TØI rapport 1780/2020

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Hvem velger elbil?

Kjennetegn ved norske elbileiere 2011-2017

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Sammendrag:

Denne rapporten beskriver kjennetegn ved alle norske elbileiere og øvrige bileiere ved hjelp av sammenkoblete norske registerdata for personer og husholdninger i perioden 2011-2017. Det er første gang denne typen data har blitt brukt i et forskningsprosjekt om elbiler og politikk for å stimulere til kjøp/bruk av elbil. Vi finner at elbileiere særlig er familier med barn, at de bor i sentrale strøk og at de har høyere inntekt og utdanning enn andre bileiere. De som må betale bompenger på vei til jobb, har også oftere elbil. Eiere av elbil har over tid blitt likere andre bileiere. Når bileiere kjøper en elbil, beholder de ofte den gamle bilen, men det har blitt vanligere enn før å kvitte seg med den gamle bilen når en kjøper elbil.

Summary:

This report characterizes owners of electric vehicles and other passenger cars in Norway based on data from matched administrative registers containing persons and households covering the period 2011-2017. This is the first time such data has been used in a research project on electric vehicles and policies to stimulate purchase and ownership of electric vehicles. We find that electric vehicle owners are more likely to be families with children, live in central areas and have high income and higher education compared to other car owners. Those who face road tolls on their road to work are also more likely to have an electric vehicle. Over time, owners of electric vehicles have become more similar to other vehicle owners. Those who buy an electric vehicle are more likely than others to keep their old vehicle, but also this difference has decreased over time.

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Forord

Denne rapporten inneholder de første resultatene fra prosjektet «Driving towards the low emission society», som er et forskningsprosjekt ledet av Frischsenteret i samarbeid med Transportøkonomisk institutt (TØI).

Formålet med prosjektet er å analysere effektene av dagens og alternative virkemidler for å fremme nullutslippsbiler i Norge. Prosjektet benytter store datasett med individuelle data for kjøretøy og deres eiere basert på administrative registre. Det er første gang denne typen data brukes i et forskningsprosjekt om bilhold i Norge.

Et viktig bidrag fra prosjektet er etableringen av en datastruktur som kan brukes til å analysere effekten av ulike virkemidler. Resultatene i denne rapporten er imidlertid kun beskrivende (deskriptive) og dokumenterer dataene og hvordan de har blitt bearbeidet. Rapporten viser nye funn når det gjelder kjennetegn ved eiere av ulike typer biler, hvordan disse kjennetegnene har utviklet seg over tid, og hvordan kjøp av elbil henger sammen med samlet bileierskap i husholdningen.

Bjørn G. Johansen (hovedansvarlig) og Elisabeth Fevang har stått for bearbeidingen av data. Alle medforfattere har bidratt i diskusjonen av struktur og resultater og i skrivingen av ulike deler av rapportteksten. Prosjektleder Oddbjørn Raaum ved Frischsenteret har koordinert arbeidet. Rapporten er kvalitetssikret av Paal B. Wangsness (TØI).

Forskningsteamet har også fått verdifulle innspill fra de vitenskapelige rådgiverne Anders Munk-Nielsen og Emma Freijinger og brukerpartnerne Statens vegvesen, Møller Mobility Group, Nissan Nordic, Norges Automobil-Forbund (NAF) og Norsk Elbilforening. Data på utlån fra Statistisk sentralbyrå (SSB) har vært essensielle for denne forskningen. I tillegg har vi benyttet data på nybilpriser fra Opplysningsrådet for veitrafikken (OFV).

Oslo, august 2020
Transportøkonomisk institutt

Gunnar Lindberg	*Kjell Werner Johansen*
Direktør	*Avdelingsleder*

Preface

This report contains the first results from the project "Driving towards the low-emission society", a research project headed by the Ragnar Frisch Centre for Economic Research in co-operation with the Institute of Transport Economics (TØI).

The project aims to develop new knowledge on the effects of current and alternative policies for promoting zero emission vehicles in Norway. To this purpose, we compile large datasets of individual vehicles and their owners based on administrative registers. This is the first research project on vehicle ownership in Norway based on this kind of data.

An important contribution of the project is to establish a data structure which can be used to analyze the effects of various policies. This report, however, is descriptive and documents the data and how it has been constructed. It presents novel evidence on the characteristics of owners of different types of vehicles, on how these characteristics have evolved over time, and on how buying an electric vehicle is associated with total car ownership of the household.

Data compilation has been done by Bjørn G. Johansen (lead) and Elisabeth Fevang. All co-authors have contributed by discussing the structure, results and written drafts of various sections of the report. Project manager Oddbjørn Raaum at the Frisch Centre has coordinated the work. The report has been subject to quality assurance by Paal B. Wangsness (TØI).

The research team has also received valuable input from the scientific advisors Anders Munk-Nielsen and Emma Freijinger, as well as the from user partners – the Norwegian Public Road Administration, Møller Mobility Group, Nissan Nordic, the Norwegian Automobile Association (NAF) and the Norwegian Electric Vehicle Association. Data on loan from Statistics Norway have been essential for this research. We have also used data on prices of new cars from Opplysningsrådet for veitrafikken (OFV).

Oslo, August 2020

Institute of Transport Economics (TØI)

Gunnar Lindberg
Managing Director

Kjell Werner Johansen
Research Director

Content

Sammendrag

Hvem velger elbil? Kjennetegn ved norske elbileiere 2011-2017

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Oslo 2020, 44 sider, engelsk

Denne rapporten beskriver kjennetegn ved alle norske elbileiere og øvrige bileiere ved hjelp av sammenkoblete norske registerdata for personer og husholdninger i perioden 2011-2017. Det er første gang denne typen data har blitt brukt i et forskningsprosjekt om elbiler og politikk for å stimulere til kjøp/bruk av elbil. Vi finner at elbileiere særlig er familier med barn, at de bor i sentrale strøk og at de har høyere inntekt og utdanning enn andre bileiere. De som må betale bompenger på vei til jobb har også oftere elbil. Eiere av elbil har over tid blitt likere andre bileiere. Når bileiere kjøper en elbil, beholder de ofte den gamle bilen, men det har blitt vanligere enn før å kvitte seg med den gamle bilen når en kjøper elbil.

Bakgrunn

Transport står for en høy andel av utslippene av klimagasser, og en innfasing av kjøretøy med null eller svært lave klimautslipp vil være et sentralt bidrag til å nå klimamålene. Foreløpig er imidlertid andelen nullutslippskjøretøy lav, og det er derfor begrenset med kunnskap om i hvilken grad slike biler er et reelt alternativ for den jevne reisende.

Norske data gir her en unik mulighet: For det første har Norge flere elbiler enn noe annet land, med 42 prosent av nybilsalget i 2019. Det ble også solgt ca. 14% ladbare hybridbiler i 2019. For det andre har vi administrative registre som inneholder detaljerte data for både bileierskap og husholdningskjennetegn som kan utnyttes i forskning. Forskningsprosjektet som denne rapporten inngår i, er det første til å utnytte denne typen data til å studere den norske elbilpolitikken.

Ved å bruke denne typen data gir vi flere viktige bidrag til forskningen på dette temaet: Mens de fleste tidligere studier fokuserer på nybilkjøp, studerer vi samlet bilhold inkludert gamle og brukte biler. Ved å kople bilene til den enkelte husholdning kan vi også se om elbilen erstatter en bil husholdningen har fra før, eller kommer i tillegg. Dataene viser faktiske valg, ikke hva bileierne sier de har tenkt å gjøre eller hva de oppgir som motivasjon for valgene sine, og de dekker hele befolkningen, ikke bare et utvalg.

Tidligere litteratur

Den eksisterende litteraturen om elbileierskap kan deles inn i tre kategorier: (1) Studier som beskriver bilkjøpernes planer om elbilkjøp og/eller motivasjon for å velge elbil basert på spørreundersøkelser, (2) modellering av kvalitative («diskrete») valg basert på hypotetiske valgeksperiment (stated preferences) og (3) modellering av kvalitative og/eller kvantitative valg basert på faktiske data for bilsalg eller bilhold. Nedenfor beskriver vi disse kategoriene kort.

På grunn av den lave andelen elbiler i mange land dreier studiene basert på spørreundersøkelser (1) seg ofte om folks planer om å kjøpe elbil. Noen funn som går igjen i disse, er at de som tenker å kjøpe elbil i større grad er menn, har høy utdanning, jobber fulltid, bor med familie utenfor en stor by med familie, har lademuligheter hjemme og eier en ladbar hybridbil fra før. Funnene når det gjelder sammenheng med inntekt og om en har flere biler er mer blandet, men studier fra Norge finner at elbileierne har høyere inntekt og eier flere biler. Det er langt mer krevende å få et bilde av tidsutviklingen, ettersom spørreundersøkelsene i liten grad er utformet for å kunne sammenlikne elbileiere og andre bileiere over tid.

Blant studiene basert på stated preference-data (2) viser noen at i tillegg til å ha høy inntekt, er de som sier de vil velge en elbil, i større grad opptatt av miljøspørsmål. En studie fra Danmark viser også dette, men finner samtidig at betydningen av andre egenskaper ved elbiler endrer seg etter at respondentene har fått prøve en elbil i en periode. Dette illustrerer én av svakhetene ved å kun basere seg på hypotetiske valg og spørsmål om plan for elbilkjøp.

Studiene basert på faktisk bilsalg eller bilhold (3) er til dels basert på data aggregert på kommune- eller et annet geografisk nivå og fokuser på effekten av ulike politiske virkemidler. Disse viser derfor i liten grad betydningen av individuelle kjennetegn. Det er også noen studier basert på individuelle data for den samlete befolkningen av bileiere, slik som studien vår, men disse er fra land der andelen elbiler er svært lav.

Datasettet vårt

Vi har etablert et datasett på utlån til forskning via Statistisk sentralbyrå (SSB) i tråd med gjeldende retningslinjer for bruk av individdata til forskning. Datasettet inneholder ikke direkte personidentifiserende opplysninger. Datasettet består av biler og individer, basert på kjøretøyregisteret til og med 2017 i kombinasjon med ulike administrative registre.

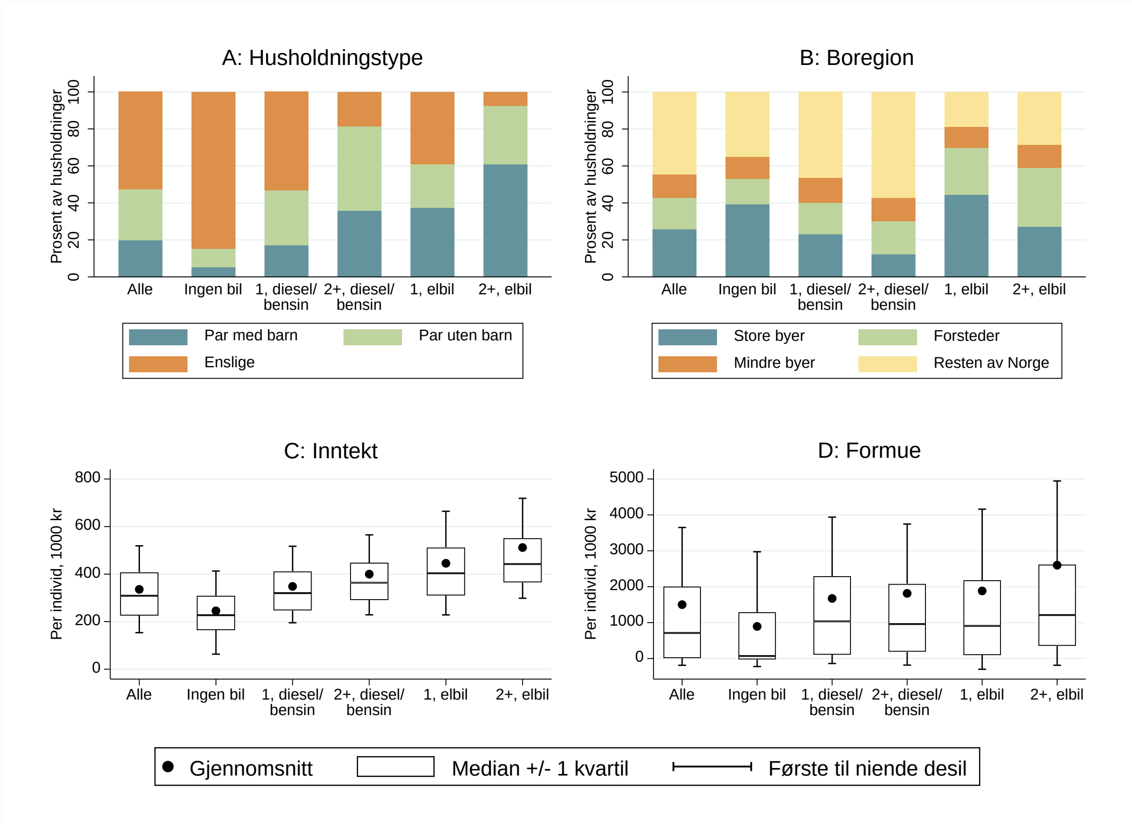
Når registrert bileier befinner seg i en husholdning med flere voksne personer, er det vanskelig å vite hvem som i virkeligheten benytter denne bilen mest. I de fleste analysene bruker vi derfor husholdning som observasjonsenhet og studerer kjennetegn ved husholdningen og bilen(e) som tilhører husholdsmedlemmene. I SSBs registre for datautlån fantes det omkring 2,5 millioner husholdninger i 2017.

Kjøretøyregisteret inneholder en rekke egenskaper ved bilene som alder, merke, vekt osv. I denne rapporten skiller vi imidlertid kun mellom biler med ulik drivstoffteknologi. For husholdningene har vi kjennetegn som størrelse, sammensetning etter alder og kjønn, inntekt, formue, utdanning, yrke, type bolig og grunnkrets for bosted. Vi har også koplet arbeidstakere og bedrifter slik at vi vet hvilken grunnkrets hvert medlem av husholdningen arbeider i. Ved hjelp av dette har vi identifisert kjennetegn ved reisen til jobb, inkludert om det er bompenger og kollektivfelt på strekningen.

Kjennetegn ved elbiler og elbileiere

Andelen husholdninger med elbil økte fra ca. 0,1 prosent i 2011 til 4,5 prosent i 2017, når vi ser bort fra hybridbiler. Over to av tre elbilhushold hadde minst to biler.

Figur 1 viser noen sentrale kjennetegn ved husholdningene i 2017 inndelt etter hvor mange biler de har, og om en av disse er en elbil. Vi ser at par med barn er overrepresentert blant husholdninger med elbil, både de med én og de med flere biler. Elbileierne bor i større grad i storbyene eller nabokommunene til disse. De har høyere inntekt og til en viss grad en større formue enn andre bileiere.



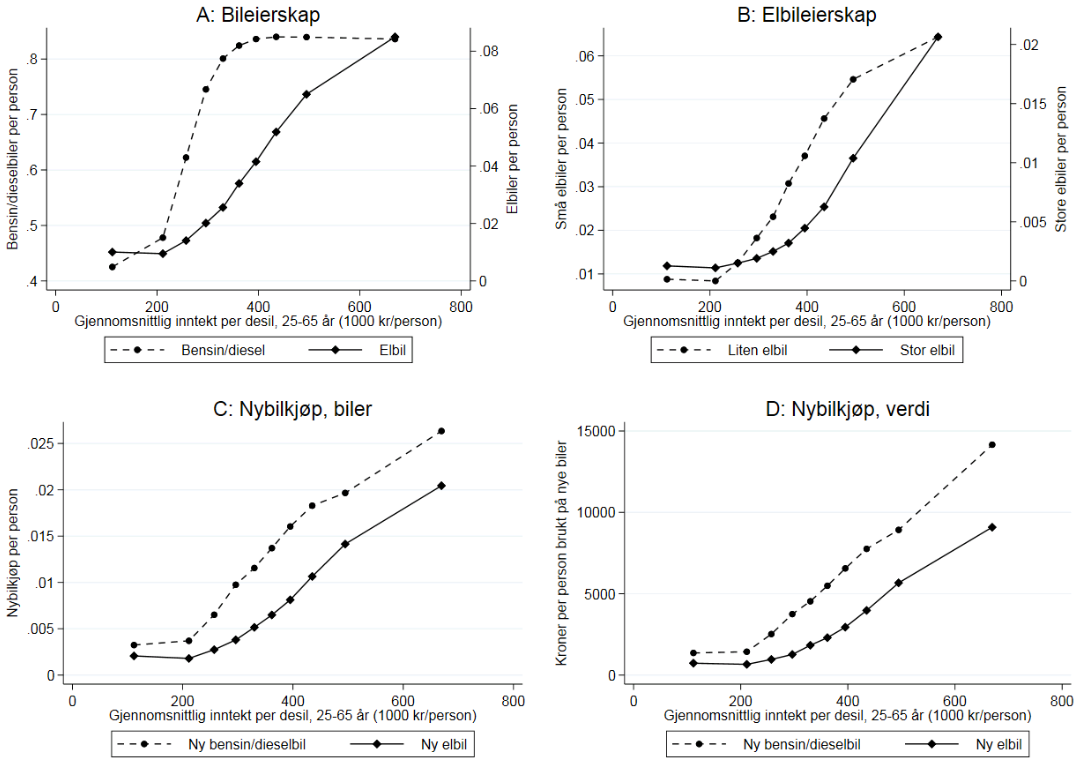
Figur 1. Bileierskap og husholdningskjennetegn, 2017.

Videre analyser viser at elbileierne er mer tilbøyelige til å tilhøre aldersgruppa 25-44 år og ha høyere utdanning. Som ventet er både gjennomsnittlige bompenger på reiseveien til jobb og andelen som har en reisevei der det er kollektivfelt, betydelig høyere blant elbileierne. Andelen som bor i enebolig og andelen som har tilgang til hytte, enten som eier eller via familienettverk, er derimot nokså lik mellom elbileiere og andre bileiere.

Vi har også sett på i hvilken grad disse sammenhengene gjelder når vi kontrollerer for alle husholdskjennetegn samtidig, og finner i ganske stor grad det samme mønsteret. En husholdningstype med høy sannsynlighet for å eie elbil er et par i alderen 25-44 som bor i nærheten av en storby og har barn, høyere utdanning og en reisevei til jobb med bompenger og kollektivfelt. Den typiske bileiende husholdningen med to voksne *uten* elbil er et par i alderen 45-65 som ikke bor i nærheten av en storby og som ikke har hjemmeboende barn, ikke høyere utdanning og ikke en reisevei med bompenger eller kollektivfelt, og der kun mannen har inntektsgivende arbeid.

