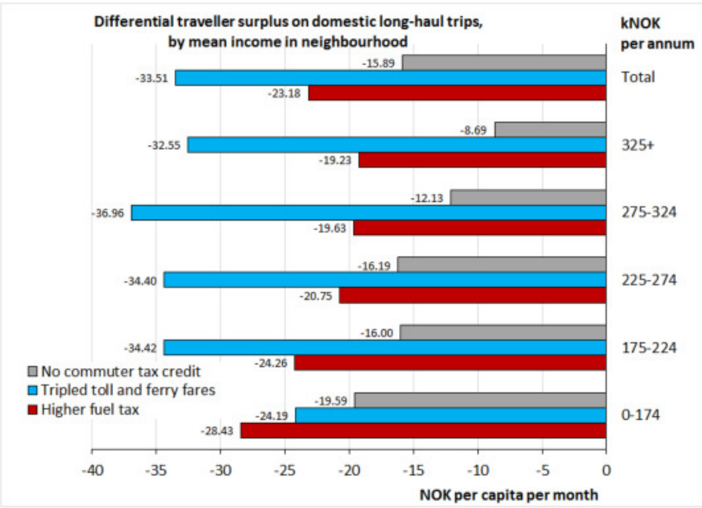
5.4.1. Effects by local income level

In Fig. 5.9, Fig. 5.10, calculated changes in traveller surplus under the three policy scenarios have been broken down by per capita income brackets as defined for the travellers' respective zones of residence,[8] which we refer to as their ‘neighbourhoods’ (confer section 4.2.4).



Download high-res image (452KB) Download full-size image

Fig. 5.9. Calculated per capita changes in traveller surplus on short-haul trips in the Oslo intercity region, under three policy scenarios, by mean income in neighbourhood in 2001.



Download high-res image (453KB) Download full-size image

Fig. 5.10. Calculated per capita changes in traveller surplus on long-haul domestic trips, under three policy scenarios, by mean income in neighbourhood in 2001.

For the tripled toll and ferry fares policy, no striking distributional pattern of effects is seen.

Under the increased fuel tax scenario, however, a relatively clear, regressive pattern emerges. Losses are higher, even in absolute terms, for travellers living in low income neighbourhoods. In the short-haul travel market, *absolute* per capita losses are more than twice as high for individuals living in neighbourhoods with a per capita income of less than kNOK 175 in 2001 than for travellers in the uppermost local income bracket (kNOK 325+).

In the long-haul domestic travel market, the tendency is the same, although weaker.

An even more regressive pattern is found for the revocation of the commuter tax credit, which, on short-haul trips, affects people from the least affluent communities 4.5 times (= 30.53/6.77) more strongly – in *absolute* terms – than most well-to-do neighbourhoods. In the long-haul market, the corresponding ratio is about half as high: 2.25 (= 19.59/8.69).

The absolute amounts of benefit lost when the commuter tax credit is revoked may appear small. However, since the commuter tax credit affects only one out of nine taxpayers (Table 2.1), the average impact on the persons affected is roughly nine times higher than shown in the graph. Also, recall that prices have risen by about 30 per cent since 2001. When both of these facts are taken account of, the monthly NOK 30.53 figure derived for low income neighbourhoods corresponds to roughly NOK 4000 (= € 475) over an 11-month working year, as evaluated at the 2015 price level.

As measured *in relation to the income level*, the inequality ratios come out several times higher. Multiplying the tax incidence factors of Fig. 5.9, Fig. 5.10 by the income ratios shown in Table 4.1, we obtain the following indicators for the excess burden borne by the residents of low income neighbourhoods as compared to those living in high income zones:

1. Tripled toll rates and ferry fares: 2.1 in short-haul model, 1.8 in long-haul model

2. NOK 0.20/km higher fuel tax: 6.9 in short-haul model, 3.5 in long-haul model

3. Abolished commuter tax credit: 14.7 in short-haul model, 5.3 in long-haul model.

That is, as measured by the relative traveller surplus change in relation to per capita local income, abolishing the commuter tax credit would affect the low income neighbourhoods about 15 times more strongly than the most affluent ones, according to the Oslo Intercity Regional Model. In the NTM6 long distance model, the corresponding inequity ratio is around 5.

