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# Who goes electric?

## The anatomy of electric car ownership in Norway<sup>1</sup>

By

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### Abstract

We describe the anatomy of electric car ownership in Norway, the country with the highest market share of low-emission vehicles, using matched administrative micro data covering the entire population of private car owners. Our results show that socioeconomic characteristics are strong predictors of the car portfolio. Battery electric vehicle (BEV) ownership is increasing in wealth, income and education. While early BEV owners differed from other car owners, over time BEV owners have become more similar to other car owners. We document a strong association between BEV privileges on the travel to work (like toll road exemptions and bus lane access) and BEV ownership. We show that BEV buyers are less likely than other car buyers to sell their old car, but this difference has diminished over time.

**Keywords:** Electric vehicles; low emission transportation; car ownership; household characteristics; distributional concerns; substitution;

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# 1 Introduction

Transport is responsible for almost 30% of EU's total CO<sub>2</sub> emissions, of which 43% can be attributed to passenger cars.<sup>2</sup> The European Union preliminary 2030 emissions reduction targets for the non-ETS sector cannot be reached without substantial reductions in emissions from the transport sector.<sup>3</sup> A transition to zero and low emission private transportation is essential for reaching emission targets. 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? 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 vehicles (PHEVs) constitute a low share of the passenger car market in most countries.<sup>4</sup> 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).

Norway is an interesting case with its higher share of BEVs and PHEVs, and the policies to favor zero emission automobiles seem stronger, than in any other country (Mock and Yang, 2014). In 2020 52,2% of new passenger cars registered in Norway were battery electric vehicles (BEV), and another 20.4 % were PHEVs. The financial incentives in Norway take the form of exemptions from relatively heavy taxes affecting vehicles equipped with an internal combustion engine. In the time period we look at in this paper, there were no road

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<sup>2</sup> <https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics>

<sup>3</sup> The EU target for transport emissions is set to at least 55% reduction by 2030 compared to 1990 (Council of the European Union, 2020).

<sup>4</sup> China had 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 made up below 2% of the market share (IEA, 2019).

tolls or public parking fees for zero emission vehicles. In addition, BEVs were subject to reduced ferry fares, were allowed to travel in bus lanes, and enjoyed free recharging in many public parking lots. Finally, cheap electricity contributes to the low user cost for BEVs and PHEVs. For more details on the Norwegian policies and incentives, see for instance Fridstrøm (2019), Fridstrøm and Østli (2021) and Figenbaum et al. (2015). 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 relevance for the green transition of private cars.

The purpose of this paper is to describe the car ownership structure using longitudinal Norwegian administrative data from 2011 to 2017. 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 paper makes several contributions. First, while most existing studies of electric cars focus on the intention to buy a BEV or new vehicles sales, we characterize (actual) car ownership including older cars and second-hand acquisition. Second, from the focus on car owners (rather than cars) we describe the substitution patterns by documenting the extent to which new BEV owners keep their old car. Third, our data reveal actual real-life choices, rather than reported intentions. For example, concerning the role of BEV privileges like toll exemptions, we compare 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. 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 more than 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 the quality of our data allow us to give a

more reliable and complete description of the anatomy of car ownership than what has previously been possible.

## 2 Previous studies on electric vehicle ownership

This section reviews previous empirical studies of BEV ownership. We divide the literature in three broad categories: (1) studies using survey data on BEV ownership or intentions to buy BEVs, (2) studies using stated preference (choice experiment) surveys to estimate discrete choice models, and (3) studies using observational data on BEV sales or ownership combined with continuous or discrete choice econometric modelling.

Among survey studies (1), many focus on *intentions* to adopt BEVs due to its low market share (Rezvani et al., 2015). Some clear patterns emerge (Coffman et al., 2017; Li et al., 2017): People wanting to buy BEVs are more likely to be men,<sup>5</sup> 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. Most studies find no effect of income on intentions to adopt BEVs.<sup>6</sup>

Other survey studies focus on households who already own a BEV. Many of these studies are from Norway, where the transition towards BEVs has come the furthest.<sup>7</sup> 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,<sup>8</sup> BEV owners are more

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<sup>5</sup> In addition, women have less experience with BEVs (Sovacool et al., 2018).

<sup>6</sup> See Tran et al. (2013) for an exception: who find that people with higher income are more likely to buy BEVs.

<sup>7</sup> A study on BEV ownership in Denmark and Sweden, also based on survey data, find similar patterns in ownership as the Norwegian studies (Haustein and Jensen, 2018).

<sup>8</sup> These include Figenbaum and Kolbenstvedt (2013), Plötz et al. (2014), Figenbaum, Kolbenstvedt, and Elvebakk (2014), Bjerkan, Nørbech, and Nordtømme (2016), Figenbaum and Kolbenstvedt (2016) and Figenbaum and Nordbakke (2019).

likely to be men, have higher education and income, own multiple cars,<sup>9</sup> have full-time jobs and children under 18 years old living at home. When it comes to age, it is less common to own BEVs in age groups under 25 and over 50.