Det er viktig å være oppmerksom på at de mønstrene vi har avdekket, i noen grad trolig henger sammen med at elbiler kun har vært på markedet i noen år, og derfor kun har vært et alternativ for de som har kjøpt bil et av de senere årene. Det kan derfor være at flere av sammenhengene vi finner, delvis gjenspeiler typiske egenskaper ved nybilkjøpere generelt.

Et tema som får mye oppmerksomhet er sammenhengen mellom elbilhold og inntekt. Vi har sammenliknet elbileiere og andre bileiere både når det gjelder bilhold, nybilkjøp og verdi på nybiler. Vi finner at elbileierne i større grad befinner seg blant de rikeste husholdningene enn eiere av ikke-elbiler. Denne forskjellen er imidlertid mindre når vi sammenlikner kjøpere av nye biler. Når vi ser på utgifter til nybilkjøp finner vi en klar positiv sammenheng med husholdningsinntekt, både for el-biler og andre biler (Figur 2).



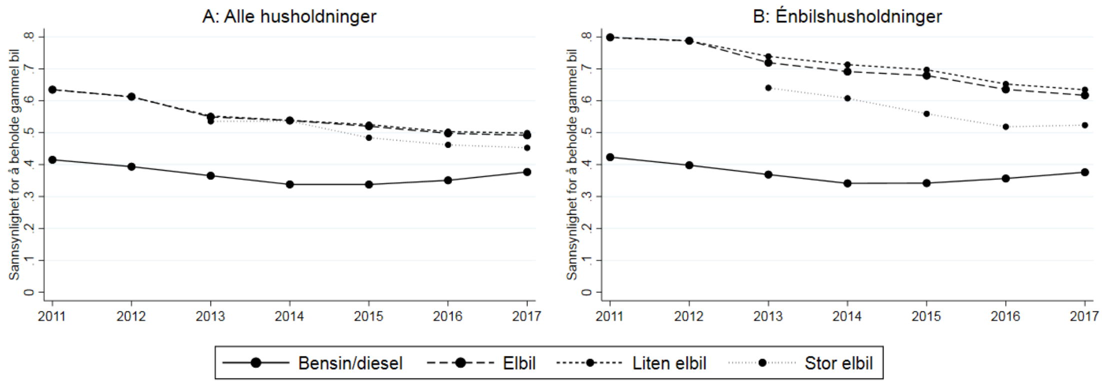
Figur 2. Bileierskap og inntektsklasse, 2017. Antall biler eller totalbeløp brukt på nye biler per husholdning.

Vi har også sett på utviklingen over tid. Disse viser at elbileierne har blitt noe mer lik andre bileiere over tid. Dette gjelder særlig formue og hvilket område en bor i, men også inntekt og utdanning. Dette kan endre seg ytterligere når data for årene etter 2017 blir tilgjengelige.

Bytter de ut den gamle bilen?

Kjøretøyregisteret inneholder opplysninger om når hver bil ble førstegangsregistrert, skiftet eier eller ble avregistrert. Ved hjelp av dette kan vi se hva som skjer med det samlete bilholdet i en husholdning når denne skaffer seg en ny bil. Nærmere bestemt ser vi på om husholdningen som kjøpte ny bil, kvittet seg med en annen bil i løpet av 240 dager rundt nybilkjøpet.

Resultatene er vist i Figur 3. Vi finner at andelen som beholdt den gamle bilen er høyere blant husholdninger som kjøpte elbil enn blant husholdninger som kjøpte en annen type bil. Andelen som beholdt den gamle bilen er særlig høy blant husholdninger som kjøpte elbil og bare hadde én bil fra før, men det er også her vi finner den største endringen over tid. Mens 80 prosent i denne gruppa beholdt den gamle bilen i 2011, var andelen i 2017 bare 62 prosent. Blant de som kjøpte en stor elbil (Tesla) er andelen som beholdt den gamle bilen betydelig lavere. Videre analyser viser også at noe av forskjellen mellom elbilkjøpere og andre bilkjøpere kan forklares av sosio-økonomiske kjennetegn ved husholdningene.



Figur 3. Sannsynligheten for å beholde den gamle bilen, etter kjøpsår for ny bil og type ny bil.

Konklusjon

Tilgang til detaljerte individdata via kopling av ulike administrative registre har de siste tiårene bidratt til betydelige framskritt innenfor samfunnsforskningen, men har i liten grad vært utnyttet til transportforskning. Koblete mikrodata fra landet med høyest elbiltetthet i verden gir unike muligheter, både til å studere egenskaper ved elbileierne, atferden deres og effekten av ulike politiske virkemidler. Funnene våre viser betydelige forskjeller mellom elbileiere og andre bileiere. Samtidig har elbileierne over tid blitt mer lik andre bileiere, både når det gjelder egenskaper ved husholdningen som eier bilen, og når det gjelder sannsynligheten for at elbilen erstatter en annen bil.

Det bør understrekes at funnene i denne rapporten er beskrivende. Det er ikke en kartlegging av spesifikke årsakssammenhenger. Dataene gir imidlertid lovende muligheter også når det gjelder å identifisere årsakssammenhenger, for eksempel når det gjelder effekten av lokale virkemidler, som bompenger og kollektivfelt, på bilhold og bilbruk. Vi forventer økt bruk av registerdata i studier av bilhold og reiseatferd de neste årene.

Summary

Who goes electric? Characteristics of electric car ownership in Norway 2011-2017

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Authors: Elisabeth Fevang, Erik Figenbaum, Lasse Fridstrøm, Askill H. Halse, Karen E. Hauge, Bjørn G. Johansen, Oddbjørn Raaum
Oslo 2020, 44 pages, English

This report characterizes owners of electric vehicles and other passenger cars in Norway based on data from matched administrative registers containing persons and households covering the period 2011-2017. This is the first time such data has been used in a research project on electric vehicles and policies to stimulate purchase and ownership of electric vehicles. We find that electric vehicle owners are more likely to be families with children, live in central areas and have high income and higher education compared to other car owners. Those who face road tolls on their commute to work are also more likely to have an electric vehicle. Over time, owners of electric vehicles have become more similar to other vehicle owners. Those who buy an electric vehicle are more likely than other car buyers to keep their old car, but also this difference has decreased over time.

We describe the anatomy of electric car ownership in Norway, the leading country in terms of the market penetration of low-emission vehicles. We use matched administrative micro data covering the entire population of private car owners in the country.

The results show that socioeconomic characteristics are strong predictors of the car portfolio, and that battery electric vehicle (BEV) ownership increases with income and education, and is higher among families with children living at home. While BEV pioneers were particularly selected, BEV owners have become more similar to other car owners over time. We document large geographic differentials in BEV ownership, partly due to a strong association between BEV ownership and certain incentives affecting the journey to work, such as toll road exemption and access to the bus lane.

The extent to which BEVs crowd out traditional cars is of major importance to the total emissions. In a study of car portfolio adjustment, we show that BEV buyers are less likely than other car buyers to sell their old car, but this difference has diminished over time.

The relationship between electric vehicle ownership and income has received considerable attention. When comparing across all vehicle owners, BEV ownership is more concentrated among the richest households than ownership of traditional vehicles with and internal combustion engine (ICEVs). However, when only comparing owners of new cars, the difference is smaller. When new car ownership is measure by the value of the car, we find a strong positive relationship between household income and money spent on buying new ICEVs as well as BEVs, as expected.

1 Introduction

Transportation is responsible for almost 30 percent of EU's total CO2 emissions, of which 60 percent can be attributed to private cars.[1] The European Union's preliminary 2030 emissions reduction targets for the non-ETS sector cannot be reached without substantial reductions in the emissions from the transport sector.[2] A transition to zero and low emission private transportation is essential for reaching emission targets, but it is less clear how it will come about. Even if the main force of low emission car expansion is technological development, a number of societal factors and national policies affect the speed at which zero emission cars are adopted. How do household characteristics determine who will go electric? How will electric car ownership spread across the population over time? More importantly, what is the role of policies that may foster such a transition, and how will the benefits and costs of such policies be distributed across households and socio-economic groups? Although the sales of zero and low emission cars are expanding fast, low emission passenger cars like battery electric vehicles (BEVs) and plug-in hybrid electric cars (PHEVs) constitute a small share of the passenger car market in most countries.[3] Moreover, motivations and characteristics of the pioneers who are the first to embrace a new technology are likely to differ from those of later adopters (Rogers, 1995).

From these perspectives, Norway is an interesting case with its high share of BEVs. In 2018, near 50% of new passenger cars sold to households in Norway were either BEVs or PHEVs. The share of BEV and PHEV ownership is higher, and the policies to favor zero emission automobiles seem stronger than in any other country (Mock and Yang 2014). In combination with exceptionally rich data on car ownership, the Norwegian experience over the last ten years or so allows for detailed empirical studies of major interest to the green transition of private cars.

This report aims to describe the car ownership structure using longitudinal Norwegian administrative data from 2011 to 2017. We present a novel description of car ownership focusing on the characteristics of BEV households that goes far beyond what is possible using traditional survey data. Focusing on the adoption of BEVs since 2011, we document how the BEV fleet has expanded across regions, income groups, education/occupation and other household characteristics, and how it interacts with internal combustion engine vehicle (ICEV) ownership and use.

This report makes several contributions. First, while most existing studies of electric cars focus on new vehicles sales or intention to buy a BEV, we characterize (actual) car ownership including older cars and second-hand acquisition. Second, from the focus on car

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[1] https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics

[2] The EU target for transport emissions is set to 30% reduction by 2030 compared to 2005 (European Parliament 2019).

[3] China has by far the largest market for electric cars in the world with 1.1 million cars (counting both BEVs and PHEVs) sold in 2018 (IEA 2019). The market shares of new electric cars in China, however, was still only around 4% in 2018. In the two next biggest markets, Europe and the US, new electric cars make up below 2% of the market share (IEA 2019).

owners (rather than cars) we can describe the substitution patterns between cars with different technologies. For example, we document the extent to which new BEV owners keep their old car. Third, our data reveal actual real-life choices, rather than intentions or expressed motivation from informants. For example, concerning the role of BEV privileges like toll exemptions, we can juxtapose the behavior of (comparable) households with varying factual travel patterns, rather than relying on how informants respond in surveys. Fourth, the data are highly representative as they include the entire population. Data reliability is high and not challenged by non-random attrition or other shortcomings of data based on informant statements. With full population data, we avoid data quality issues related to selected, small samples with substantial attrition over time. Finally, the high share of BEVs in the Norwegian car market allows us to describe one of the more mature BEV car markets to date, including not only pioneering BEV owners. Given the political goals of reducing transport emissions across the world, our evidence represents a case of external interest. Overall, the richness and quality of our data allow us to give a more reliable and complete description of the anatomy of car ownership than has previously been possible.

The remainder of the report is organized as follows. Chapter 2 briefly describes the development of the electric car market in Norway, while Chapter 3 reviews empirical studies of low-emission vehicle demand. Our longitudinal micro data are described in Chapter 4, along with the methods used in our analyses. Chapter 5 presents our results; first we describe car ownership, focusing on how BEVs are distributed across households and how characteristics of BEV owners have changed over time. Second, we show that the richer households spend considerably more on new cars, both BEVs and ICEVs. Third, we estimate a multinomial logit model and show conditional effects of socio-economic characteristics and BEV privileges arising from toll road exemptions and bus lane access on the travel between home and work. Fourth, we zoom in on households around the time of purchasing a new car and study the extent to which total number of cars increase when a new BEVs arrives. Chapter 6 concludes.

2 Electric vehicles in Norway

The first BEVs in Norway appeared on the market in the early 1990s, yet in 2010 the total number of BEVs in Norway was not higher than around 2,500 vehicles. Figure 1 illustrates the development over time in the total number, and composition, of new car sales from 2002-2019. As illustrated, the sales of BEVs did not start expanding before 2011, the year the first mass produced purpose built modern BEV (Nissan Leaf) was introduced in Norway. In 2019, 42.4 per cent of new passenger cars registered in Norway were battery electric vehicles (BEV), 13.6 per cent were plug-in hybrid electric vehicles (PHEV), and 12.3 per cent were ordinary (non-plug-in) hybrid electric vehicles (HEV). Traditional diesel and gasoline cars only constituted 31.7 per cent, of which 15.7 per cent were gasoline driven and 16.0 per cent were diesel fueled (Figure 1).[4]

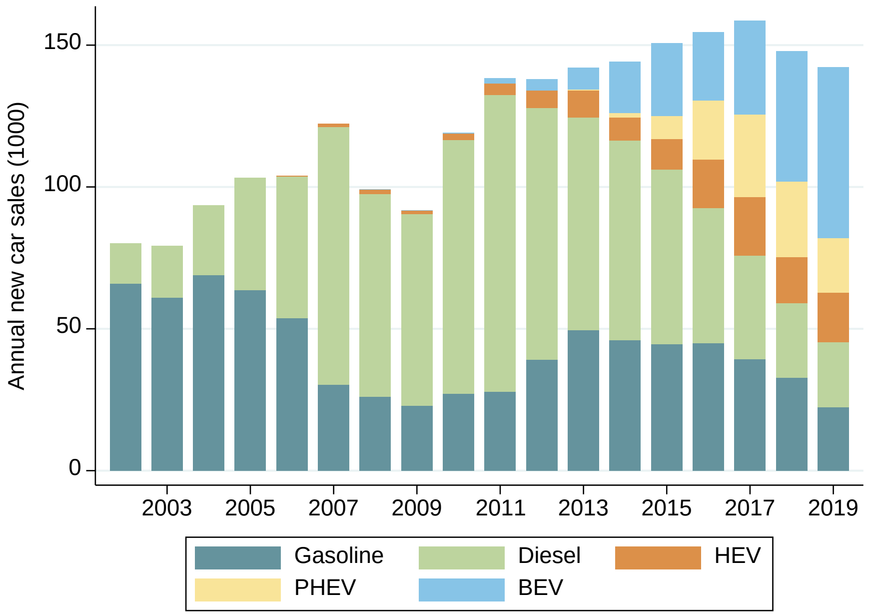


Figure 1. New passenger cars registered in Norway, by year and powertrain. 2002-2019. Source: OFV (Norwegian Road Federation).

Zero/low emission automobiles have expanded under a persistent government policy of favorable treatment. While no cash subsidies are being paid out in support of electric passenger cars[5], all of the Norwegian incentives take the form of exemptions from relatively heavy taxes and regulations affecting vehicles equipped with an internal

[4] The rest (not included in the figure) was made up by fuel cell electric vehicles (0.034 per cent) and compressed natural gas (0.042 per cent).

[5] Some NOK 50 million are, however, being paid out annually in support of fast charging and hydrogen refueling facilities, or to foot the electricity bill at public parking lots – see Fig. A3 in Appendix A. For light commercial vehicles, certain subsidy schemes have been introduced in 2018 and 2019.

combustion engine (ICE). The most important are exemptions from the general 25% value added tax (VAT), from the one-off registration tax[6] and from the annual ownership tax. Zero emission vehicles[7] have been fully exempted from road toll and public parking fees, but from 2020, BEVs are subject to maximally 50% of the rates applicable to ICE vehicles (ICEVs). Reduced ferry fares also apply, and free BEV recharging in many public parking lots. Zero emission vehicles also have access to bus lanes, although some restrictions may apply during the rush hours. For more details on policies and incentives see Appendix A.

As a direct consequence of the technology, fuel taxes are not applicable. Finally, cheap electricity also contributes to the low user cost for BEVs and PHEVs. Norway is the country in Europe where BEV owners will experience the largest savings in terms of energy cost when going electric (Figenbaum 2020).

[6] The CO_2-component and NO_X-component of this tax would in any case always be zero

[7] I.e., BEVs and fuel cell electric vehicles.

3 Previous studies on electric vehicle ownership

This chapter reviews empirical studies of BEV ownership. We divide the literature on BEVs in three broad categories. The first category consists of descriptive studies using survey data on intentions to buy BEVs or BEV ownership. The second category uses stated preference (choice experiment) surveys to estimate discrete choice models. The third is based on observational data on BEV sales using continuous or discrete choice econometric modeling.

The first category of the literature are studies based on survey data. Due to the (current) low market share of BEVs in most countries, many studies on BEV ownership focus on intentions to adopt rather than actual choice (Rezvani et al. 2015). Based on two review articles of studies on intentions to adopt BEVs (Coffman et al. 2017; Li et al. 2017), and some additional studies not included in the review studies,[8] some clear patterns emerge related to demographic characteristics: people who report wanting to buy BEVs are more likely to be men[9], have higher education, work full-time, live outside large cities, have a hybrid-electric car already, have a place to charge at home, and live in multi-person households. For other household characteristics, studies on intentions to adopt BEVs are inconclusive. According to (Coffman et al. 2017) and (Li et al. 2017), most studies find no effect of income on intentions to adopt BEVs, while one study (Tran et al. 2013) find that people with higher income are more likely to buy BEVs. There is also mixed evidence on whether multi-car owners are more, less or equally likely to buy BEVs.

Other survey studies focus on BEV ownership. Many of these studies are from Norway, since Norway is the country where the transition towards BEVs has come the furthest. However, these studies have small samples, and one might be concerned that the respondents are not representative of all BEV owners. According to these studies,[10] BEV owners are more likely to be men, have higher education and income, own multiple cars,[11] have full-time jobs and children under 18 years old living at home. When it comes to age, it is less likely to own BEVs in age groups under 25 and over 55.

Emerging technologies are often analyzed in context of Rogers' theory of the diffusion of innovations (Rogers 1995), according to which the adaptation decision is a social process influenced by the user peers. A small group of adventurous innovators are the first to take the innovation into use followed by a larger group of early adopters. The next adopter groups are the early and late majority, while the final group of buyers are the laggards, left

[8] These include Plötz et al. (2014), and Sovacool et al. (2018).

[9] In addition, women have less experience with BEVs (Sovacool et al. 2018).

[10] These include Figenbaum and Kolbenstvedt (2013), Plötz et al. (2014), Figenbaum et al. (2014), Bjerkan et al. (2016), Figenbaum and Kolbenstvedt (2016) and Figenbaum and Nordbakke (2019).