The augmented fuel tax option results in analogous inequity indicators of 7 and 3.5 in the short- and long-haul models, respectively. The tripled toll rates and ferry fares option results in indicators around 2 – suggesting twice as high a relative burden on low income neighbourhoods as on high income areas.

The picture emerging is one of very strong regressivity, especially in the case of abolishing the commuter tax credit, but also in the higher fuel tax case.

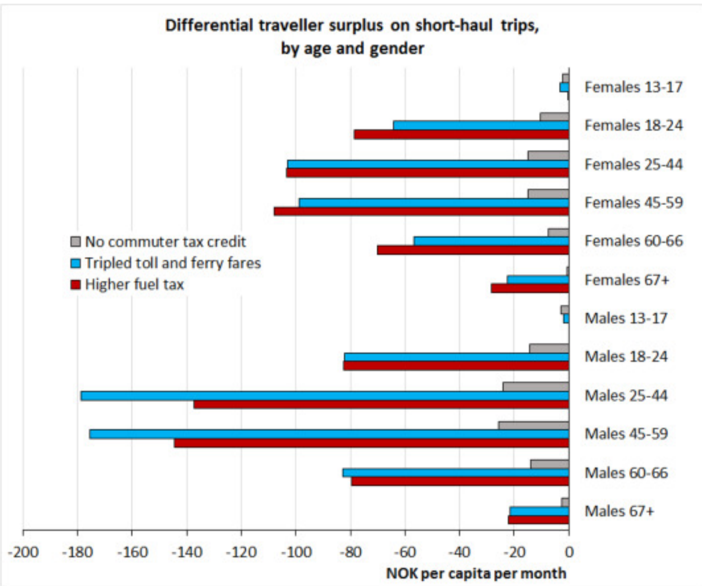
Since we have not been able to relate travel behaviour response to individual or household income, but only to the mean local income as of 2001, results must be interpreted with some caution. There is, however, reason to believe that there is a strong degree of permanence in the spatial income pattern.

Income levels tend to diminish as one moves out from the capital city, or – more generally – from any large urbanization. This may be a reflection of the well-known rent gradient phenomenon. In or near the city centre, rents are generally higher than in the suburban and exurban areas. Hence these areas tend to be inhabited by the more affluent families. Since jobs tend to be concentrated in or near the city centre, workers living in more remote neighbourhoods, with lower rents and lower income level, generally sustain longer commutes.

Therefore, low income earners tend to be more strongly affected by increases in the fuel cost. They benefit from the commuter tax credit to a significantly larger extent than do urban or suburban dwellers. They will, in other words, be more severely drabbed by its revocation.

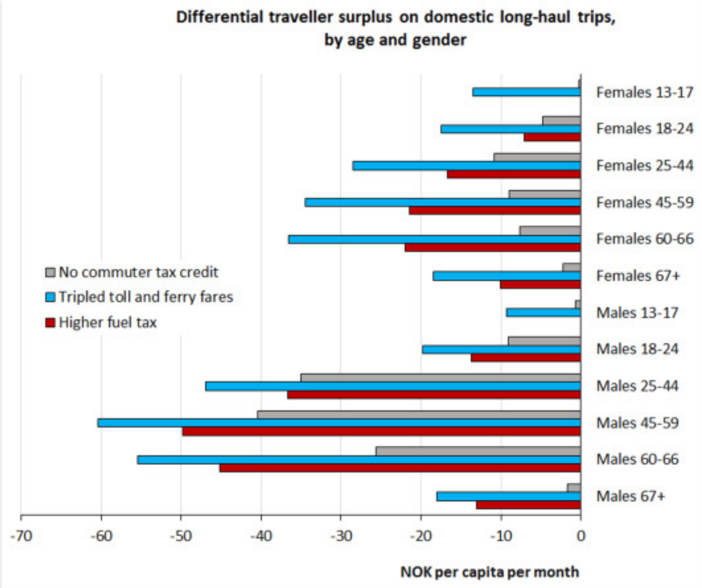
5.4.2. Effects by age and gender

Age and gender effects are shown in Fig. 5.11, Fig. 5.12.



Download high-res image (468KB) Download full-size image

Fig. 5.11. Calculated per capita changes in traveller surplus on short-haul trips in the Oslo intercity region, under three policy scenarios, by age and gender.