Comparing answers from these surveys over time <sup>10</sup>, BEV owners seem to have become more similar to ICEV owners with respect to work status, education, age, household size and the number of cars. However, this evidence of convergence is only indicative since the surveys are not designed for explicit comparisons between ICEV and BEV households over time. There is a tendency that BEVs are more common than ICEVs as a second vehicles, but the most recent survey points at increased attractiveness of BEVs in single vehicle households and increased use of BEVs for long distance driving (Figenbaum, 2019).

In category (2), studies based on stated preference (SP) survey data, attitudinal and behavioral factors are typically integrated in the decision-making process in a hybrid choice model setup (Walker, 2001; Walker and Ben-Akiva, 2002). In an early study from Canada, Bolduc et al. (2008) find that environmental concerns and appreciation of new car features have positive impact on preferences for low-emission cars. A Swiss study characterizes typical BEV customers as young public transport users, two-car households and high-income households (Glerum et al., 2014).

In a review of recent studies of this kind Liao, Molin, and van Wee (2017) find that the attractiveness of EVs (their focus is on both BEVs and PHEVs) increase with tax incentives related to car purchase and 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 education is positively associated with EV adoption in all studies that include this variable.

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<sup>9</sup> Bjerkan, Nørbech, and Nordtømme (2016) is an exception and reports 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.

<sup>10</sup> See Fevang et al. 2020, Table 1, for comparison of the survey results over time.

Jensen, Cherchi, and Mabit (2013) find that experience with using BEVs influence preferences, as the importance attached to several attributes of BEVs changed significantly after having used a BEV for three months. This points to one of the weaknesses with studies in this category - that choices are hypothetical and respondents therefore might not have experience with BEVs. According to Coffman, Bernstein, and Wee (2017), “There is strong evidence 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 who has experience with driving BEVs.

The last strand of literature (3) relies on detailed car sales data to estimate econometric discrete choice models of car ownership. The strength of these model frameworks is the potential to do counterfactual simulations of (equilibrium) outcomes under alternative policies. However, these studies tend to either not include any information regarding the owner at all, or rely on socio-economic characteristics aggregated to the municipality or other regional level. Østli et al. (2017) estimate a nested logit model for passenger car purchase in Norway. Beresteanu and Li (2011) focuses on hybrid-electric vehicles in the US car market. Later studies include studies of the relationship between demand for BEVs and policies such as tax exemptions, access to charging stations (Zhang et al., 2016), charging subsidies (Springel, 2017), charging standards (Li 2017) and substitution between BEVs and other car types (Fridstrøm and Østli, 2021; Xing et al., 2019).

Within (3), there are also some 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 (Gillingham et al., 2015a; Gillingham and Munk-Nielsen, 2019; Glerum et al., 2013). Unfortunately, these studies are conducted in countries where the shares of BEVs were too low to include BEVs as an alternative in the model.

Hasan, Hanssen, and Mathisen (2019) provide a short review and bibliometric study of the entire research literature on electric vehicles<sup>11</sup> 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. The authors conclude that is concerning, since the goal of policies is to increase consumer adoption of electric vehicles.

## 3 Data and descriptives

### 3.1 Data sources

This study describes BEV ownership in Norway, based on micro data from administrative registers encompassing the entire Norwegian population between 2011 and 2017. We combine information on all passenger cars with detailed information about their owners. A unique personal identifier makes it possible to link data from various sources and track individual car ownership over time.

The 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, drivetrain, 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. Around 10% of passenger cars were registered to companies, including cars 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.

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<sup>11</sup> This study does not distinguish between battery electric vehicles, plug-in hybrid electric vehicles and hybrid electric vehicles.

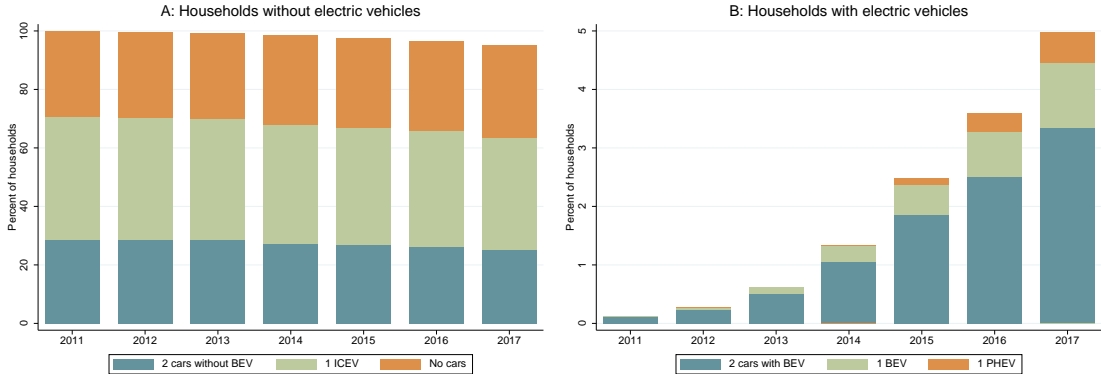


Car ownership data can be organized using either the individual or the household as the analytical unit. In our data, we observe nearly 4.2 million individuals, and about 2.5 million households annually. As individuals are linked via a household identification number (ID) in the data,<sup>12</sup> household characteristics can be established by aggregating individuals within households.