[11] Bjerkan et al. (2016) is an exception, reporting quite similar numbers when comparing households owning BEVs to other new car households. See also Jakobsson et al. (2016) and Björnsson and Karlsson (2017) regarding the suitability of multi-car households and BEVs.

with no choice but to adopt. The change in socio-demographic composition of BEV users in Norwegian surveys illustrates Rogers' theory. Over time, the survey indicates a transition in the buyer groups from typical innovators and early adopters in the first surveys in 2014 and 2016 (Figenbaum et al. 2014; Figenbaum and Kolbenstvedt 2016) towards the early majority group of buyers according to the last survey (Figenbaum and Nordbakke 2019), see Table 1.

Table 1. Survey data on BEV owners in Norway in 2014, 2016 and 2018

	ICEV owners 2016 (N: 3,018)	Bev owners 2014 (N: 1,721)	BEV owners 2016 (N: 3,111)	BEV owners 2018 (N: 3,659)
Work status				
Employed/self-employed (%)	67	91	91	85
Retired/benefit recipient/student (%)	33	9	9	14
Education				
High school (%)	33	19.2	22	24
Higher education, up to 4 years (%)	56	38.2	47	51
Higher education, more than 4 years (%)	26	40.5	40	37
Demographics				
Male share (%)	78	76	80	72
Average age (years)	56	47	47	51
Household size (persons)	2.5	3.24	3.17	2.95
Households with children (%)	27	1.17*	56	45
Car related				
Multivehicle households (%)	52	78	79	73
Average distance to work (km)	18	26	25.5	25.4
Gross household income (%)				
0 – 600,000 NOK	26	12	11	11
600,000 – 1,000,000 NOK	41	38	36	30
More than 1,000,000 NOK	24	43	47	52
Do not want to report	9	7	6	7

*Note: * Avg. number of children, as opposed to percent of households with children. ICEV owners 2016 is included for reference. The table only displays respondents owning a car from 2011 or newer. Sources: Figenbaum et al. (2014) and Figenbaum and Nordbakke (2019).*

Table 1 suggests that work status, education, age, household size and the number of cars among BEV owners have become more similar to that of ICEV owners over time. However, BEV owners have become richer. Overall, this evidence of convergence is only indicative since the surveys are not designed for explicit comparisons between ICEV and BEV households over time. In the recent surveys, respondents report that "economy of use" is by far the most important motivation for a BEV purchase (Figenbaum and Nordbakke 2019), followed by environmental concerns. Once they have become BEV drivers, few want to switch back to ICEs. There is a tendency that BEVs are more common as a second vehicle than ICEVs, although Figenbaum and Nordbakke (2019) estimate that more than 90 per cent of BEVs replaced an ICEV. BEVs are much more common in multi-vehicle households, but the most recent survey points to an increased attractiveness of BEVs in single vehicle households. Finally, BEVs can increasingly be used for long distance driving, partly due to the expansion of fast charging infrastructure (Figenbaum 2019).

The second category of literature is based on stated preference (SP) survey data for choice modeling, integrating attitudinal and behavioral factors in the decision-making process in a hybrid choice model setup (Walker and Ben-Akiva 2002; Walker 2001). An early article from Canada uses a choice experiment to study the tradeoff between a conventional vehicle, a vehicle on natural gas, a hybrid (gasoline electric) vehicle and a hydrogen fuel cell vehicle (Bolduc et al. 2008). They find that environmental concerns and appreciation of new car features have positive impact on the preferences for low-emission cars. A Swiss study within this category characterizes typical BEV customers as young public transport users, two-car households and high-income households (Glerum et al. 2014).

Liao et al. (2017) review a number of recent studies of this kind. They find that the attractiveness of EVs (their focus is on both BEVs and PHEVs) increase with the tax incentives related to car purchase and with the access to charging infrastructure, while the evidence on the effect of other policies is mixed. The findings also differ when it comes to the effect of sociodemographic characteristics, but higher educational level is positively associated with EV adoption in all studies that include this variable.

Jensen et al. (2013) study whether experience with using BEVs influence preferences. They conduct a two-wave stated preference study in Denmark, comparing preferences reported before and after using a BEV for three months. Environmental concern positively affects the preferences for BEVs and is persistent before and after experiencing a BEV; however, the importance attached to other attributes of BEVs changed significantly after having used a BEV for three months. This result points to one of the weaknesses with the studies in this category – that they are based on hypothetical choice data and that respondents therefore might not have experience with BEVs. According to Coffman et al. (2017), "There is strong evidence that that actual purchases is much lower than consumers' stated preferences". Consumer who have experienced driving BEVs also report a higher willingness-to-pay for BEVs (Larson et al. 2015), although that could be due to selection in terms of who has experience with driving BEVs.

When interpreting results from the first two strands of literature, one must have in mind that the BEV technology, availability of BEVs on the market, and their characteristics have evolved significantly over time. For instance the lowest cost Nissan Leaf is now equipped with a 40 kWh battery, and a version with a 62 kWh battery is also available, whereas the first generation Leaf back in 2011 had a 24 kWh battery.

The third strand of literature relies on detailed car sales data to estimate econometric discrete choice models to understand BEV adoption. The strength of these model frameworks is the potential to do counterfactual simulations on (equilibrium) outcomes under alternative policies. However, these studies tend to either not include any information regarding the owner at all, or rely on aggregated regional data (such as demographics and income data aggregated to the municipality or other regional level). Østli et al. (2017) and Fridstrøm and Østli (2018) estimate disaggregate nested logit models for passenger cars purchases in Norway, deriving direct and cross price elasticities of demand as well as well as estimates of how consumers respond to vehicle and fuel pricing and taxation. Being void of information on the human beings behind vehicle ownership or acquisition, these models cannot predict the effect of changes pertaining primarily to the owners, such as a higher income or a change in residential location. On the positive side, the model does not need any information, aggregate or disaggregate, on the vehicle owners or on society in general, in order to produce a market forecast. Only the characteristics of the vehicles themselves need to be known.

The most popular strand of this literature is based around the random coefficient discrete choice model framework (Berry et al. 1995). Early studies within this tradition, for instance Beresteanu and Li (2011), focused on hybrid-electric vehicles since there still were too few BEVs in the car market, in this case in the US car market, for credible inference. Later studies include studies of the relationship between demand for BEVs and policies such as tax exemptions and access to charging stations (Zhang et al. 2016), charging subsidies (Springel 2017), charging standards (Li 2017) and substitution between BEVs and other car types (Xing et al. 2019). According to these studies, the policies increase demand for BEVs.

Finally, there are a couple of studies using full population administrative register data on the entire population of cars and car owners, linking demographic information about the car owners to data about the cars owned (Glerum et al. 2013; Gillingham et al. 2015; Gillingham and Munk-Nielsen 2019). Unfortunately, these studies are conducted in countries where the shares of BEVs were too low to include them explicitly and they consider the choice between gasoline and diesel cars only.

Hasan et al. (2019) provide a short review and bibliometric study of the entire literature on electric vehicles[12] since 1995. They find that studies with a technological focus dominate the field. Only one of the ten most cited articles (Rezvani et al. 2015) concerns consumer characteristics and behavior, and other topics are mentioned much more frequently than "behavior" is. The authors conclude that that is concerning, since the goal of policies is to increase consumer adoption of electric vehicles.

Our paper will be the first paper using full population administrative register data describing the demographics of actual BEV and ICEV ownership. Our contribution is thus to provide a more detailed description of car ownership with a particular focus on BEVs, based on full population, linked micro data from population and motor vehicle registers. Our study is not based on hypothetical intentions, but on actual car owners. The analysis is not based on small samples, but on data for the full population of car owners in an entire country. We therefore address a number of methodological weaknesses of surveys like small, self-selected samples with potentially non-random attrition, measurement error from self-reporting, as well as reported behavioral intentions that not always turn into actual behavior. Compared to transaction data studies, our contribution is to study car ownership and not only sales, and also include characteristics of each decision maker instead of relying on aggregate data.

Many of the factors important for BEV ownership are likely to be correlated (for instance residential location and income). We also contribute by providing conditional associations between socio-economic household characteristics and car ownership. We observe the owners' complete car portfolio at each point in time, allowing us to shed light on BEVs' role as either a substitute or a complement to vehicles with traditional propulsion systems. Moreover, by linking car owners to various population registers we are able to give a demographical characterization of all BEV owners in Norway, as well as highlighting changes in the demographical composition over time. We do not only capture early adopters, but are able to describe the transition to a more mature market.

[12] This study does not distinguish between battery electric vehicles, plug-in hybrid electric vehicles and hybrid electric vehicles.

4 Data and methods

4.1 Data

This study describes BEV ownership in Norway, based on micro data from administrative registers encompassing the entire Norwegian population in 2017. We combine information on all passenger cars by the end of 2017 with detailed information about their owners. For an overview of the data structure, see Figure A4 in Appendix B. A personal identifier makes it possible to link data from various sources. All datasets are available from 2009 onwards, implying that we can also track individual car ownership over time.

The Norwegian micro data on passenger cars cover all vehicles and contain information about technical characteristics such as vehicle attributes (age, make, size, weight, seat number, engine power, powertrain, fuel carrier, per km energy consumption), vehicle prices (purchase prices as new), driving distance (measured in kilometers, bi-annually after age four), as well as owner attributes. In 2017 there were roughly 2.7 million cars registered in Norway. Abount 10% of passenger cars were registered to a company, including leased by private persons from a leasing company.) In our analysis, we include only cars registered to a private person, constituting around 2.5 million cars in 2017 registered to individuals of age 18 or higher who live or have lived in Norway.

Car ownership can be organized using either the individual or the household as the analytical unit. In our data, we observe nearly 4.2 million individuals, and about 2.5 million households annually. Individual characteristics include age, gender, employer, occupation, income by source, wealth, transfers/benefits, taxes as well as educational attainment. However, since cars are typically owned and used jointly by adult members of the household, it is meaningful to use households as the unit of study, even if only one person is formally registered as the owner of the car. As individuals are linked via a household identification number (ID) in the data, household characteristics can be established by simply aggregating individual characteristics.

In Table A1 of Appendix B we present descriptive statistics for our population. Data include the location of residence, workplace (neighborhood) and secondary homes (municipality). The travel between home and work, and between primary and secondary home (if relevant) are two of the most frequent and relevant travels for car ownership and use. The data include characteristics of the travels between home residence and work, such as time, distance, toll payments and bus lanes open to zero emission vehicles.[13]

[13] The travel to work characteristics are obtained from a publically available road network (ELVEG) maintained by the Norwegian Public Roads Administration, where we have merged information about toll payments during rush hours to specific road links. We use the average of “to work” and “from work” characteristics for each individual, meaning that characteristics will correspond a one-way work trip. The travel to work characteristics are associated with the route along the road network that minimizes travel time between the road links closest to the centroids of the “home” and “work” neighborhoods. “Travel time” is according to the speed limit with a correction factor that depends on the type of road (but not on potential congestion).

4.2 Methods

We use a multinomial logit (MNL) model to explore the conditional correlation between household characteristics and the household's car portfolio (see Section 5.2 for results). A desirable property of MNL models is their internal consistency: first, choice probabilities are bounded between zero and one; second, the sum of probabilities (over choices) per individual is always equal to one; third, the sum of probabilities (over individuals) for a given choice is a consistent measure of the market share; fourth, choice probability gradients decrease smoothly as the probability approaches zero or one.

In the analysis of car acquisition (in Section 5.3), where we examine whether those that buy electric vehicles are more inclined to keep their old vehicle or not, we prefer to condition on a large set of factors ($K \approx 13{,}000$) to avoid confounders, making non-linear estimation infeasible. We therefore estimate a linear probability model.

The MNL model and linear probability model are described in the next paragraphs.

4.2.1 Multinomial logit

This method is standard in the discrete choice literature in general, and in the transport literature in particular, and assumes that household i chooses the discrete alternative $d \in D$ with the highest utility, where alternative specific utilities are represented by the function: $u_{id} = v_d(x_i; \theta) + \varepsilon_{id}$. The first term on the right hand side, the systematic part of the utility, is a function of a K-dimensional vector of characteristics (x_i) and a parameter vector to be estimated (θ). The second term is a random component capturing unobserved factors that affect preferences, and is assumed to be IID Extreme Value Type I distributed. This ensures that choice probabilities will have the following functional form:

$$P_{id} = \frac{e^{v_d(x_i;\theta)}}{\sum_{j \in D} e^{v_j(x_i;\theta)}} \qquad (1)$$

where P_{id} denotes the household's probability of choosing alternative d. We assume that the systematic part of the choice specific utility function has the following linear, additive form: $v_d = \sum_{k \in K} \theta_{kd} x_{ik}$. The interpretation of θ_{kd} is therefore how much the utility from choosing alternative d changes with a marginal increase in x_{ik}, everything else equal.

Instead of focusing on estimated coefficients in the main text, we present average effects on choice probabilities from marginal changes in attributes. The effect on choice probability d from changing attribute k is calculated in the following manner:

$$\frac{1}{N} \sum_{1=i}^{N} \frac{\partial P_{id}}{\partial x_{ik}} \times \frac{1}{P_{id}} \qquad (2)$$

In other words, this is the average (over the population) percentage change in P_{id} from a marginal increase in x_{ik}.

4.2.2 Linear probability model

Observations consist of households that have bought a new car (not a used car) in the period 2011-2017, and owned at least one car prior to the purchase, and the outcome is whether the first car was kept or not. Buying and selling cars do not happen simultaneously, so we define a transaction time interval before and after the day of a new car registration. A narrow interval will not give households time enough to sell their old car, while a wide interval introduces noise as well as interference with other car transactions in the data. We have chosen a time interval of +/- 120 days around the day a new car registration for our analysis.[14] We distinguish between new car purchases (events) of a BEV and an ICEV. BEV purchasers are further split between those purchasing a small, typical BEV and those buying a large BEV à la Tesla. If the number of cars pre/post remained unchanged, we define it as "replacing" a vehicle. However, if the car ownership increased, the household has kept the old vehicle. Our final model specification has the following specification:

$$y_i = \beta_0' z_i + \beta_1' z_i \times d_{BEV} + \alpha_0' t_i + \alpha_1' t_i \times d_{BEV} + \gamma_{age} + \gamma_{inc} + \gamma_{car} + \gamma_n + \varepsilon_i \quad (3)$$

Where y_i is a dummy for keeping the existing car portfolio; d_{BEV} is a dummy for if the new car is a BEV; z_i is a vector of household characteristics; t_i is a vector of year dummies; γ_{age} is age fixed effects for the oldest household member; γ_{inc} is income percentile fixed effects; γ_{car} is age fixed effects of the newest car owned; and finally γ_n is neighborhood fixed effects.

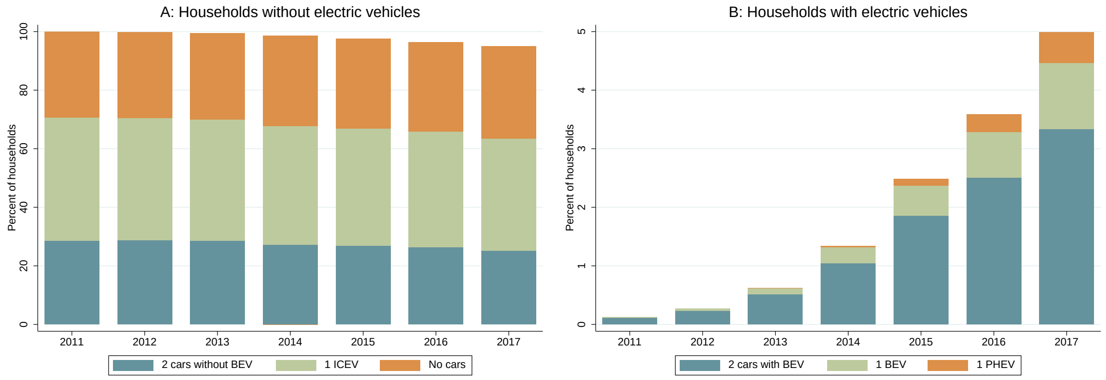
Since this model is linear in parameters, it can be estimated by the ordinary last squares (OLS) method. By interacting the BEV dummy with year dummies and household characteristics, we are able to show how the effect of buying an electric vehicle on the probability of keeping the old one changes over time and across households. Linear probability models have the convenient property that coefficients can be interpreted directly as the corresponding variable's marginal contribution to the probability. The drawback is that the linear property can lead to predicted probabilities outside the [0,1] interval.

[14] By definition, fewer household keep their initial cars as time expands. For BEVs, the fraction converges to around 2 of 3. The probability for ICEV buyers to keep their car continues to drop as time passes. In Appendix B Figure A5, we display how sensitive the probability of keeping the old cars are to changing the threshold.

5 Results

5.1 Describing car ownership

The novelty of our data is the car-household link that exists for all cars. Since cars are typically shared by individuals who live together and pool resources, we find it most adequate to describe car ownership at the household level (independent of who is the registered owner). In Figure 2 we report the annual (by 31 December) distribution of six car ownership segments along two dimensions; number of cars (0, 1 of 2+) and propulsion technology (ICEV[15], BEV or PHEV). Two-car owners with a PHEV are included in the group of multicar households without a BEV ("2 cars without BEV"). We ignore the periods before 2011 because BEV sales were negligible.



Note: households are split according to car ownership: 0, 1 or 2 or more cars. One car households are split between ICEV, PHEV and BEV. Multicar households are split in two groups: with or without BEV. The zero or low emission car ownership options are displayed in the right panel. In sum, the left and the right panel include all households in Norway, with the exception of some alternative fuel type owners (natural gas, kerosene and hydrogen, < 100 households in total).

Figure 2. Distribution of car ownership. Households. 2011-2017. Source: own calculations.

Panel A shows households who do not own electric vehicles, divided into the three largest groups; owning no cars, owning one ICEV and owning two cars which are not BEVs. In 2017, about one third (31.7%) had no car, 38.3% had one ICEV and about one in four had two cars or more. Panel B shows households with BEVs. About 4.5 per cent of all households had a BEV – more than two thirds of them were multicar households. In 2017, the large BEVs like Tesla had a substantial share of new vehicle sales, but is found in a small fraction of the total number of households (about 0.7%).

[15] Counting ordinary (non-plug-in) hybrids as ICEVs.