Download high-res image (451KB) Download full-size image

Fig. 5.12. Calculated per capita changes in traveller surplus on long-haul domestic trips, under three policy scenarios, by age and gender.

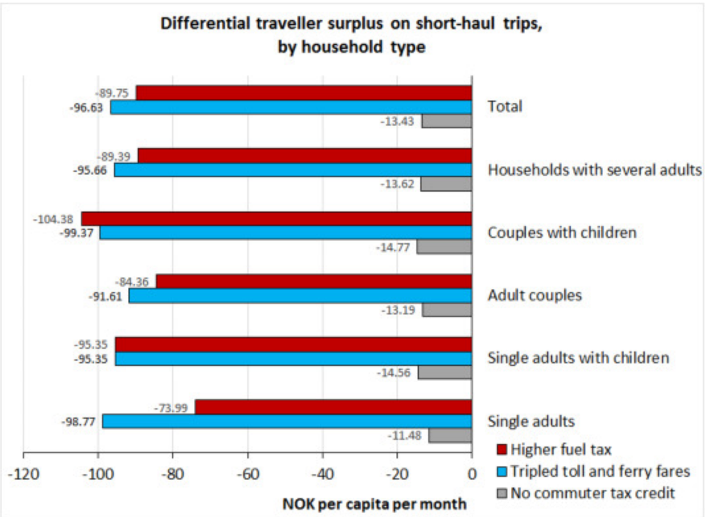
There is a clear tendency for all three policy measures to affect males more strongly than females. The gender difference is particularly noticeable in the case of abolished commuter tax credit. Long-haul commutes are far more frequent among males than among females.

The gender gap is clearly visible also in the scenario based on tripled toll rates and ferry fares. This probably reflects the gender difference in modal choice and car use.

The age profile offers no surprise. Persons aged 25 to 59 incur higher fuel, toll and ferry costs than the younger or the older. Obviously, they are also harder hit by cutbacks in the commuter tax credit.

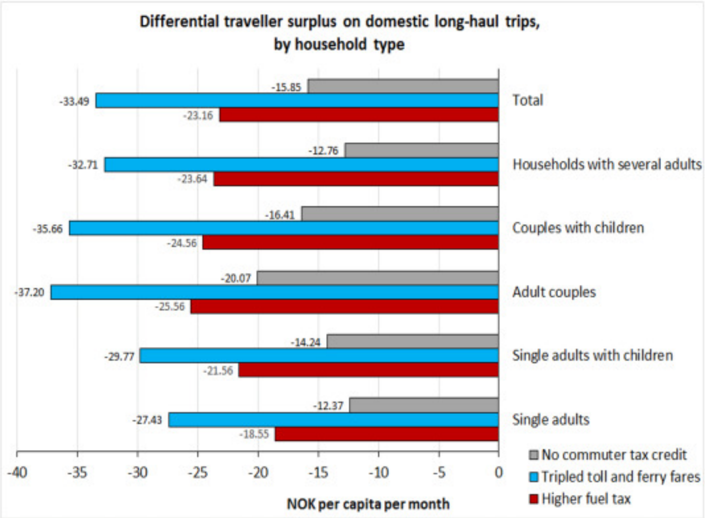
5.4.3. Effects by household structure

The policy measures considered do not, according to the models, result in grossly inequitable effects across family types. Per capita losses vary comparatively little by type of households (Fig. 5.13, Fig. 5.14), although the fuel tax increase hits somewhat harder in families with children than for single adults. The most 'vulnerable' group, single adults with children, incur per capita losses that are just about average.



Download high-res image (446KB) Download full-size image

Fig. 5.13. Calculated per capita changes in traveller surplus on short-haul trips in the Oslo intercity region, under three policy scenarios, by household size and structure.



Download high-res image (443KB) Download full-size image

Fig. 5.14. Calculated per capita changes in traveller surplus on long-haul domestic trips, under three policy scenarios, by household size and structure.

6. Caveats and qualifications

On account of imperfections in the modelling apparatus used in this study, results must be interpreted with some caution.

6.1. Income proxies

While our *travel demand* models fail to contain income data at the individual or household level, the best proxy available is the mean taxable income recorded in 2001 among residents within each ‘neighbourhood’ or basic statistical unit (BSU).

The validity of this proxy depends (i) on the relative income homogeneity of residents of a given BSU and (ii) on the temporal stability of regional and local income differentials. While both of these assumptions can be questioned, there is no doubt that there are large and permanent income differences between BSUs, since high income earners tend to cluster in certain zones, as do also low income earners. This phenomenon is closely linked to the so-called rent gradient, i. e. to the fact that housing rents are generally higher near the city centre, tapering off as we move out into the suburban and exurban areas.

6.2. External effects

Although we are primarily interested in private economic costs and their distribution, certain external costs have been taken account of in our calculations, so as to assess the net economic cost or benefit to society of the various policy measures considered.

6.2.1. Road use externalities

Thune-Larsen et al. (2016) have estimated the average marginal external costs of petrol and diesel driven cars, respectively. While the fuel tax comes fairly close to internalising the average external cost of petrol cars, the same is not true of diesel driven vehicles. Hence, policy measures that limit road use demand also serve to reduce negative externalities. When we take this into account, the net social costs of certain policies are turned into net benefits. This applies in three out of six cases studied. The end result is, in other words, sensitive to changes in the external cost assessment.

6.2.2. Cost of public funds

According to Pigou (1948), since nearly all forms of taxation distort the price signals in the economy, leading to reduced economic efficiency, public funds should be valued at a premium compared to private money. According to the Norwegian Ministry of Finance (2014), the premium should be set uniformly at NOK 0.20 per NOK 1 expenditure or revenue. However, Sandmo (1998) notes that unless the taxation system is already optimally designed as seen from a welfare economic point of view, the marginal cost of public funds depends on the tax instrument. Bjertnæs (2015) concludes, in a recent general equilibrium analysis of the Norwegian economy, that the rate is only 0.05 for general income taxation and VAT, but possibly as high as 0.20 for taxes on capital dividends and corporate profits.

Whether or not one takes account of the cost of public funds, and at what rate, can reverse the sign of the overall economic benefit. For the NOK 0.20 per km increased fuel tax option, the break-even premium on public funds is found to be NOK 0.118 per NOK tax revenue in the short-haul market and NOK 0.173 in the long-haul market. In other words, a rate as low as 0.05 would make this policy socially unprofitable before CO_2 abatement benefits.

For the abolishment of the commuter tax credit, the corresponding break-even points are negative in the short-haul market and 0.0165, i. e. is less than two per cent, in the long-haul market. Tripling the toll rates and ferry fares would remain unprofitable no matter what value is assigned to increased public revenue.

6.2.3. Wider economic effects

Our analysis is a partial one, that does not take into account possible repercussions outside the travel market. For instance, value added in the tourist industry may be negatively affected by higher fuel prices, toll rates or ferry fares, as visitors and vacationers choose other destinations than Norway. More generally, when consumers experience, e. g., a higher fuel tax, not only will they buy less fuel at a higher price, the income effect of increased fuel expenditure will mean reduced demand for certain other goods. This will also affect the government budget. The increase in fuel tax revenue will to some extent be counteracted by reduced revenue from VAT and other consumption taxes. These economy-wide effects have not been incorporated in our modelling. To assess them, general equilibrium modelling would be needed.

The effects of the 'abolished commuter tax credit' policy option may be particularly susceptible to wider economic repercussions. When the model predicts CO_2 emissions to go down in this scenario, it is primarily due to shorter commuting distances, in other words that people move, change jobs or cease to be employed. In all of these cases, a welfare loss can be expected over and above the traveller surplus change calculated. According to Venables (2007), job-seekers living outside the city trade off wage differentials against commuting costs. They may obtain a better paid job if willing to commute out of the local community. Increasing the cost of commuting means restraining the labour market, with negative effects on overall productivity. These effects have not been encompassed in our calculations. Thus, the economic cost of the 'abolished commuter tax credit' policy could be markedly underestimated.

When the 'tripled toll rates and ferry fares' scenario comes out as economically highly inefficient, this reflects a massive increase in the deadweight loss sustained at tolling stations and ferry crossings. In a few instances, higher toll rates may serve to internalise the costs of congestion, road wear, accidents, noise or local pollutants, but in the large majority of cases, Norwegian toll rates are already too high compared to the marginal external costs of using that particular road. Benefits are lost when a road is underused, especially if traffic is diverted into local road networks, where the nuisance caused by noise, accidents or emissions may be worse than on the toll road. Moreover, certain economy-wide general equilibrium effects may arise even in this scenario. Taken together, this suggests that the economic cost of tripling the toll rates and ferry fares may be even higher than suggested by the travel demand model.