5.1.1 Car ownership across socio-economic groups

This section documents the associations between various socio-demographic characteristics and car ownership in 2017 (Figure 3 to 5). Each of the figure panels has a common structure as we first present the distribution of characteristics for all households (Figure 3) or all individuals (Figure 4 and 5) – labeled "All". Then we report characteristics by the following car ownership categories: No car, one conventional car (1 ICEV), two or more conventional cars (2+ ICEV), one electric car (1 BEV) and two or more cars including a BEV (2+ BEV)[16]. The relative sizes of these five categories is displayed in Figure 2 in the previous subsection.

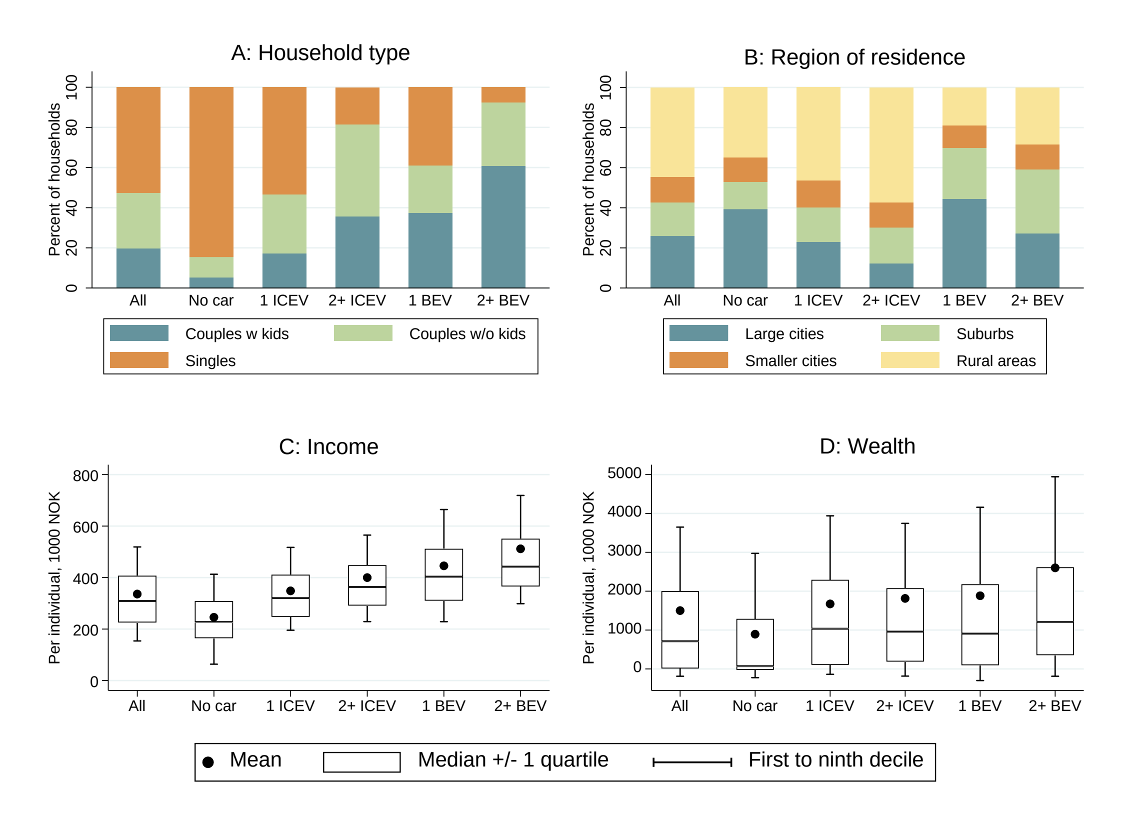


Figure 3. Car ownership and household demographics. 2017.

In Figure 3, we see that car ownership is unevenly distributed across households. While car ownership generally increases with family size, the car type also differs (Panel A). Couples with children are largely overrepresented among BEV owners both in one-car and in multi-car households, even compared to the corresponding ICEV categories. The fraction of one-adult households (singles) is particularly low among BEV owners. Panel B illustrates that BEV owners tend to live in larger cities and their suburbs, while ICEV owners often live in rural areas. For multicar households, only 30% of BEV owners live in rural areas compared to 60% among those with ICEVs. In Panels C and D, we show that the type of car portfolio is strongly correlated with economic resources. Most importantly from our perspective, BEV owners earn substantially more (per adult member of the household) than ICEV owners with an equal number of cars. Among multicar households, after-tax

[16] In this section, all non-BEV vehicles including PEVs are counted as "ICEVs".

income is on average 28 % higher for those with a BEV. This also holds for wealth (Panel D), but the difference is negligible among single-car households.[17]

Turning to the individual characteristics in Figure 4 and 5, we still define ownership at the household level and allocate this category to the individual based on household affiliation. The age structure of BEV owners is different from that of other car owners (Panel A in Figure 4). BEV owners tend to be in the age group 25-44 years old and very few are above 65. Older people make fewer short trips a day that compensate for the disadvantages BEVs have on long-distance travels. About 16.6 percent of adults are immigrants or children of immigrants, but they constitute close to 30% of those without a car (Panel B in Figure 4). They are underrepresented in multicar households. Among single-car owners, we find more owners with an immigrant background.[18] Perhaps most notable is the many with immigrant parents among BEV owners.

Panel C shows that BEV owners are more educated, even compared to other car owners with the same number of cars. The share with tertiary education (university or college) among BEV owners is close to 50%, and less than one in five BEV owners have not completed high school. To illustrate that the field of education matters for car ownership, and not only the attainment level, we have selected three types of education (Figure 4 Panel D). First, car mechanics with a vocational upper secondary education are overrepresented among multicar owners, including (but to a lesser extent) among BEV owners. Second, BEV owners often have a technical or business/economics oriented degree from college or university. While these education groups represent about 5% of the adult population, they constitute more than 10% of BEV owners. Although we do not know what the causal mechanism behind this pattern is, it is striking that two of the education types that seem over-represented among BEV owners are the ones concerned with understanding (1) monetary incentives and (2) new technology.

[17] Wealth is net wealth based on market values of financial assets and debt. House wealth is included at the estimated market value used by local and national tax authorities.

[18] Immigrants are split in two by country of origin. High income countries include Europe, North America and Oceania. xxx

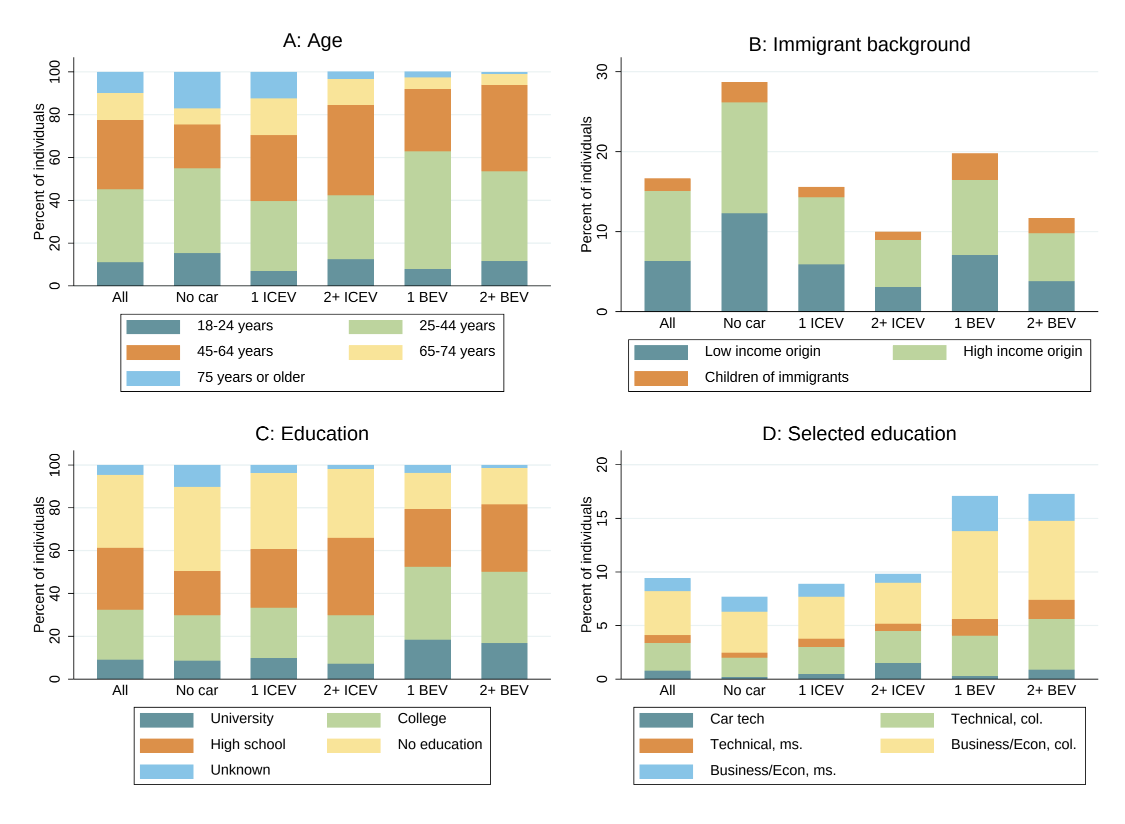


Figure 4. Household car ownership, economic resources and education. Individuals, 2017. Note: Panels B and D show selected categories as shares of the total population. These shares therefore do not sum to 100 percent.

BEVs are more attractive for households with charging facilities at home, when the car is typically used for short or medium range distances and if commuting involves roads with toll and/or bus lanes. Figure 5 shows how car ownership varies with factors that reflect transport demand and/or local regulatory BEV incentives. In Panel A, we see that about 35% of households have road tolls on their journey to work. The toll is typically between 25 and 50 NOK (2.5 to 5 Euro) per trip, but BEVs are exempted in the period that we consider.[19] Among BEV owners, close to 55% have a toll cordon to cross on their way to work. Panel B shows that BEV ownership is also strongly associated with bus lanes (to which BEVs have access) on the car owner´s commute.

Panel C shows that BEV owners tend to have longer work trips, but not dramatically so. Type of residence may influence preferences for BEV cars via how easy it is to install or use charging facilities at home, and households with a secondary home may be reluctant to rely on a single BEV due to range concerns and lack of charging facilities at the secondary home. We find, however, that living in a detached house and having access to a secondary home is equally common among between BEV and ICEV owners (Panel D) when we compare to households with the same number of cars.

[19] Road tolls for BEVs have later been introduced. Currently, the law states that the toll for BEVs cannot exceed 50% of the maximum toll.

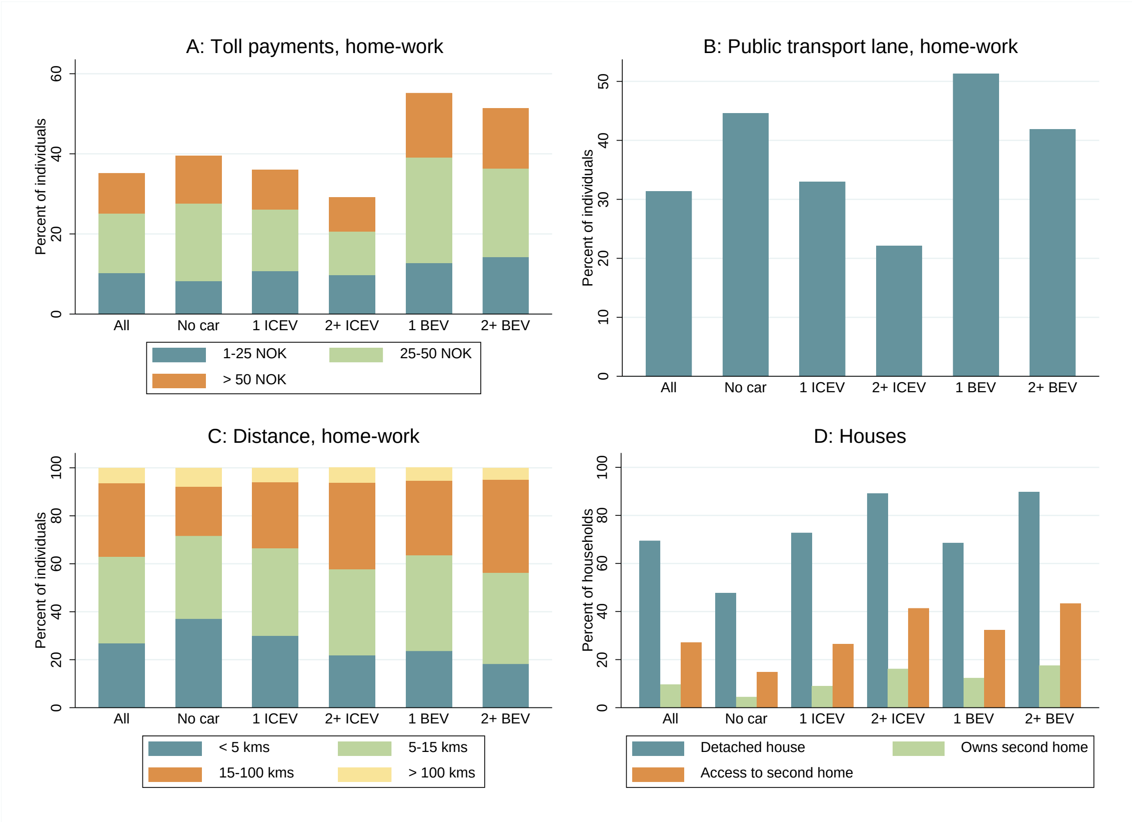


Figure 5. Car ownership and drivers of travel demand. Individuals, 2017. Note: Categories in panel D are not mutually exclusive.

Note: Toll payments relate to the one-way commute (the average payment of "to" and "from" work). Detached house includes semi-detached or terraced house, but not flats. "Owns second home" is binary defined as ownership at the household level, while "access to second home" is defined as ownership by either the adults in the household, their parents and/or their children.

While Figure 3 shows that BEV owners have higher income than households with ICEVs, Figure 6 provides more details on car ownership across the income distribution. We combine single and couple households, and sort them according to their after-tax income per adult in ten equally large groups (deciles). First, we see in panel A that the average number of BEVs per adult is strongly increasing in income throughout the income distribution. In the lower end, only one in hundred household owns a BEV compared to just above 8 percent in the top income decile. This contrasts the ICEV ownership structure where ICEVs per adult is constant (around 0.85) above the median. In the lower half of the income distribution, car ownership is close to doubled from the lowest ten percent to the median.

In Panel B we split BEV ownership by size. In 2017, the only available BEVs in the 'large car' segment were Tesla Model S and Tesla Model X. As expected, the income gradient is less steep for the typical small BEV than for large BEVs. Note that the two scales are different and almost no one in the lower half of the income distribution owns a large BEV.

The income gradients for BEVs and ICEVs are different for many reasons. An important feature is that BEVs are younger. When we turn to new car purchases[20] in Panel C, the

[20] Household car ownership is defined at the end of the year. New cars are here defined as cars that are bought new during the year, regardless of whether they are bought by the same household.

gradients are much more similar for BEVs and ICEVs. Still, moving from the median to the top decile increases new car purchases by a factor of less than two for ICEVs and more than three for BEVs. Thus, in relative terms the income gradient is stronger for BEVs than for ICEVs in the upper half of the income distribution.

On average, new BEVs are cheaper than new ICEVs. Moreover, the price variation for ICEVs is larger, as the variation in car models offered on the marked is larger. Another representation of "new car consumption" that better captures this heterogeneity is the total *value* (including taxes) of new cars purchased per household, as illustrated in panel D.

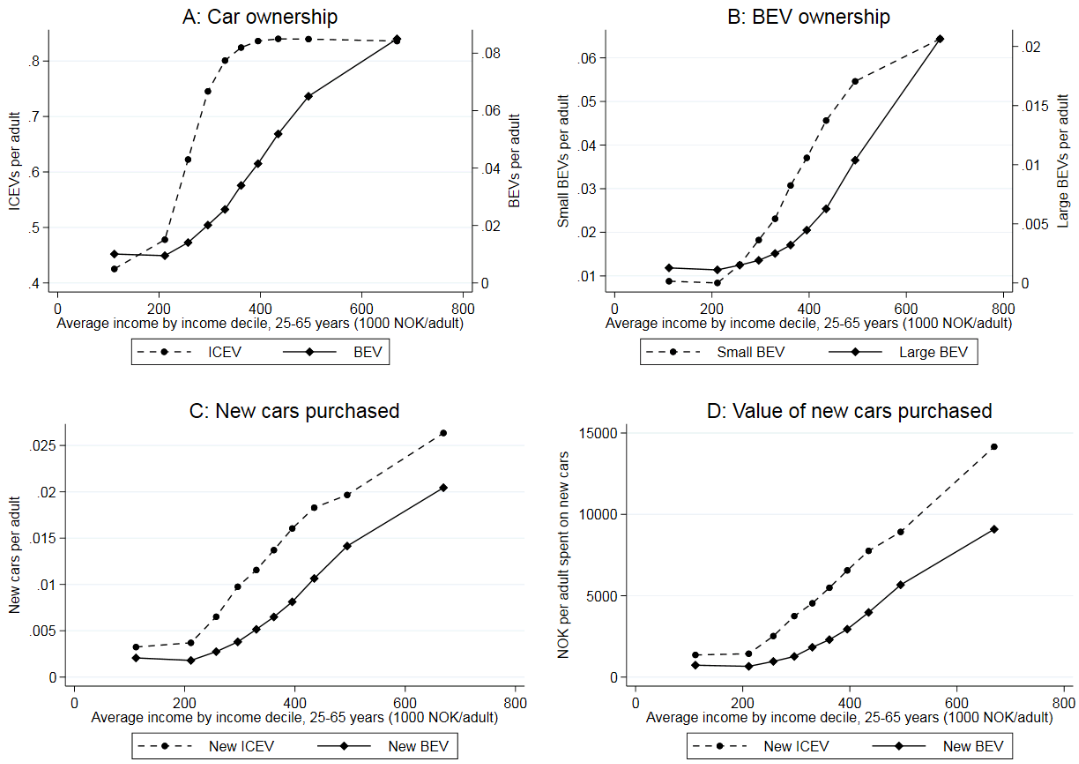


Figure 6. Car ownership and new car purchase across the income distribution. Number of cars or total value of cars per household, 2017.