Note, however, that the deadweight loss created by toll is roughly proportional to the square of the toll rate. The loss induced by a tripled toll rate is thus out of proportion to the effect of more moderate increases, say a 50 per cent adjustment, which would generate just about one quarter of the gross benefits, but a roughly sixteen times smaller deadweight loss. Smaller changes in the toll rates and ferry fares would therefore not be as unprofitable, per unit of CO_2, as tripling the rate.

7. Summary and conclusions

Network models of travel demand have been adapted and used to assess the equity implications of selected, potential GHG abatement measures as implemented in Norwegian transport. The three measures studied include (i) a NOK 0.20 kilometre charge on private cars, or an equivalent increase in the fuel tax, (ii) a uniform 200 per cent increase in toll rates and ferry fares, and (iii) a revocation of the commuter tax credit for persons travelling more than 10 000 km per annum to and from their job.

By study design, all three measures result in comparable reductions in GHG emissions, between 80 000 and 120 000 tCO_2/annum on short distance trips in the Oslo intercity region, and between 12 000 and 17 000 tCO_2/annum on long distance trips nationwide.

The cost efficiency and equity of these three measures differ, however, widely.

Apparently, the most cost efficient measure is the *revocation of the commuter tax credit*. When account is taken of known external effects, including the prescribed 20 per cent extra value assigned to public funds, this policy results in a net social *gain* before GHG abatement benefits of € 100–120 per tonne CO_2 in the short-haul market around Oslo and € 1200–1500 in the long-haul domestic market. The abatement cost is, in other words, negative.

Note, however, that our cost-benefit analysis is a partial one, disregarding effects outside the travel market. Higher commuting costs may result in a de facto contraction of the labour market, leading to loss of productivity. If present, such effects may well reverse the sign of the result, turning the net benefit into a net loss.

An almost equally profitable measure is the NOK 0.20 increase in car kilometre cost, be it on account of a new kilometre charge or a *higher fuel tax*. Compared to the revocation of the commuter tax credit, the fuel tax option results in very similar benefits in the short-haul market, but smaller benefits in the long distance market: € 180–220 per tonne CO_2. Even here, certain wider economic costs may be suspected, reducing the net economic benefit.

By far the least efficient GHG abatement measure considered is to *triple the toll and ferry fares*. Here, CO_2 abatement comes at a *cost* of € 1700–2000 and € 8000-10 000 per tonne on short, resp. long distance trips.

In terms of equity effects, however, the ranking between the three measures becomes exactly opposite.

Revoking the commuter tax credit is a clearly regressive measure, hitting low income and remote districts five to fifteen times harder than high income, urban neighbourhoods. The tax credit rule in itself is, in other words, distinctly progressive.

A *fuel tax increase* will have similar distributional effects as a revocation of the commuter tax credit, although the pattern is less pronounced than for the commuter tax credit, with inequity ratios between three and seven. Inhabitants of low income neighbourhoods travel longer distances, also by car, than those living in more well-to-do and central communities. They are therefore harder hit by a fuel tax increase.

Families with children are somewhat harder hit by a fuel tax increase than are households without children. Males are harder hit than females.

Increased road toll and ferry fares would affect the various parts of the population in more haphazard ways, depending on how many toll roads and ferry crossings are in operation in each region. Thus, the inequity caused by increased toll and ferry fares is more a question of geography per se than of local income levels.

Males are more affected by toll and ferry fares than are women. There are only small differences across household size and types.

In summary, when policy makers are to choose among the above three options, the contradiction between equity and efficiency is as present as ever. In principle, however, the final equity effect will depend crucially on how the public revenue from tax, toll or ferry fares is being used. For some policy options, it might be possible to redistribute the increased public revenue in such a way that the final distributional effect would become progressive. At least this would be true of policies affecting travellers more or less in general, such as a fuel tax increase. A reduced VAT on food might, for instance, do the trick. It might be harder to design redistribution schemes to compensate the relatively few affected by an abolished commuter tax credit, or the relatively haphazard set of travellers hit by higher toll rates or ferry fares.