In general, the income gradient (i.e. the relative difference between two income deciles) is stronger for value (panel D) than for number of cars (panel C), because richer households tend to buy more expensive cars. When considering the entire income distribution, the income gradient is stronger for BEVs than for ICEVs in both panels[21], although the difference is smaller in panel D. However, among top incomes these patterns are slightly different. For example, moving from the ninth to the tenth decile, both the number and the value of new BEVs increase by about 50 percent. For ICEVs on the other hand, the number of new cars purchased increases by about 40 percent while the value of new cars purchased increases by about 60 percent. This has to do with the car models offered – while the most expensive BEV offered in 2017 (Tesla Model X) is certainly costly compared to the average new car, it is still more affordable than cars in the ICEV luxury

[21] The income gradient is defined as the relative difference in the outcome variable when comparing between income classes. Although the ICEV curve is steeper in absolute terms, the number or total value of new BEVs increases more in relative terms when moving up the income distribution.

segment. This is partly due to the Norwegian car tax scheme – for luxury ICEVs, the various tax components will typically increase the consumer price by a factor of two or more.

Most of the demographic characteristics shown in this section are likely to be correlated, such as family structure and age, income and education, or region of residence and local regulatory incentives. In Section 5.2, we examine the conditional association between each characteristic and car ownership in a multivariate regression model, including a larger set of socio-economic characteristics. Before we present these estimates, we describe the changes in car ownership over time.

5.1.2 Car ownership over time - Early and late adopters

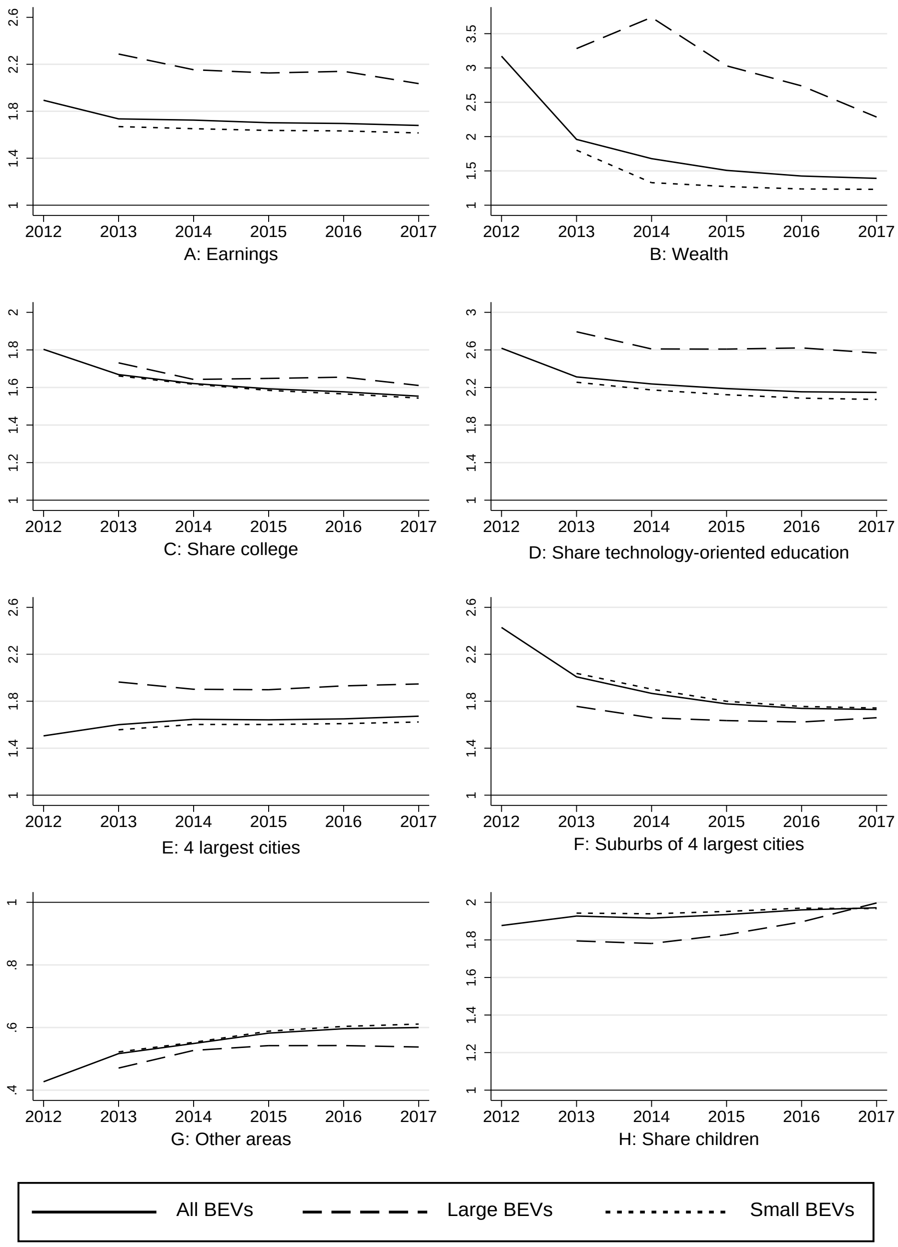
While the previous section described the car ownership structure in 2017, when BEVs had reached a substantial number, it is of considerable interest whether these patterns have changed as the BEV market share has increased. The advantage of the register data is that all households are covered, meaning that we can compare changes over time in household characteristics of BEV owners to other households.

In Figure 7 we display selected household characteristics of particular interest to BEV ownership. First, in Panel A and B we compare mean economic resources of BEV households, relative to ICEV households. In Panel A, as an example, we display the earnings of BEV households in relation to ICEV households. Numbers higher than 1 thus imply that BEV households have higher earnings than ICEV households. The solid lines represent all BEVs, while the dotted are split into small and large vehicles. For example, net wealth (see Panel B) of BEV households was about two times that of ICEV owners in 2013. As for labor earnings, the BEV household earned about 75 percent more than ICEV owners did in 2013.

Panel C to H display the relative share of other selected characteristics of BEV owners, relative to ICEV owners. In Panel E, we see that the share of BEV owners that has completed college was 80 percent higher compared to that of ICEV owners in 2012.

When we compare BEV owners over time, we see that the early pioneers are a particularly select group. They are wealthier, more educated with a technical orientation and strongly represented in suburbs around the large cities. After the initial phase, BEV owners have become more similar to ICEV owners over time.[22] Although this "convergence" is slow and far from complete, the patterns illustrate the demand structure from early phases of a product based on a new technology, consistent with Rogers (1995).

[22] Except for households with children and for share with a home located in one of the 4 largest cities.



Note: 2012 also includes 2011. All variables are defined at household level. Earnings and wealth are measured per adult in each household. College and technology-oriented education equals one if at least one of the household members has completed this education, and zero otherwise. The numbers display BEV owners relative to ICEV owners each year, meaning that the values for ICEV owners are normalized to one.

Figure 7. BEV owner characteristics relative to ICEV owners.

5.2 Socio-economic gradients

While the figures in Section 5.1 give clear indications of who the typical BEV owner is, many of the socio-economic characteristics are highly correlated across households. Those who pass a toll cordon on their commute are indeed more likely to own a BEV, but they are *also* rich, highly educated and live in attractive neighborhoods outside the larger cities. Is tolling a predictor of BEV ownership, conditional on (other) household characteristics?

Our multivariate regressions provide more insight about such conditional, or marginal, differences across households. We emphasize that these conditional "effects" are not necessarily causal, as there could be unobserved (confounding) characteristics correlated with car preferences as well as explanatory factors observed. In addition, the direction of causality could potentially go both ways. Residential location affects preferred mode of transport, but car ownership may also influence place of residence.

In Table 2, we present average marginal effects from an MNL model (see section 4.2.1) estimated on the sample of couples in 2017[23], with the same six alternatives of car ownership: No car, single car (ICEV, BEV, PHEV) and multicar (2+ ICEV, 2+ BEV).[24] Since the shares are very uneven across categories, we report average marginal effects *scaled* with the respective sample means reported in the bottom row.[25] For example, the estimate 0.346 in the 2BEV column for children means that households with children below 18 living at home have a 35% higher probability of owning two cars including a BEV, holding all other characteristics of the household and its adult members constant.[26] With few exceptions, all effects are statistically significant. As in Section 5.1, we focus on the differences between BEV and ICEV owners, not on factors associated with car ownership in general.

In general, the patterns described by the figures in Section 5.1 remain valid when we adjust for other correlated factors observed in the data. Relative to an ICEV, a BEV is a more popular choice among families with children. Households living in a detached house and/or with access to a secondary home are more likely to be a multicar household. This holds both with and without a BEV. The regional differences are substantial. While single car BEV households are most likely to be found in the four large cities, a suburb location increases the probability of multicar household. Living outside any one of the four the largest urban areas is associated with a higher probability of more than one ICEV, but lowers the share of multicar household with a BEV. Immigrants are less likely to own a car, but the pattern is mixed for BEV ownership. If anything, immigrants from low-income countries are more likely to own a BEV, conditional on all other characteristics. Norwegians with immigrant parents stand out as a group with particularly high preferences for BEVs. In households where both adults have immigrant parents, the probability of owning one BEV is more than doubled, and the probability of several cars, of which one is a BEV, is more than 60% higher than for a non-immigrant household (other characteristics equal).

Car ownership is strongly related to economic resources. Moving one decile up in the income distribution for males is associated with a significantly higher probability (11.3 per cent) of owning a BEV or a PHEV.[27] BEV ownership is positively associated with female income as well, but less so than for men. The effect of wealth on multicar BEV is also positive, but weaker than for income.

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23 Only couples with one female and one male are included. This allows us to study gender differences in the effects of socio-economic characteristics.

24 Unlike in the descriptive figures above, we look at household with a PHEV as a separate category among one-car households. Among multicar households, PHEV owners are including in the "2+ BEV" category if they also own at least one BEV and in the "2+ ICEV" category otherwise. Estimated parameters with standard errors are found in Appendix B, Table A4.

25 That is $(\partial P_j/\partial X_k)P_j$.

26 The reference household is a non-immigrant couple, in Oslo/Bergen/Trondheim/Stavanger, less than high school, aged 18-24, both employed in private sector with T2Work<5 km, neither toll nor bus lane to work.

27 Note that this effect is conditional on being employed.

Table 2. Car ownership and household characteristics, two-adult households. Average marginal effects $(dP_j/dX_k)/P_j$.

	No car	1 ICEV	2+ ICEV	1 PHEV	1 BEV	2+ BEV
Children	-0.358***	-0.016***	0.046***	-0.163***	0.143***	0.346***
Detached house	-0.499***	-0.186***	0.221***	-0.100***	-0.090***	0.444***
Access cabin	-0.067***	-0.080***	0.074***	-0.166***	0.039**	0.092***
Suburbs of O/B/S/T	-0.621***	-0.103***	0.234***	-0.249***	-0.364***	0.150***
Five other cities	-0.587***	-0.052***	0.223***	-0.213***	-0.604***	-0.079***
Other areas	-0.849***	-0.128***	0.427***	-0.480***	-1.120***	-0.420***
Imm rich ctry, male	0.050***	0.056***	-0.040***	-0.147***	-0.047	-0.108***
Imm low-inc ctry, m	0.108***	0.003	-0.044***	-0.353***	0.072*	0.129***
Imm parents, male	0.073***	-0.015	-0.078***	-0.008	0.731***	0.324***
Imm rich ctry, female	0.026***	0.016***	-0.020***	-0.126***	0.061**	0.001
Imm low-inc ctry, f	0.193***	0.131***	-0.165***	-0.058	0.214***	-0.015
Imm parents, female	-0.021	0.022*	-0.073***	0.144	0.587***	0.237***
Income decile, male	-0,077	-0,017	0.011***	0.155***	0.075***	0.113***
Income decile, f	-0,043	-0,018	0.016***	0.053***	0.033***	0.054***
Wealth decile, male	-0,060	0,001	0.014***	0.035***	-0,031	0.003***
Wealth decile, f	-0,055	-0,0003	0.008***	0.051***	-0,001	0.028***
High school, male	-0.077***	0.002	-0.008***	0.143***	0.110***	0.121***
College/uni, male	0.165***	0.079***	-0.159***	0.193***	0.268***	0.248***
High school, fem	-0.040***	-0.080***	0.050***	0.014	0.118***	0.169***
College/uni, female	0.072***	-0.038***	-0.038***	0.080**	0.268***	0.288***
Age 25-44, male	-0.739***	-0.020*	0.128***	0.522***	-0.251**	0.435***
Age 45-64, male	-0.924***	-0.125***	0.285***	0.308**	-0.599***	0.406***
Age 65-74, male	-1.19***	0.041***	0.241***	0.491***	-0.800***	0.168***
Age 75+, male	-0.977***	0.164***	0.096***	0.307**	-0.758***	0.093
Age 25-44, female	-0.358***	-0.039***	0.077***	-0.0254	-0.190***	0.320***
Age 45-64, female	-0.519***	-0.103***	0.191***	-0.143	-0.396***	0.266***
Age 65-74, female	-0.792***	0.092***	0.108***	0.190	-0.445***	0.0836**
Age 75+, female	-0.220***	0.221***	-0.123***	-0.048	-0.126	-0.091*
Car-tech voc HS, m	-0.389***	-0.267***	0.344***	-0.424***	-0.496***	0.059**
Tech college, male	-0.189***	-0.074***	0.075***	-0.0301	0.0314	0.229***
Tech master, male	-0.101***	-0.031***	0.040***	-0.084	-0.152***	0.124***
Econ college, male	0.108***	-0.062***	0.014***	-0.004	0.196***	0.050***
Econ master, male	0.184***	0.017*	-0.075***	0.0671	0.159***	0.064***
Car-tech vocHS, f	-0.217	-0.211***	0.203***	0.771	-0.050	0.144
Tech college, female	-0.043	-0.039**	0.038***	0.083	-0.008	0.033
Tech master, female	0.028	0.070***	-0.060***	-0.134	-0.086	-0.018
Econ college, female	0.009	-0.021***	0.009*	0.021	0.060*	0.034**
Econ master, female	0.100***	0.053***	-0.078***	0.079	0.043	0.028
T2Work5-15K, m	-0.272***	-0.117***	0.151***	-0.127***	-0.093***	0.150***
T2Work15-100K, m	-0.357***	-0.226***	0.244***	-0.275***	-0.101***	0.328***

	No car	1 ICEV	2+ ICEV	1 PHEV	1 BEV	2+ BEV
T2Work>100 km, m	-0.279***	-0.235***	0.302***	-0.330***	-0.320***	-0.082***
T2Work5-15 km, f	-0.234***	-0.159***	0.177***	-0.213***	-0.056**	0.163***
T2Work15-100 km, f	-0.297***	-0.264***	0.269***	-0.272***	-0.0214	0.260***
T2Work>100 km, f	-0.169***	-0.238***	0.297***	-0.360***	-0.353***	-0.188***
Toll 1-25 kr, male	-0.119***	0.058***	-0.063***	-0.0140	0.183***	0.231***
Toll 25-50 kr, male	0.154***	0.080***	-0.157***	0.107***	0.365***	0.240***
Toll>50kr, male	0.0269*	0.068***	-0.159***	0.181***	0.500***	0.481***
Toll 1-25 kr, female	-0.109***	0.064***	-0.084***	-0.045	0.221***	0.315***
Toll 25-50 kr, female	0.131***	0.102***	-0.170***	0.104**	0.332***	0.237***
Toll>50kr, female	0.013	0.085***	-0.186***	0.087	0.561***	0.584***
Public lane, male	0.204***	0.069***	-0.109***	0.058*	0.123***	-0.034***
Public lane, female	0.185***	0.089***	-0.117***	0.067*	0.069***	-0.064***
Governmental, male	-0.196***	0.023***	0.016***	0.067	-0.086***	0.079***
Municipality, male	-0.131***	0.048***	-0.013***	0.030	-0.160***	0.052***
Empl, not A-reg, m	0.013	-0.058***	0.043***	0.033	0.063*	0.012
Government, female	-0.211***	0.010***	0.058***	-0.060*	-0.205***	-0.051***
Municipality, female	-0.067***	0.061***	-0.025***	-0.003	-0.174***	-0.045***
Empl, not A-reg, f	-0.117***	-0.045***	0.048***	-0.092*	0.011	0.142***
Mean	0.103	0.378	0.431	0.008	0.015	0.065

Note: Reference category; Non-immigrant couple, residents of Oslo/Bergen/Trondheim/Stavanger in a flat, less than high school, aged 18-24, both employed in private sector with T2Work<5 km, no toll nor bus lane. The sample consists of households with one adult female and one adult male.

We find large differences across age groups. Few young couples (< 25 years) own more than one car, with or without a BEV. However, controlling for other characteristics, it seems like the youngest group is the one most likely to have a BEV as their only car. Since we have data for just one cross section, age differentials will reflect differences in car ownership (preferences) over the life cycle as well as birth cohort differentials.

Educational attainment is also a strong predictor of BEV ownership. While tertiary education reduces the probability of multiple ICEVs, it raises the probability of having a BEV (with or without an ICEV). Female educational attainment appears to be equally important as that of the male. Concerning specific educational fields, households with a male trained as a car mechanic are less likely to own a BEV, relative to owning an ICEV. When he holds a technical degree (e.g. engineering) the probability of combining a BEV and an ICEV increases, but the household is less likely to have a BEV as their sole car. Household with a business/economics oriented education are much more likely to own a BEV, as the only one or in combination with other cars. The effect of being a government employee tends to be negative both for single women and for those living with a partner, but is mixed for men.

By combining the location of the home residence and the workplace, we include travel to work characteristics for both the male and female adult household member. The effect of travel distance is potentially non-linear, partly due to the range limitations of BEV batteries. We therefore split travel to work distance into four categories with less than 5 km as the reference case. A medium travel distance to work of 15-100 km (T2work5-15K) has a positive effect on BEV ownership relative to ICEV ownership. Those with commutes larger than 100 km (T2work>100km) are less likely to own a BEV, presumably because of range limitations. The effects of travel distances for husband and wife are strikingly similar. Tolling on the road to work has a large positive effect on BEV ownership. When there is a toll of 50 NOK or more on the journey to work (Toll>50km), the BEV ownership probabilities increase by about 50%. The effects of toll rates between home and work appear to be monotonous and strikingly similar for both partners. The effects of having a bus lane between home and work are mixed, as it increases the probability of owning a single BEV but reduces the chances of multicar ownership with a BEV. This could be because having bus lanes between home and work is correlated with the mass transit level of service (left out of the model).