Acknowledgements

This research was funded primarily through BISEK – a Swedish-Norwegian research programme (TRV 2015/7976) on the social and economic significance of the private car. Thanks are due to Björn Carlén of the Swedish National Institute of Economic Research (Konjunkturinstitutet), to Henrik Swahn and the Board of BISEK, and to the editor and two anonymous referees. Their insightful comments helped improve this publication substantially.

References

Aamaas et al., 2013 B. Aamaas, J. Borken-Kleefeld, G.P. Peters
The climate impact of travel behavior: a German case study with illustrative mitigation options
Environ. Sci. Pol., 33 (2013), pp. 273-282
Article Download PDF View Record in Scopus Google Scholar

Aasness and Larsen, 2003 J. Aasness, E.R. Larsen
Distributional effects of environmental taxes on transportation
J. Consum. Pol., 26 (2003), pp. 297-300
View Record in Scopus Google Scholar

Ahola et al., 2009 H. Ahola, E. Carlsson, T. Sterner
Är bensinskatten regressiv?
Ekon. Debatt, 37 (2) (2009), pp. 71-77
View Record in Scopus Google Scholar

Berri et al., 2014 A. Berri, S.V. Lyk-Jensen, I. Mulalic, T. Zachariadis
Household transport consumption inequalities and redistributive effects of taxes: a repeated cross-sectional evaluation for France, Denmark and Cyprus
Transport Pol., 36 (2014), pp. 206-216
Article Download PDF View Record in Scopus Google Scholar

Bjertnæs, 2015 G.M.H. Bjertnæs
Samfunnsøkonomiske kostnader av å kreve inn skatteinntekter – en generell likevektsanalyse av den norske økonomien
Statistics Norway, report 2015/15
(2015)
Google Scholar

Borken-Kleefeld et al., 2010 J. Borken-Kleefeld, T. Berntsen, J. Fuglestvedt

Specific climate impact of passenger and freight transport
Environ. Sci. Technol., 44 (15) (2010), pp. 5700-5706
CrossRef View Record in Scopus Google Scholar

Borken-Kleefeld et al., 2013 J. Borken-Kleefeld, J. Fuglestvedt, T. Berntsen
Mode, load, and specific climate impact from passenger trips
Environ. Sci. Technol., 47 (2013), pp. 7608-7614
CrossRef View Record in Scopus Google Scholar

Bureau, 2011 B. Bureau
Distributional effects of a carbon tax car fuel in France
Energy Econ., 33 (2011), pp. 121-130
Article Download PDF View Record in Scopus Google Scholar

Callan et al., 2009 T. Callan, S. Lyons, S. Scott, R.S.J. Tol, S. Verde
The distributional implications of a carbon tax in Ireland
Energy Econ., 37 (2009), pp. 407-412
Article Download PDF View Record in Scopus Google Scholar

Deakin et al., 1996 E. Deakin, G. Harvey, R. Pozdena, G. Yarema
Transportation Pricing Strategies for California: an Assessment of Congestion, Emissions, Energy, and Equity Impacts
University of California Transportation Center, Berkeley, Ca (1996)
Google Scholar

Denstadli and Hjorthol, 2002 J.M. Denstadli, R. Hjorthol
Den nasjonale reisevaneundersøkelsen 2001 – nøkkelrapport
TØI Report 588
Institute of Transport Economics, Oslo (2002)
Google Scholar

Dupuit, 1844 A.J.E.J. Dupuit
De la mesure de l'utilité des travaux publics. Annales des ponts et chaussées
Série II, 8. Reprinted 1995 in Revue française d'économie
10 (2) (1844), pp. 55-94
View Record in Scopus Google Scholar

Eliasson and Mattsson, 2006 J. Eliasson, L.-G. Mattsson
Equity effects of congestion pricing: quantitative methodology and a case study for Stockholm
Transport. Res., 40 (2006), pp. 602-620
Article Download PDF View Record in Scopus Google Scholar

Fridstrøm et al., 2000 L. Fridstrøm, H. Minken, P. Moilanen, S. Shepherd, A. Vold
Economic and Equity Effects of Marginal Cost Pricing in Transport
VATT Research Papers 71
Government Institute for Economic Research, Helsinki (2000)
Google Scholar