Plugin hybrid owners are similar to owners of fully electric cars along some dimensions. Relative to an ICEV, a PHEV is a more popular choice among house owners with high education and income. The positive effect of income on PHEV ownership is in fact larger than the effect on BEV ownership, and the effect of wealth is also positive.[28] The effect of car-related vocational high school is negative, just as for BEV ownership. However, having children, living in a big city, immigrant background and young age (< 25 years) have a more negative effects on PHEV ownership than on BEV ownership, while being a public employee has a more positive effect. In contrast to BEVs, the effect of road toll is negative for PHEVs, which is expected since PHEVs are not exempt of road toll.

Single person households are common, but less than 2 per cent of these households own a BEV. Results comparable to those presented in Table 2, but for single person households, are presented in Table A3 in Appendix B.[29] The probability of owning a BEV is higher for individuals with a house and/or a secondary home, living in the four large cities or their suburbs. BEV ownership is increasing in educational attainment, income and wealth. The effect of higher education within economics and business also tends to be positive, particularly for single women with a master's degree. Male immigrants are less likely to own a BEV, compared to natives with the same characteristics. Sons and daughters of immigrants, however, are much more likely to own a BEV than the majority without an immigrant background. As for couples, travel to work characteristics matter. If the road toll exceeds 50 NOK, the probability of owning a BEV increases by about 100 per cent and even more so among women. Moreover, medium range travel to work distances also do raise BEV ownership.

The fact that BEV owners share these characteristics does not necessarily mean that they identify which households prefer BEVs over ICEVs. Since BEVs have only been on the market for a short time, they have only been an option for those that have considered buying a new car during the last couple of years. Hence, it could be that our analysis partly captures characteristics of households with new cars in general.

[28] A possible explanation for this finding is that there are no small, low-cost PHEVs available on the marked.

[29] Since few single people have more than one car, we merge the car ownership alternatives into three in this sample; No car, ICEV (or PHEV) and BEV. Here the results are presented separately for men and women.

Table 3. Predicted car ownership by household type. Percent.

	A. Highly educated, suburb, middle class		B. Highly educated Rural middle class		C. Low educated Rural without children	
Household characteristics	Children, age 25-44, non-immigrant, tertiary education, suburb large cities, house		Children, age 25-44, non-immigrant, tertiary education, outside cities or suburb large cities, house		No children, age 45-64, non-immigrant, high school dropouts, outside cities or suburb large cities, house	
Travel to work	Both employed with toll > 50 NOK, 15-50 km and public bus lane to work		Both employed with no toll or public lane, 15-50 km distance		Male employed with no toll or public lane, 15-50 km distance. Female non-employed	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
2+ BEV	32	27	11	10	2	1
2+ ICEV	25	18	65	73	67	66
1 BEV	7	4	1	1	0	0
1 ICEV	30	41	21	15	27	30
No car	5	8	2	1	4	2
1 PHEV	1	2	1	1	0	0
Households	399		769		540	

Table 3 gives a final illustration of the heterogeneity in car ownership across households. Based on the MNL estimates (see Table A4 in Appendix B) we predict the set of ownership probabilities at the household level and select three types of households. In the pro-BEV-household (A), both adults have university/college education, age between 25 and 44, living in their own house with children below 18 located in the suburb of a larger city. If they commute by car, both adults have to pay a high toll, unless she/he drives a BEV. The BEV also offers access to the bus lane. The average probability of owning a BEV in combination with a least one more car is 32%, exceeding that of multicar ownership without a BEV (25%). The one car BEV probability is also relatively high compared to the share of 1 BEV households in the population. In sum, our estimates predict that four out of ten households with these characteristics own a BEV.

Turning to the opposite type of household (C in Table 3), i.e. households located in rural areas with members 45-64 years old, without children at home, less than high school education, just one employed adult and without tolls on the way to work, we find a probability of multicar BEV ownership of 2%, and the predicted share of BEV as the only car is close to zero. In these households, two out of three are predicted to have 2 ICEVs or more.

5.3 Do BEVs substitute ICEVs?

The adoption of the BEVs involves household decisions along a number of different margins. One important choice is the total number of cars owned and, in particular, whether a new BEV replaces an ICEV or not. Here we study this empirically at the household level within an event study framework. We track the car transaction(s) of the household, before and after they bought a new car. This is not the causal effect of a BEV purchase, but a description of *substitution patterns* and how they vary across households.

Since buyers of new cars often increase the number of cars in the household, we explicitly compare BEV buyers to those who buy an ICEV.

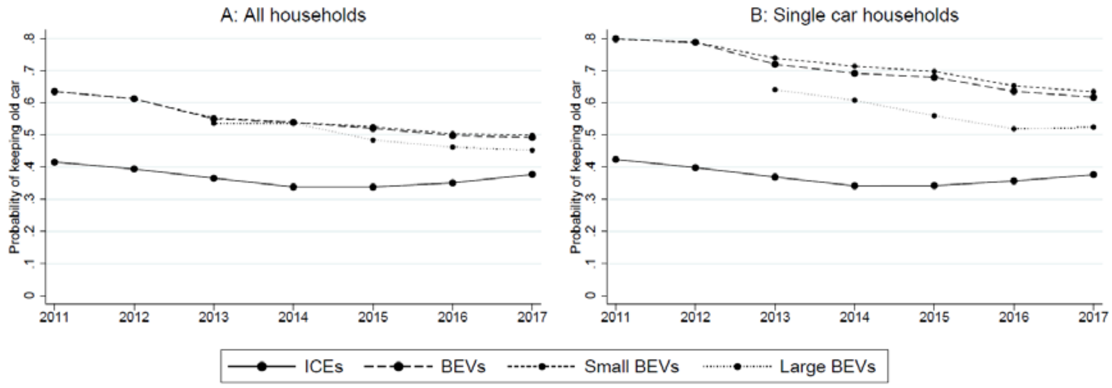

Figure 8. Probability of keeping the old car. By year of purchase and type of car acquistion.

Note: Data include the most recent purchase from January 1st 2011 until July 1st 2017 for all households that have bought a new car. Large BEVs were not available on the market until 2013. The new car purchased needs to be kept at least 120 days after the purchase by the same household to be part of the analysis.

Figure 8 shows the share of the households that kept their old car(s), within the +/- 120 days window. Panel A includes all households and shows that BEV buyers are more likely to keep their old cars. However, the fraction keeping the old car declines over time, and BEV buyers have become more similar to ICEV buyers in recent years. Households buying large BEVs are less likely to keep the old car, but the difference from other BEV buyers is not large. Panel B focuses on households that own one vehicle 120 days prior to the new car purchase. Among BEV buyers, (initial) single-car households are much more likely to keep their old car, while initial car ownership appears to be less important among ICEV buyers.

Table 4 presents the results of a regression analysis where we test whether the difference in the probability of keeping existing car(s) can be explained by household characteristics that affect car consumption in general. The outcome of the linear probability model (see section 4.2.2) is whether the household kept their old car or not within 120 days. Our main focus is the comparison between new BEV and ICEV buyers. Over the period 2011 to June 2017, the fraction of BEV buyers who kept their old car was 51.7 %, compared to 36.7% among ICEV buyers; an overall difference of 15 percentage points.

Column (1) in Table 4 displays the difference between BEV and ICEV households by size of the new BEV, initial number of cars and across time (conditional on initial car age). The main BEV coefficient of 25.6 refers to the increased probability (in percentage points) that one-car BEV buyer household in 2017 kept their car compared to an ICEV household. The negative coefficient for large BEVs suggests that they are slightly more similar to ICEV buyers. The large positive interactions between BEV and initial number of cars imply that multicar households are equally likely to keep their old cars, whether they are BEV or ICEV buyers. The positive year×BEV interactions indicate that the difference between BEVs and ICEVs is smaller in 2017 than in previous years.

Table 4. Who keeps the old car? Linear probability model. 2011-2017.

		(1)		(2)		(3)	
	Sample share	Estimate	Std.err	Estimate	Std.err	Estimate	Std.err
BEV	13.8 %	25.6	(0.636)	20.1	(0.656)	24.0	(0.740)
Large BEV segment	1.96 %	-2.50	(0.606)	-3.69	(0.626)	-3.33	(0.632)
*BEV * initials cars (base one)*							
BEV*2 cars	6.07 %	-25.4	(0.469)	-22.7	(0.479)	-24.4	(0.493)
BEV*3 or more cars	1.58 %	-25.9	(0.752)	-21.5	(0.761)	-23.8	(0.774)
BEV Year (base 2017):*							
BEV*2011	0.16 %	9.90	(1.92)	9.07	(1.91)	9.36	(1.91)
BEV*2012	0.44 %	9.21	(1.26)	9.08	(1.29)	9.48	(1.29)
BEV*2013	0.94 %	6.65	(0.989)	6.45	(0.988)	6.75	(0.987)
BEV*2014	2.44 %	8.05	(0.786)	7.91	(0.778)	8.13	(0.776)
BEV*2015	3.87 %	6.14	(0.724)	5.86	(0.739)	6.02	(0.740)
*BEV*2016*	3.60 %	7.89	(0.735)	2.93	(0.751)	3.11	(0.750)
*BEV*Household char.*							
BEV*Children	8.41 %					-3.05	(0.503)
BEV*Single	1.80 %					-11.2	(0.733)
BEV*Access cabin	2.31 %					0.67^{ns}	(0.615)
Common controls:							
2 cars	33.6 %	-4.81	(0.187)	-11.1	(0.211)	-10.9	(0.212)
3 or more cars	9.05 %	-5.02	(0.320)	-14.7	(0.352)	-14.4	(0.353)
Children	33.5 %			2.82	(0.251)	3.15	(0.268)
Single	21.9 %			-8.53	(0.207)	-7.53	(0.216)
Access to cabin	14.2 %			4.20	(0.232)	4.10	(0.251)
Year dummies:		6		6		6	
Age dummies:		0		83		83	
Income pct dummies:		0		99		99	
Car age dummies:		30		30		30	
Neighbourhood dummies:		0		12,756		12,756	
	Adjusted R^2	0.0354		0.0629		0.0635	
	N	399,318		399,318		399,318	
	Mean dependent variable	0.3874		0.3874		0.3874	
	Mean depvar | BEV == 0	0.3667		0.3667		0.3667	
	Mean depvar | BEV == 1	0.5168		0.5168		0.5168	

Note: ^{ns} *not* significant at 0.05. Standard errors are robust in (1) and clustered at the neighborhood level in (2) and (3). The sample consists of car owner households and we exclude households with a reduction in the number of cars owned, those owning at least one veteran vehicle (30+ years) and those who sold their *new* car within the timeframe (120 days).

The heterogeneity in car ownership implies that the BEV-ICEV differential of about 25 % is partly explained by selection on household characteristics. In Column (2) in Table 4, we include a large set of household controls, including age fixed effects of the oldest household member, presence of children below 18, single household, income percentile (per adult) fixed effects and neighborhood fixed effects. Couples are more likely to keep their old car, especially if they have children, and so are households with access to a secondary home. When we compare similarly observed households (i.e. include household characteristics as controls in Column 2), the additional probability that a BEV buying one-car household kept their car in 2017 drops down to 20.1% (from 25.6%). Note also that the time trend captured by the year*BEV interactions is close to linear when we adjust for compositional change of buyers in Column (2).

Finally, in Column (3) we test whether the role of household characteristics differ between BEV and ICEV households. Among couples without children and without access to a second home, those who buy a BEV are 24 percentage points more likely to keep the old car than those who buy an ICEV. Single persons are much less likely to keep their old car and this holds for BEV buyers in particular. Among BEV buyers, households with and without children below 18 of age are equally likely to keep their old car (since the main coefficient of 3.15 is very similar in magnitude to the interaction of -3.05). Access to a secondary home raises the probability of keeping the car, but equally so for BEV and ICEV households.

6 Conclusions

The emergence of population wide matched administrative micro data in recent decades has led to significant progress in empirical social science research, but has not yet been common within transportation research. Such data from the leading country in terms of market penetration of low-emission vehicles offer an excellent opportunity to study socio-economic gradients and the importance of privileges for low-emission car in explaining the uptake of a new technology.

Socioeconomic characteristics are shown to be strong predictors of the car portfolio. In particular, battery electric vehicle (BEV) ownership is increasing in wealth, income and education. While BEV pioneers were particularly selected, BEV owners have become more similar to other car owners over time. Consequently, the external validity of BEV studies from the early days of adoption is likely to be low. We document a strong association between BEV privileges on the travel to work (like road toll exemption and bus lane access) and BEV ownership. In Norway, tolling is a particularly strong predictor of BEV ownership. Unlike previous studies with regional data, we compare households with and without toll roads on their commute.

For transport and environmental externalities, the degree of substitution between BEV and ICEV cars is vital. Using a simple event setup, we document that one in two households that buy a BEV actually keep their existing ICEV. When we compare BEV buyers with other household that buy a new car, we still find that the BEV households are more likely to expand their car fleet, but the difference only hold for single car households and less so in recent years.

Our contribution is a descriptive overview without any ambition of establishing counterfactual outcomes. The data offer, however, ample opportunities to study causal effects of financial incentives as well as local privileges, using structural approaches for ex ante policy evaluations or reduced form ex post analysis of policies to promote adaptation of the BEV technology. Over the next years, the use of matched administrative micro data is expected to rise rapidly within studies of travel behavior.

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Appendices

Appendix A. Incentives for zero and low emission vehicles

The zero and low emission automobile incentives in Norway include

(i) value added tax (VAT), generally 25 per cent, with zero emission vehicles (ZEVs) fully exempt since 2008,
(ii) CO_2 and weight graduated, one-off registration tax, with ZEVs fully exempt since 1990,
(iii) re-registration tax on second hand sales, with ZEVs fully exempt since 2018,
(iv) annual circulation (ownership) tax, with ZEVs partly or fully exempt since 1996,
(v) road toll, with ZEVs fully exempt 1997-2018 and at least 50 per cent exempt thereafter,
(vi) ferry fares, with strongly reduced rates for ZEVs since 2009,
(vii) public parking fees, often with full or partial exemption for ZEVs (since 1999),
(viii) free recharging at some public parking lots,
(ix) income tax on private use of company cars, with lower rates for ZEVs
(x) access to bus lanes, in general open to ZEVs since 2003/2005, now with some exceptions in rush hours.

The registration tax is one of the most important policy instruments in the Norwegian transport sector. Unlike most other western countries, Norway levies a high one-off registration tax on passenger cars. As of 2016, the tax, applicable to all passenger cars equipped with an internal combustion engine (ICE), consisted of four components: a fixed car scrappage deposit of NOK 2400 and three variable components, calculated on the basis of curb weight and type approval CO_2 and NO_X emission rates, respectively (Figure A1). Since 2017, the engine effect component has been dropped. As of 2019-2020, the CO_2 component is negative and hence deductible below 70 gCO_2/km. The total purchase tax rate cannot, however, become negative, as in the French or Swedish bonus-malus system.

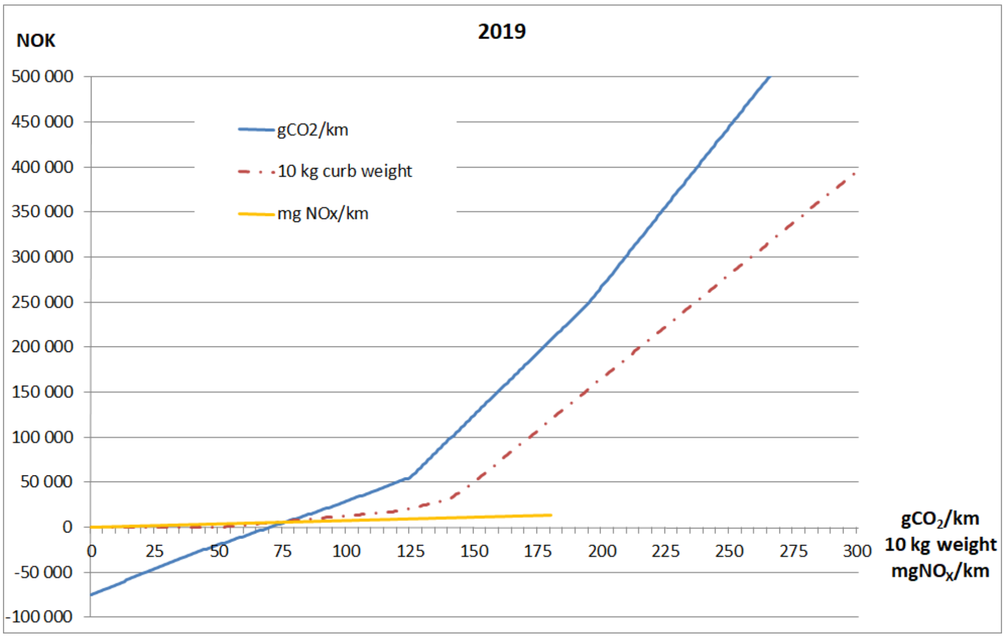


Figure A1. One-off Norwegian automobile registration tax 2019, as a function of curb weight and type approval CO_2 and NO_X emission rates. Source: Fridstrøm (2019).

Certain tax advantages apply also to plug-in hybrid vehicles (PHEVs). As of 2019, their taxable curb weight is to be reduced by up to 23 per cent prior to calculating the weight component. The deduction is contingent upon the vehicle's type approval electric range. Only PHEVs exhibiting an all-electric driving range of at least 50 km are eligible for a full 23 per cent reduction. For these vehicles, each point on the red curve in Fig. 3 is shifted 29.9 per cent to the right (since 1/(1 – 0.23) = 1.299). If the range is $r < 50$ km, the weight reduction is set at $23 \cdot r/50$ per cent. Thus, for some light-weight PHEVs, the registration tax may come out at zero. Unlike ZEVs, however, PHEVs are not exempt of VAT, nor of road toll, ownership tax, reregistration tax, or parking fees.

The CO_2 and weight components of the one-off registration tax are convex. At its steepest, above 195 gCO_2/km, the CO_2 component corresponds to a carbon price of NOK 9775 = US$ 1200 per ton of CO_2, if we assume a 260 000 km lifetime vehicle mileage and a 40 per cent higher emission rate in real traffic than at the type approval test (Tietge et al. 2019). The tax rate is thus several times higher than just about any reasonable estimate of the global carbon mitigation cost before 2030, unless the most stringent interpretation of the Paris agreement is applied – no overshooting of 1.5ºC before 2100 (Rogelj et al. 2018).