Gini, 1912 C. Gini
Variabilità e mutabilità. *Studi economico-giuridici*
Università di Cagliari III, 2a (1912)
Google Scholar

Gonzalez, 2012 F. Gonzalez
Distributional effects of carbon taxes: the case of Mexico
Energy Econ., 34 (2012), pp. 2102-2115
Article Download PDF View Record in Scopus Google Scholar

Kakwani, 1987 N. Kakwani
Lorenz curve. Pp. 242–244
J. Eatwell, M. Milgate, P. Newman (Eds.), The New Palgrave: a Dictionary of Economics, vol. 3, The Macmillan Press Ltd, London (1987)
Google Scholar

Klinge Jacobsen et al., 2001 H. Klinge Jacobsen, K. Birr-Pedersen, M. Wier
Fordelingsvirkninger af energi- og miljøafgifter
Risø National Laboratory, Roskilde (2001)
Google Scholar

Kosonen, 2012 K. Kosonen
Regressivity of environmental taxation: myth or reality? Pp. 161–174
J.E. Milne, M.S. Andersen (Eds.), Handbook of Research on Environmental Taxation, Edward Elgar Publishing Ltd., Cheltenham (2012)

Google Scholar

Lorenz, 1905 M.O. Lorenz
Method for measuring concentration of wealth
J. Am. Stat. Assoc., 9 (1905), pp. 209-219
CrossRef View Record in Scopus Google Scholar

Madslien et al., 2005 A. Madslien, J. Rekdal, O.I. Larsen
Utvikling av regionale modeller for persontransport i Norge. TØI Report 766
Institute of Transport Economics, Oslo (2005)
Google Scholar

Meurs et al., 2013 H. Meurs, R. Haaijer, K.T. Geurs
Modeling the effects of environmentally differentiated distance-based car-use charges in The Netherlands
Transport. Res. Part D, 22 (2013), pp. 1-9
Article Download PDF View Record in Scopus Google Scholar

Mohring, 1972 H. Mohring
Optimization and scale economics in urban bus transportation
Am. Econ. Rev., 62 (1972), pp. 591-604
View Record in Scopus Google Scholar

Mullahy, 1986 J. Mullahy
Specification and testing of some modified count data models
J. Econom., 33 (1986), pp. 341-365
Article Download PDF View Record in Scopus Google Scholar

Neuburger, 1971 H. Neuburger
User benefit in the evaluation of transport and land use plans
J. Transport Econ. Pol., 5 (1) (1971), pp. 52-75
View Record in Scopus Google Scholar

NOU, 2015 NOU 2015:15
Sett pris på miljøet. Rapport fra grønn skattekommisjon
Norwegian Ministry of Finance, Oslo (2015)
Google Scholar

Norwegian Ministry of Finance, 2014 Norwegian Ministry of Finance
Prinsipper og krav ved utarbeidelse av samfunnsøkonomiske analyser mv
Rundskriv R-109/14
(2014)
Google Scholar

Pigou, 1948 A.C. Pigou
A Study in Public Finance
(third ed.), Macmillan, London (1948)
Google Scholar

Poterba, 1991 J.M. Poterba
Is the gasoline tax regressive?
Tax Pol. Econ., 5 (1991), pp. 145-264
CrossRef View Record in Scopus Google Scholar

Rekdal et al., 2014 J. Rekdal, T.N. Hamre, S. Flügel, C. Steinsland, A. Madslien, A. Hoff, W. Zhang, O.I. Larsen
NTM6 – Transportmodeller for reiser lengre enn 70 km. Paper 1414
Møreforskning Molde (2014)
Google Scholar

Rekdal et al., 2013 J. Rekdal, O.I. Larsen, A. Løkketangen, T.N. Hamre
TraMod_By Del 1: Etablering av nytt modellsystem. Paper 1203
Møreforskning Molde (2013)
Revised version: Paper 1313
Google Scholar

Samakovlis et al., 2015 E. Samakovlis, C. Berg, B. Carlén, A. Mansikkasalo, P. Marklund, L.S. Östman, H. Scharin
Miljö, ekonomi och politik 2015
Konjunkturinstitutet, Stockholm (2015)
Google Scholar