When policy makers have decided on such a high rate of CO_2 taxation, it must be understood in light of the rather demanding commitments made through the Paris accord and the agreement between Norway and the European Union (EU) on the common enforcement of greenhouse gas (GHG) abatement policies. Also, the Norwegian government has set rather ambitious unilateral targets for GHG mitigation in the non-ETS sector, quantified as a 50-55 per cent reduction between 2005 and 2030.

Traditionally, motor vehicle taxes have represented a major source of revenue for the Norwegian public treasury. In 2018, the total revenue from the eight different taxes shown in Figure A1 was around 59 billion Norwegian kroner (NOK), or approximately US$ 7.23 billion, corresponding to around $ 1360 per capita.

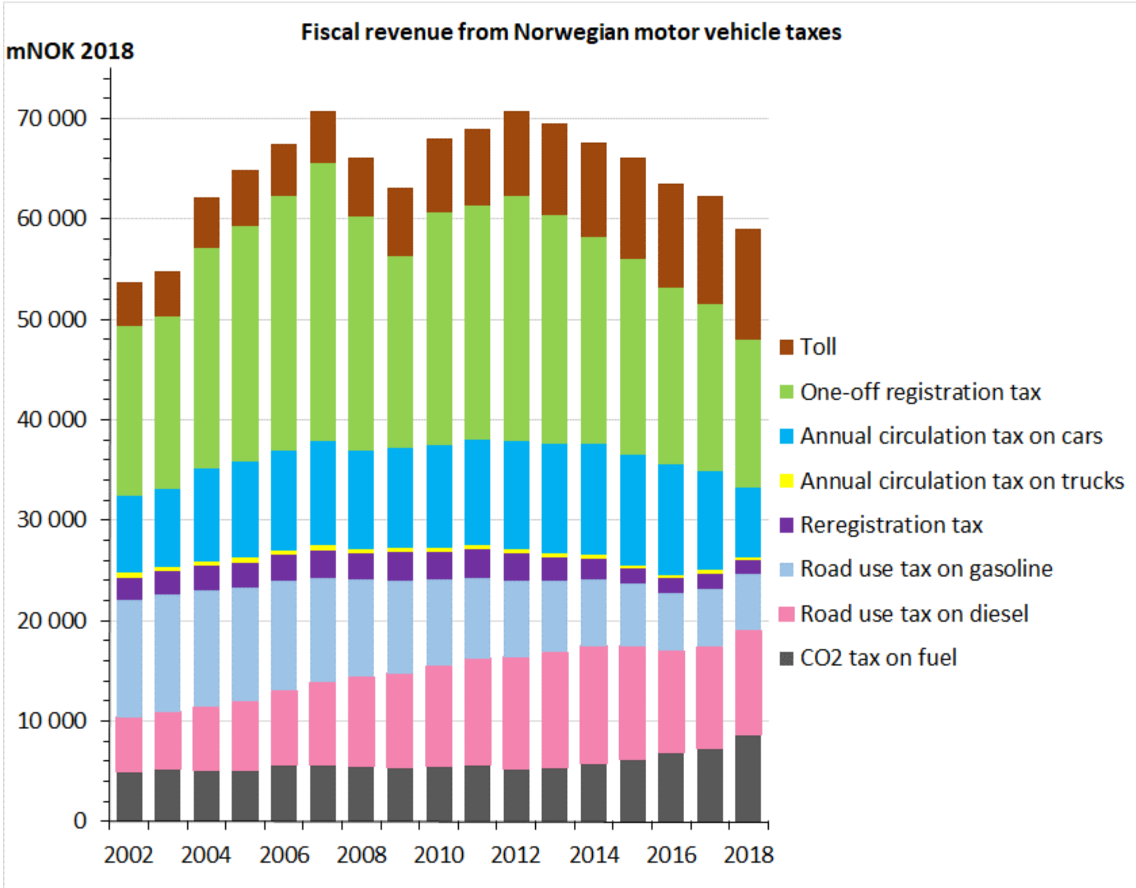


Figure A2. Annual fiscal revenue from selected motor vehicle taxes 2002-2018, adjusted to the 2018 price level. Source: Fridstrøm (2019).

The fiscal revenue from automobile taxation has, however, been dropping in line with the increasing market share of plug-in hybrid and zero emission vehicles (ZEVs). A growing source of public revenue in Norway is road toll, totalling NOK 11 billion in 2018 (Figure A2).

Taken together, the value of the tax breaks and bus lane access benefiting ZEV owners was of the order of NOK 6.6 billion in 2017, or around € 700 million (Figure A3). The single most important tax measure, in terms of foregone public revenue, is the exemption from value added tax.

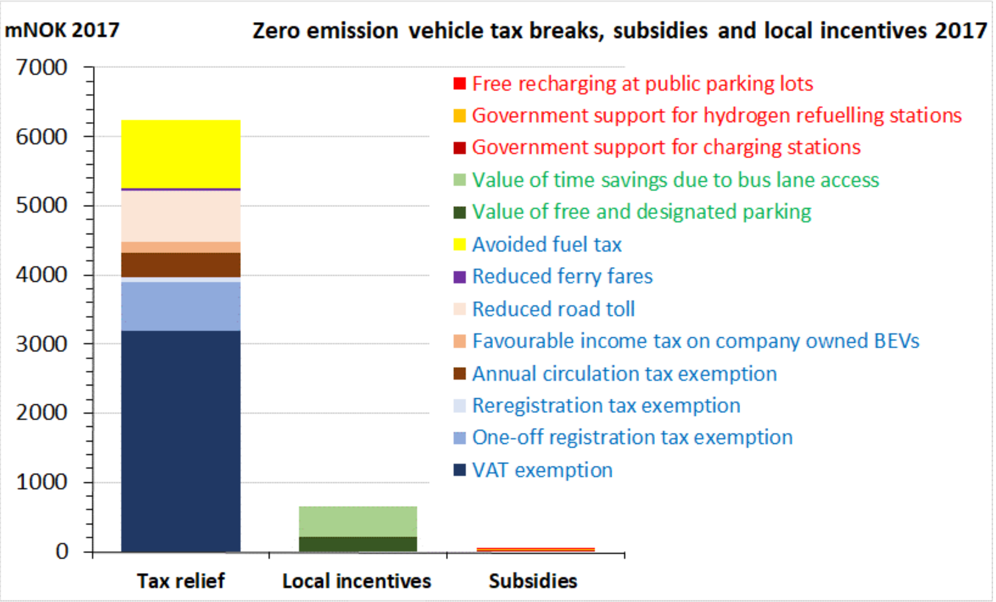


Figure A3. Estimated value of tax breaks, local regulatory incentives and government subsidies for zero emission vehicles in Norway 2017. Source: Fridstrøm (2019).

Appendix B: Additional tables and figures

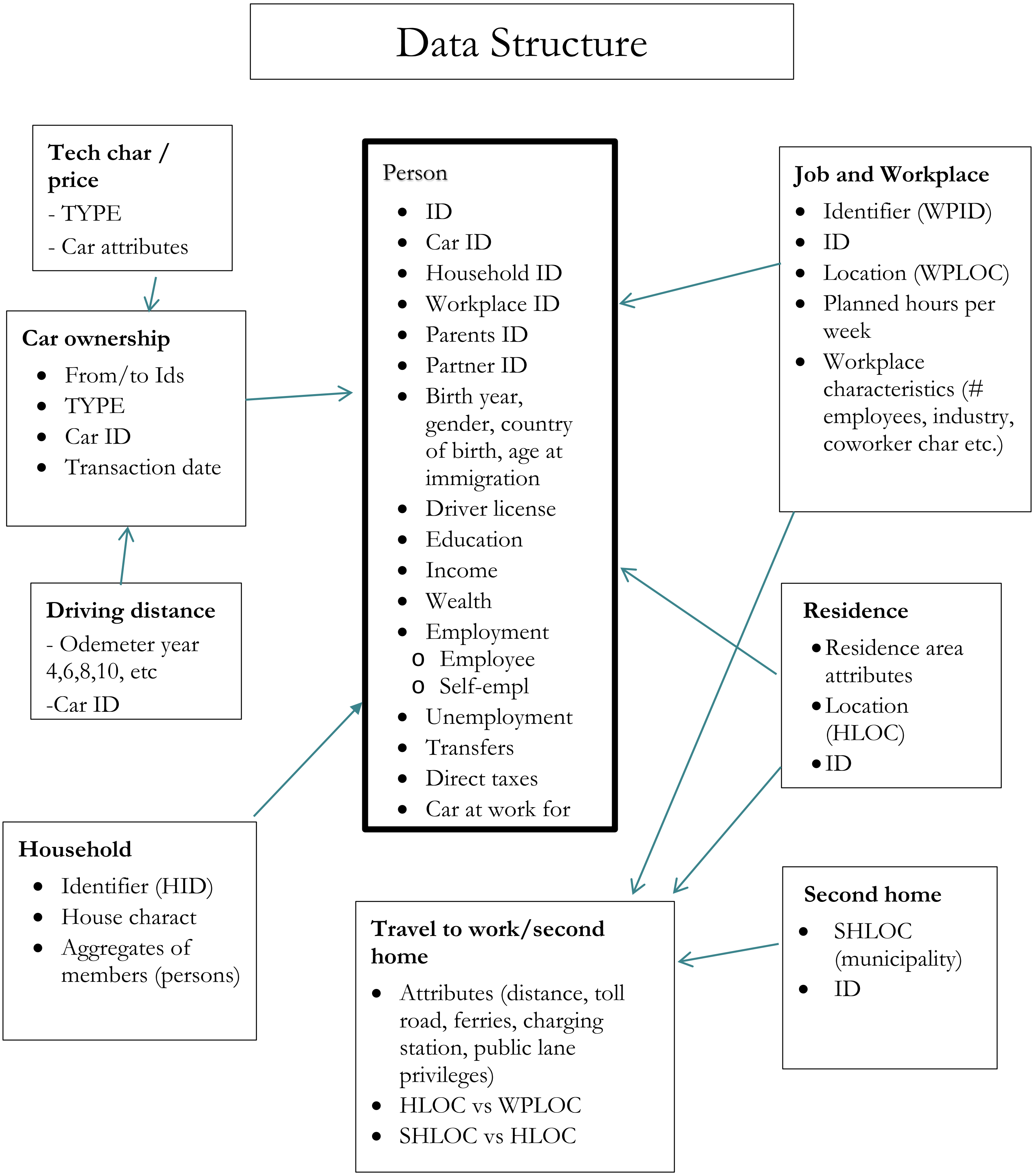


Figure B1. Overview of data structure.

Table B1. Car ownership, 2017. Household. Means by car ownership type.

	All	No car	One car			Two cars +	
			ICEV	BEV	PHEV	Without BEV	With BEV
All	100	31.7	38.3	1.1	0.5	25.0	3.3
Single (no kids/18+)	47.5	79.1	46.5	29.8	23.6	15.7	5.9
Single (kids<18)	5.2	5.5	6.8	9.2	3.8	2.7	1.6
Couple (no kids/18+)	27.6	10.2	29.6	23.5	43.5	45.8	31.5
Couple (kids<18)	19.8	5.2	17.2	37.5	29.1	35.7	60.9
Income (in 1000 NOK)							
Mean	336	246	348	446	485	400	512
P10	154	64	195	229	264	229	299
P90	519	413	517	664	715	565	719
Wealth (in 1000 NOK)							
Mean	1,501	894	1,673	1,883	2,922	1,815	2,601
P10	-188	-224	-139	-299	-4	-184	-188
P90	3,649	2,973	3,939	4,160	5,807	3,745	4,943
Detached house	69.5	47.7	72.8	68.6	76.5	89.2	89.8
Cabin	9.7	4.5	9.0	12.4	13.4	16.2	17.5
Access to cabin	27.2	14.8	26.5	32.3	35.1	41.4	43.4
*Travel to work**							
T2Work<5 km, m	22.8	33.0	25.3	20.1	26.0	17.9	14.3
T2Work5-15 km, m	34.5	34.6	35.5	38.4	37.6	33.1	35.0
T2Work15-100 km, m	34.3	23.4	31.0	34.2	28.9	40.1	43.7
T2Work>100 km, m	8.5	9.0	8.2	7.3	7.5	8.9	6.9
T2Work<5 km, f	31.4	40.9	34.7	27.1	35.8	26.0	21.8
T2Work5-15 km, f	38.0	34.6	37.7	41.0	38.6	39.0	41.4
T2Work15-100 km, f	26.8	17.8	23.9	28.3	22.8	32.1	34.3
T2Work>100 km, f	3.7	6.6	3.6	3.6	2.8	2.8	2.5
No toll, male	59.9	57.0	59.2	40.5	53.2	65.5	42.8
Toll 1-25 kr, male	10.8	8.8	11.3	12.9	11.3	10.4	14.4
Toll 25-50 kr, male	16.5	20.6	17.0	28.1	21.7	12.7	24.3
Toll>50kr, male	12.8	13.6	12.5	18.4	13.9	11.5	18.5
No toll, male	69.9	63.9	69.0	49.1	64.2	76.8	54.0
Toll 1-25 kr, female	9.6	7.6	10.1	12.5	9.7	9.0	14.3
Toll 25-50 kr, female	13.3	18.2	13.9	24.7	18.5	9.1	20.3
Toll>50kr, female	7.2	10.3	7.1	13.7	7.6	5.1	11.4
Public lane, male	34.9	46.7	36.3	54.9	44.9	25.9	46.5
Public lane, female	28.1	42.7	29.5	47.6	37.4	18.1	37.6
Region of residence							
Oslo	14.2	24.8	11.3	23.4	17.2	5.0	11.7
Suburbs of Oslo	11.4	9.9	11.5	16.5	15.5	11.5	20.0
Bergen/Trondh/Stav	11.8	14.5	11.8	21.1	16.6	7.2	15.5
Suburbss of B/T/Stav	5.5	3.8	5.6	8.8	5.8	6.3	11.9
Five other large cities	12.7	12.1	13.4	11.4	13.1	12.6	12.5

	All	No car	One car			Two cars +	
			ICEV	BEV	PHEV	Without BEV	With BEV
Small cities	19.6	16.5	20.9	10.7	16.4	22.7	14.4
Others areas	24.9	18.5	25.4	8.1	15.4	34.6	14.0
# households	2,560,495	812,007	980,296	28,843	13,568	640,465	85,316
# households with workplace info, male	974,371	146,324	360,033	16,294	7,857	379,565	64,298
# households with workplace info, female	922,914	144,880	344,647	15,083	6,722	352,529	59,053

Note: Car ownership by the end of 2017. * Travel to work information is for sample of households with at least one adult member with a job record in 2014 (last year with workplace information). The sample consists of one-adult households and households with one adult female and one adult male.

Table B2. Car ownership, 2017. Individuals. Means by car ownership type of household.

	All	No car	One car			Two cars +	
			ICEV	BEV	PHEV	Without BEV	With BEV
All	100	23.3	37.0	1.2	0.6	33.3	4.6
Women	49.8	53.6	50.3	49.8	46.9	46.9	48.3
Men	50.1	46.4	49.7	50.2	53.1	53.1	51.7
Age group							
18-24	11.1	15.4	7.2	8.0	5.1	12.5	11.7
25-34	17.2	24.8	16.0	25.2	13.6	13.5	14.2
35-44	16.8	14.8	16.5	29.7	20.3	16.3	27.8
45-54	17.7	11.4	15.6	19.0	17.2	23.1	26.2
55-64	15.0	9.0	15.2	10.2	18.4	19.1	14.2
65-74	12.6	7.6	17.2	5.3	19.7	12.1	4.9
75+	9.7	17.0	12.3	2.6	5.8	3.4	0.9
Employed	60.9	43.1	58.5	81.2	71.5	72.2	83.0
Private	48.0	45.0	47.7	52.9	50.7	48.9	50.7
Municipality	18.3	11.6	19.0	13.7	16.8	20.9	17.0
Other public	12.8	9.5	14.3	15.0	18.4	12.0	17.3
Unknown sector	20.8	33.9	19.0	18.4	14.2	18.1	15.1
Educational attainm.							
Less than high school	34.1	39.4	35.5	17.0	22.1	31.9	17.0
High school	29.0	20.7	27.3	27.0	27.5	36.4	31.3
Some college	23.3	21.1	23.5	33.9	31.3	22.6	33.5
University	9.2	8.7	9.9	18.6	17.6	7.2	16.8
Unknown	4.5	10.2	3.8	3.5	1.5	1.9	1.4
Field of education							
Car-tech voc high sch	0.8	0.2	0.5	0.3	0.4	1.5	0.9
Technical college	2.6	1.8	2.5	3.8	4.1	3.0	4.7
Technical master	0.7	0.5	0.8	1.5	1.6	0.6	1.8
Economics college	4.1	3.8	3.9	8.2	6.7	3.8	7.4
Economics master	1.2	1.4	1.2	3.3	2.4	0.8	2.4
Immigrant background	15.1	26.2	14.3	16.5	8.6	9.0	9.8
High income country	8.7	13.9	8.4	9.4	5.7	5.9	6.0
Low income country	6.4	12.3	5.9	7.1	2.9	3.1	3.8
Second generation	1.5	2.5	1.3	3.3	1.1	1.0	1.9
Norwegian	83.4	71.3	84.4	80.2	90.3	89.9	88.3
# individuals	4,169,963	971,825	1,542,627	50,134	24,879	1,389,153	191,345

Note: Car ownership by the end of 2017. Employed is defined as annual labor earnings above the basic social insurance amount (G).

Table B3. Car ownership and individual characteristics, single person households. Average marginal effects $(dP_i/dX_j)/P_i$.