Sandmo, 1998 A. Sandmo
Redistribution and the marginal cost of public funds

J. Publ. Econ., 70 (1998), pp. 365-382
Article Download PDF View Record in Scopus Google Scholar

Santos and Catchesides, 2005 G. Santos, T. Catchesides
Distributional consequences of gasoline taxation in the United Kingdom
Transport. Res. Rec., 1924 (2005), pp. 103-111
CrossRef View Record in Scopus Google Scholar

Statens vegvesen, 2018 Statens vegvesen
Konsekvensanalyser. Håndbok V712
Norwegian Public Roads Administration, Oslo (2018)
Google Scholar

Steinsland, 2009 C. Steinsland
Etablering av transportmodell for Oslofjordområdet basert på RTM Sør og Øst
TØI Report 1035
Institute of Transport Economics, Oslo (2009)
Google Scholar

Steinsland, 2011 C. Steinsland
Utvidelse av Oslofjordmodellen. Working Paper ØL/2316/2011
Institute of Transport Economics, Oslo (2011)
Google Scholar

Steinsland, 2014 C. Steinsland
Vedlegg 1: modellberegninger. Pp. 249–278
Fridstrøm, Alfsen (Eds.) (2014)
Google Scholar

Thune-Larsen et al., 2016 H. Thune-Larsen, K. Veisten, K.L. Rødseth, R. Klæboe
Marginale eksterne kostnader ved vegtrafikk med korrigerte ulykkeskostnader
TØI Report 1307
Institute of Transport Economics, Oslo (2016)
Google Scholar

Tuuli, 2009 J. Tuuli
Polttoaineverojen ja muiden ympäristöverojen tulonjakovaikutukset. VATT Memorandum
Government Institute for Economic Research, Helsinki (2009)
Google Scholar

Venables, 2007 T. Venables
Evaluating urban transport improvements – cost-benefit analysis in the presence of agglomeration and income taxation
J. Transport Econ. Pol., 41 (2) (2007), pp. 173-188
View Record in Scopus Google Scholar

Vickrey, 1947 W. Vickrey
Agenda for Progressive Taxation
Ronald Press, New York (1947)
Google Scholar

Vickrey, 1949 W. Vickrey
Resource distribution patterns and the classification of families. Pp. 266–297
Studies in Income and Wealth, vol. 10, National Bureau of Economic Research, New York (1949)
Google Scholar

Vickrey, 1987 W. Vickrey
Progressive and regressive taxation. Pp. 1021–1025
J. Eatwell, M. Milgate, P. Newman (Eds.), The New Palgrave: a Dictionary of Economics, vol. 3, The Macmillan Press Ltd, London (1987)
Google Scholar

Williams, 1977 H.C.W.L. Williams
On the formation of travel demand models and economic evaluation measures of user benefit
Environ. Plann., 9 (1977), pp. 285-334
CrossRef View Record in Scopus Google Scholar

[1] In this paper we use the terms ‘car’, ‘private car’, ‘passenger car’ and ‘automobile’ as synonyms, encompassing all four-wheel vehicles meant for eight or less passengers, including sport-utility vehicles (SUVs) and mini-vans.

[2] Norwegian kroner. As of 1 July 2014, NOK 1 = US$ 0.162 = € 0.119. As of 5 March 2018, the NOK value has fallen to US$ 0.127 = € 0.104.

[3] 30 miles per gallon, corresponding to 184 g CO_2 per km for a petrol driven car and 212 g/km for a diesel car.

[4] In 2016, the threshold was raised to NOK 22 000, corresponding to 14 667 annual kilometres travelled, and the marginal tax rate was lowered to 25 per cent.

[5] EEA = European Economic Area, i. e. the EU plus Norway, Iceland and Liechtenstein.

[6] The Engel elasticity measures the percentage change in spending on a certain good when total expenditure expands by one per cent. It is larger than one for 'luxury' goods and distinctly smaller than one for 'necessities'.

[7] According to the guidelines of the Norwegian Ministry of Finance (2014), a NOK 1 incremental revenue for the public treasury is to be valued at NOK 1.20, i. e. at a 20 per cent 'premium' compared to private funds, since taxes are in general distortionary, and hence public revenue comes at a price in terms of reduced allocative efficiency throughout the economy (Pigou, 1948).

[8] More precisely, the zones coincide with the 'basic statistical units' (BSUs), see Section 4.2.4.