	No car		ICEV		BEV	
	Male	Female	Male	Female	Male	Female
Children	-0.457	-0.201***	0.359***	0.211***	0.799***	0.558***
Detached house	-0.261***	-0.238***	0.207***	0.253***	0.384***	0.498***
Access cabin	-0.106***	-0.089***	0.079***	0.091***	0.338***	0.341***
Suburbs of O/B/S/T	-0.283***	-0.268***	0.237***	0.298***	0.023	0.065
Five other cities	-0.248***	-0.245***	0.221***	0.287***	-0.420***	-0.480***
Other areas	-0.355***	-0.330***	0.321***	0.390***	-0.751***	-0.836***
Immigrant rich ctry	0.265***	0.158***	-0.213***	-0.177***	-0.271***	-0.006
Imm low inc ctry	0.214***	0.297***	-0.175***	-0.332***	-0.159***	0.016
Immigrant parents	0.153***	0.131***	-0.157***	-0.159***	0.913***	0.479***
Income decile	-0,064	-0,070	0.049***	0.076***	0.145***	0.115***
Wealth decile	-0,057	-0,048	0.047***	0.053***	0.034***	0.038***
High school	-0.043***	-0.087***	0.031***	0.092***	0.171***	0.200***
College/uni	0.092***	-0.019***	-0.090***	0.010***	0.394***	0.444***
Age 25-44	0.0680***	0.123***	-0.047***	-0.120***	-0.333***	-0.711***
Age 45-64	0.004	-0.044***	0.017***	0.071***	-0.655***	-0.854***
Age 65-74	-0.117***	-0.067***	0.128***	0.110***	-0.955***	-1.25***
Age 75+	0.091***	0.347***	-0.043***	-0.347***	-1.05***	-1.56***
Car-tech voc high sch	-0.337***	-0.197***	0.282***	0.225***	0.008	-0.162
Tech college	-0.074***	0.022	0.056***	-0.027*	0.176***	0.058
Tech master	-0.001	0.053**	-0.002	-0.065**	0.078	0.240
Econ/business colleg	0.001	0.005	-0.004	-0.007	0.097**	0.050
Econ/business mast	0.095***	0.098***	-0.082**	-0.116***	0.074	0.242***
T2Work5-15K	-0.175***	-0.164***	0.142***	0.179***	0.129***	0.163***
T2Work15-100K	-0.259***	-0.241***	0.204***	0.262***	0.371***	0.329***
T2Work>100 km	-0.189***	-0.168***	0.166***	0.199***	-0.245***	-0.412***
Toll 1-25 kr	-0.022***	-0.052***	0.005	0.044***	0.430***	0.556***
Toll 25-50 kr	0.081***	0.089***	-0.084***	-0.113***	0.513***	0.555***
Toll>50kr	0.047***	0.056***	-0.065***	-0.097***	0.829***	1.34***
Public lane	0.125***	0.126***	-0.104***	-0.138***	-0.034	-0.130***
Governmental	-0.080***	-0.065***	0.062***	0.076***	0.148***	-0.118***
Municipality	-0.072***	-0.008*	0.058***	0.012**	0.072**	-0.114***
Mean	0.448	0.522	0.535	0.466	0.017	0.012

Note: Separate regressions by gender. Reference category; Non-immigrant living in Oslo/Bergen/Trondheim/Stavanger in a flat, less than high school, aged 18-24, employed in private sector with T2Work<5 km, no toll nor bus lane.

Table B4. Multinominal logit estimates. Car ownership. Couples.

	No car	1 ICEV	2+ ICEV	1 PHEV	1 BEV	2+ BEV
Children		0.439***	0.551***	0.327***	0.619***	0.876***
		(0.009)	(0.009)	(0.029)	(0.021)	(0.013)
Detached house		0.485***	1.018***	0.632***	0.606***	1.258***
		(0.008)	(0.009)	(0.029)	(0.021)	(0.015)
Access cabin		0.020**	0.209***	-0.052**	0.147***	0.228***
		(0.008)	(0.009)	(0.023)	(0.018)	(0.011)
Suburbs of O/B/S/T		0.549***	1.021***	0.491***	0.416***	0.876***
		(0.011)	(0.012)	(0.032)	(0.023)	(0.015)
Five other cities		0.547***	0.943***	0.461***	0.129***	0.602***
		(0.012)	(0.013)	(0.038)	(0.029)	(0.018)
Other areas		0.861***	1.577***	0.585***	-0.223***	0.642***
		(0.01)	(0.011)	(0.032)	(0.027)	(0.016)
Imm hig-inc ctry, male		-0.019	-0.135***	-0.239***	-0.131***	-0.215***
		(0.014)	(0.016)	(0.053)	(0.035)	(0.023)
Imm low-inc ctry, m		-0.131***	-0.195***	-0.561***	-0.053	-0.016
		(0.017)	(0.019)	(0.083)	(0.043)	(0.03)
Imm parents, male		-0.112***	-0.194***	-0.094	0.493***	0.209***
		(0.031)	(0.037)	(0.124)	(0.058)	(0.048)
Imm high-inc ctry, f		-0.021	-0.065***	-0.172***	0.025	-0.042**
		(0.014)	(0.015)	(0.049)	(0.033)	(0.021)
Imm low-inc ctry, f		-0.131***	-0.499***	-0.334***	-0.053	-0.322***
		(0.016)	(0.018)	(0.066)	(0.039)	(0.027)
Imm parents, female		0.039	-0.071**	0.16	0.517***	0.250***
		(0.031)	(0.035)	(0.116)	(0.058)	(0.047)
Income decile, male		0.083***	0.125***	0.266***	0.185***	0.237***
		(0.002)	(0.002)	(0.006)	(0.005)	(0.003)
Income decile, f		0.040***	0.083***	0.116***	0.095***	0.125***
		(0.002)	(0.002)	(0.006)	(0.004)	(0.003)
Wealth decile, male		0.077***	0.099***	0.115***	0.044***	0.087***
		(0.001)	(0.001)	(0.004)	(0.003)	(0.002)
Wealth decile, f		0.069***	0.098***	0.125***	0.069***	0.107***
		(0.001)	(0.002)	(0.005)	(0.003)	(0.002)
High school, male		0.104***	0.103***	0.263***	0.234***	0.254***
		(0.01)	(0.01)	(0.032)	(0.027)	(0.016)
College/uni, male		-0.141***	-0.434***	-0.029	0.078***	0.016
		(0.011)	(0.012)	(0.036)	(0.029)	(0.017)
High school, fem		-0.013	0.142***	0.096***	0.214***	0.295***
		(0.011)	(0.011)	(0.034)	(0.029)	(0.017)
College/uni, female		-0.123***	-0.128***	0.002	0.220***	0.244***
		(0.011)	(0.011)	(0.033)	(0.028)	(0.017)
Age 25-44, male		0.625***	0.881***	1.313***	0.482***	1.286***
		(0.021)	(0.026)	(0.203)	(0.076)	(0.085)
Age 45-64, male		0.759***	1.334***	1.358***	0.381***	1.537***
		(0.024)	(0.029)	(0.207)	(0.081)	(0.087)
Age 65-74, male		1.274***	1.634***	1.887***	0.454***	1.600***
		(0.03)	(0.034)	(0.211)	(0.094)	(0.09)
Age 75+, male		1.043***	1.089***	1.343***	0.169	1.109***
		(0.034)	(0.039)	(0.218)	(0.117)	(0.101)
Age 25-44, female		0.332***	0.500***	0.374***	0.223***	0.797***
		(0.017)	(0.02)	(0.104)	(0.055)	(0.05)
Age 45-64, female		0.477***	0.866***	0.477***	0.219***	0.983***
		(0.022)	(0.024)	(0.111)	(0.062)	(0.053)
Age 65-74, female		1.048***	1.152***	1.165***	0.529***	1.141***
		(0.029)	(0.031)	(0.12)	(0.083)	(0.061)

	No car	1 ICEV	2+ ICEV	1 PHEV	1 BEV	2+ BEV
Age 75+, female		0.364***	-0.004	0.118	0.058	0.012
		(0.033)	(0.036)	(0.136)	(0.111)	(0.083)
Car-tech voc HS, m		0.365***	1.115***	0.176	-0.032	0.850***
		(0.045)	(0.044)	(0.129)	(0.105)	(0.052)
Tech college, male		0.199***	0.394***	0.270***	0.320***	0.545***
		(0.019)	(0.019)	(0.046)	(0.036)	(0.023)
Tech master, male		0.110***	0.204***	0.067	-0.021	0.289***
		(0.03)	(0.031)	(0.071)	(0.056)	(0.036)
Econ college, male		-0.183***	-0.105***	-0.124***	0.071**	-0.063***
		(0.017)	(0.018)	(0.046)	(0.033)	(0.022)
Econ master, male		-0.202***	-0.330***	-0.164**	-0.06	-0.174***
		(0.025)	(0.028)	(0.069)	(0.047)	(0.033)
Car-tech vocHS, f		0.115	0.630**	0.965	0.314	0.580*
		(0.292)	(0.284)	(0.639)	(0.567)	(0.343)
Tech college, female		0.024	0.118**	0.151	0.058	0.114*
		(0.048)	(0.05)	(0.123)	(0.09)	(0.058)
Tech master, female		0.019	-0.134*	-0.202	-0.143	-0.089
		(0.065)	(0.071)	(0.172)	(0.116)	(0.078)
Econ college, female		-0.029	0.005	0.016	0.054	0.032
		(0.018)	(0.019)	(0.048)	(0.034)	(0.022)
Econ master, female		-0.080***	-0.245***	-0.066	-0.086*	-0.127***
		(0.027)	(0.03)	(0.076)	(0.05)	(0.035)
T2Work5-15K, m		0.256***	0.587***	0.276***	0.277***	0.585***
		(0.014)	(0.014)	(0.038)	(0.03)	(0.019)
T2Work15-100K, m		0.288***	0.863***	0.285***	0.430***	0.940***
		(0.016)	(0.017)	(0.044)	(0.034)	(0.021)
T2Work>100 km, m		0.164***	0.797***	0.082	0.029	0.371***
		(0.027)	(0.027)	(0.074)	(0.055)	(0.034)
T2Work5-15 km, f		0.179***	0.582***	0.153***	0.281***	0.566***
		(0.014)	(0.014)	(0.035)	(0.029)	(0.018)
T2Work15-100 km, f		0.175***	0.818***	0.218***	0.438***	0.806***
		(0.017)	(0.018)	(0.045)	(0.035)	(0.022)
T2Work>100 km, f		0.017	0.635***	-0.109	-0.183***	0.076*
		(0.033)	(0.034)	(0.102)	(0.07)	(0.045)
Toll 1-25 kr, male		0.203***	0.078***	0.141***	0.348***	0.393***
		(0.019)	(0.019)	(0.049)	(0.036)	(0.023)
Toll 25-50 kr, male		-0.126***	-0.422***	-0.109***	0.163***	0.011
		(0.015)	(0.016)	(0.042)	(0.03)	(0.02)
Toll>50kr, male		0.012	-0.256***	0.124**	0.431***	0.389***
		(0.021)	(0.022)	(0.055)	(0.039)	(0.025)
Toll 1-25 kr, female		0.192***	0.035*	0.095*	0.366***	0.445***
		(0.021)	(0.021)	(0.052)	(0.038)	(0.025)
Toll 25-50 kr, female		-0.083***	-0.418***	-0.091**	0.148***	0.023
		(0.017)	(0.018)	(0.045)	(0.032)	(0.021)
Toll>50kr, female		0.041*	-0.281***	0.053	0.480***	0.469***
		(0.025)	(0.026)	(0.067)	(0.044)	(0.03)
Public lane, male		-0.193***	-0.423***	-0.223***	-0.139***	-0.339***
		(0.012)	(0.013)	(0.034)	(0.024)	(0.016)
Public lane, female		-0.154***	-0.415***	-0.195***	-0.176***	-0.355***
		(0.013)	(0.014)	(0.036)	(0.026)	(0.017)
Governmental, male		0.301***	0.313***	0.360***	0.189***	0.377***
		(0.018)	(0.018)	(0.045)	(0.036)	(0.022)
Municipality, male		0.220***	0.165***	0.210***	0	0.231***
		(0.015)	(0.015)	(0.036)	(0.029)	(0.018)
Empl, not A-reg, m		-0.066***	0.050***	0.034	0.057	0.019

	No car	1 ICEV	2+ ICEV	1 PHEV	1 BEV	2+ BEV
		(0.016)	(0.016)	(0.05)	(0.038)	(0.023)
Government, female		0.301***	0.375***	0.239***	0.070**	0.257***
		(0.014)	(0.014)	(0.035)	(0.027)	(0.017)
Municipality, female		0.135***	0.044***	0.069*	-0.108***	0.019
		(0.015)	(0.016)	(0.038)	(0.029)	(0.019)
Empl, not A-reg, f		0.115***	0.237***	0.082	0.180***	0.327***
		(0.017)	(0.018)	(0.054)	(0.04)	(0.024)

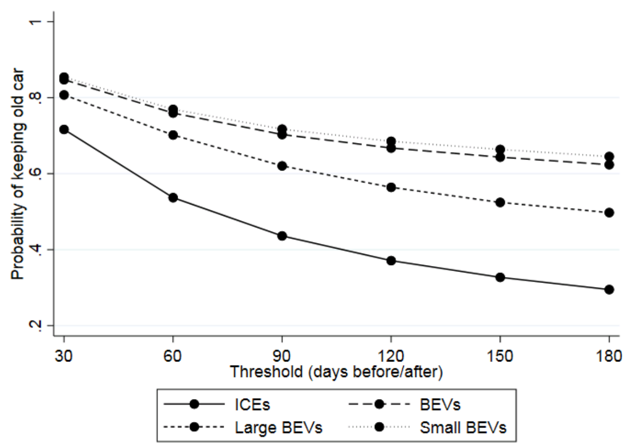
Note: Reference category; Non-immigrant couple, in Oslo/Bergen/Trondheim/Stavanger, less than high school, aged 18-24, both employed in private sector with T2Work<5 km, no toll nor bus lane. The sample consists of households with one adult female and one adult male.

Table B5. Multinominal logit estimates. Single person households.

	No car		ICEV		BEV	
	Male	Female	Male	Female	Male	Female
Children			1.114***	0.572***	1.588***	0.929***
			(0.014)	(0.009)	(0.029)	(0.026)
Owns house			0.640***	0.678***	0.833***	0.933***
			(0.006)	(0.006)	(0.023)	(0.026)
Access cabin			0.255***	0.249***	0.526***	0.506***
			(0.008)	(0.007)	(0.022)	(0.025)
Suburbs of O/B/S/T			0.680***	0.777***	0.472***	0.517***
			(0.009)	(0.009)	(0.027)	(0.03)
Five other cities			0.608***	0.726***	0.026	0.005
			(0.01)	(0.01)	(0.035)	(0.039)
Other areas			0.874***	0.972***	-0.218***	-0.326***
			(0.008)	(0.008)	(0.029)	(0.033)
Imm high inc ctry			-0.628***	-0.456***	-0.722***	-0.280***
			(0.01)	(0.012)	(0.042)	(0.047)
Imm low inc ctry			-0.510***	-0.884***	-0.507***	-0.488***
			(0.011)	(0.014)	(0.049)	(0.051)
Immigrant parents			-0.399***	-0.390***	0.409***	0.172**
			(0.022)	(0.024)	(0.054)	(0.068)
Income decile			0.154***	0.202***	0.256***	0.243***
			(0.001)	(0.002)	(0.005)	(0.006)
Wealth decile			0.141***	0.139***	0.130***	0.012***
			(0.002)	(0.001)	(0.004)	(0.005)
High school			0.101***	0.243***	0.267***	0.391***
			(0.007)	(0.008)	(0.027)	(0.034)
College/uni			-0.238***	0.044***	0.252***	0.504***
			(0.009)	(0.008)	(0.031)	(0.033)
Age 25-44			-0.159***	-0.323***	-0.368***	-0.694***
			(0.009)	(0.01)	(0.036)	(0.042)
Age 45-64			0.008	0.141***	-0.580***	-0.539***
			(0.01)	(0.011)	(0.039)	(0.046)
Age 65-74			0.319***	0.221***	-0.794***	-0.989***
			(0.014)	(0.013)	(0.058)	(0.063)
Age 75+			-0.193***	-0.937***	-1.322***	-2.377***
			(0.014)	(0.013)	(0.072)	(0.078)
Car-tech voc HS			0.877***	0.575***	0.646***	0.191
			(0.034)	(0.179)	(0.083)	(0.602)
Tech college			0.179***	-0.067*	0.295***	0.018
			(0.016)	(0.04)	(0.041)	(0.11)
Tech master			-0.002	-0.159**	0.078	0.129

	No car		ICEV		BEV	
	Male	Female	Male	Female	Male	Female
			(0.031)	(0.072)	(0.069)	(0.162)
Econ/business coll			-0.006	-0.016	0.094**	0.042
			(0.017)	(0.016)	(0.044)	(0.047)
Econ/business mast			-0.236***	-0.294***	-0.08	0.05
			(0.029)	(0.031)	(0.068)	(0.075)
T2Work5-15K			0.423***	0.458***	0.417***	0.443***
			(0.012)	(0.012)	(0.038)	(0.039)
T2Work15-100K			0.627***	0.677***	0.777***	0.731***
			(0.014)	(0.014)	(0.041)	(0.044)
T2Work>100 km			0.469***	0.484***	-0.001	-0.294***
			(0.023)	(0.028)	(0.064)	(0.089)
Toll 1-25 kr			0.041**	0.136***	0.453***	0.603***
			(0.017)	(0.018)	(0.041)	(0.047)
Toll 25-50 kr			-0.218***	-0.275***	0.346***	0.354***
			(0.015)	(0.016)	(0.037)	(0.043)
Toll>50kr			-0.144***	-0.201***	0.616***	0.862***
			(0.019)	(0.022)	(0.045)	(0.052)
Public lane			-0.310***	-0.368***	-0.245***	-0.364***
			(0.011)	(0.012)	(0.029)	(0.034)
Governmental			0.195***	0.187***	0.274***	0.003
			(0.016)	(0.011)	(0.041)	(0.035)
Municipality			0.177***	0.026*	0.192***	-0.095**
			(0.015)	(0.014)	(0.034)	(0.038)

Note: Separate regressions by gender. Reference category; Non-immigrant living in a flat in Oslo/Bergen/Trondheim/Stavanger , less than high school, aged 18-24, employed in private sector with T2Work<5 km, no toll nor bus lane.



FigureB2. Probability of keeping old car for one car households. Sensitivity to time interval threshold.

Transportøkonomisk institutt (TØI)
Stiftelsen Norsk senter for samferdselsforskning

TØI er et anvendt forskningsinstitutt, som mottar basisbevilgning fra Norges forskningsråd og gjennomfører forsknings- og utredningsoppdrag for næringsliv og offentlige etater. TØI ble opprettet i 1964 og er organisert som uavhengig stiftelse.

TØI utvikler og formidler kunnskap om samferdsel med vitenskapelig kvalitet og praktisk anvendelse. Instituttet har et tverrfaglig miljø med rundt 90 høyt spesialiserte forskere.

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