### 3.2 Describing car ownership

The novelty of our data is the car-ownership link that exists for all cars. Since individuals who live together and pool resources typically share cars, we find it most appropriate to define car ownership at the household level (independent of who the registered owner is).

We split car ownership in six segments along two dimensions; number of cars (0,1 or 2+) and propulsion technology (ICEV,<sup>13</sup> BEV and PHEV). Two-car owners with a PHEV are included in the group of multicar households without a BEV (“2 cars without BEV”). In Figure 1 we report the annual (by 31 December) car ownership distribution, ignoring periods before 2011 because BEV sales were negligible.



Note: Sample: full sample from 2011 to 2017. Households are split according to car ownership: 0, 1 or 2 or more cars. One car households are split between ICEV, PHEV and BEV. Multiple car 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 panels include all households in Norway, with the exception of some alternative fuel type owners (natural gas, kerosene and hydrogen, < 100 households in total).

<sup>12</sup> Our definition of households follows Statistics Norway’s definition of couples: two persons living in the same housing and are married to each other, are registered partners or cohabit without being married or registered partners. To count as cohabitants, the two persons must be registered in the same housing and be of opposite gender and either have common children, or have reported in a specific survey that they are cohabitants. Statistics Norway report that their data are not good enough regarding cohabitants of the same gender, so same-gender cohabiting couples are not included.

<sup>13</sup> Counting ordinary (non-plug-in) hybrids as ICEVs.

***Figure 1. 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 that are not BEVs. Panel B shows households with BEVs. In 2017, about 4.5% of all households had a BEV, and more than two thirds of these were multicar households.

In Table 1 we present descriptive statistics for our population in 2017. Panel A lists household characteristics including family structure, economic resources, housing and residential region. Panel B displays individual characteristics like age, gender, immigrant background, educational attainment and travel to work characteristics. Note that ownership is still defined at the household level<sup>14</sup>.

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<sup>14</sup> 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 to 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).

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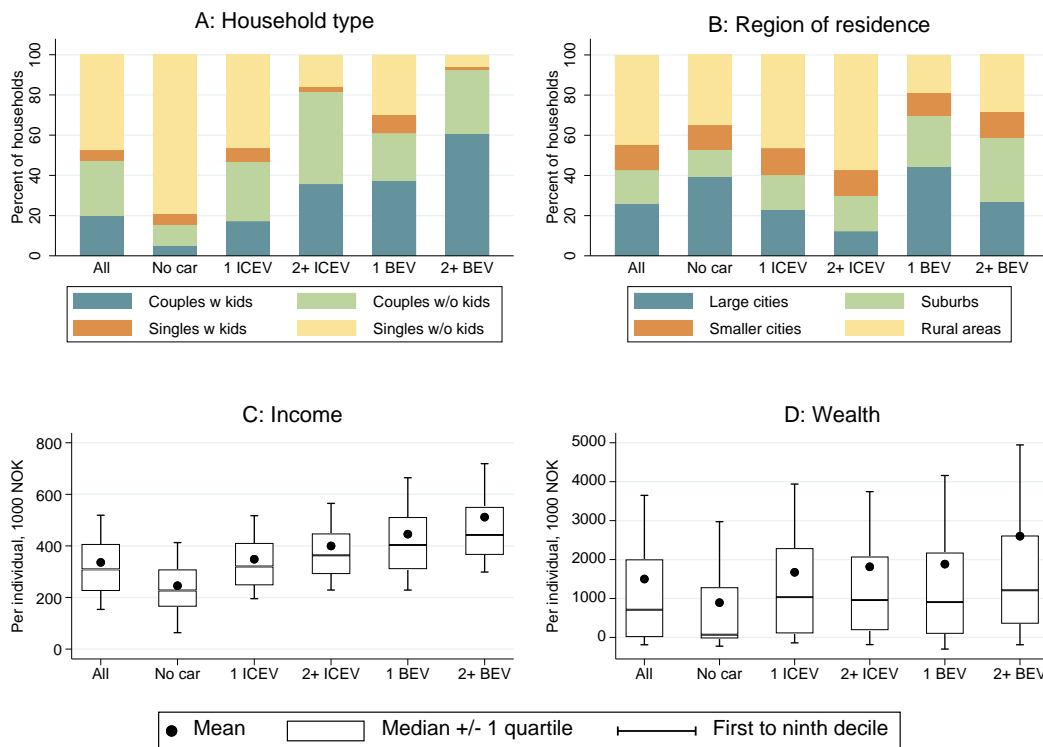
**Table 1. Car ownership, 2017. Household. Means by car ownership type.**

	All	No car	One car			Two cars +	
			ICE	BEV	PHEV	Without BEV	With BEV
<b>All (%)</b>	100	31.7	38.3	1.1	0.5	25.0	3.3
<b>Panel A. Household characteristics</b>							
<i>Type of household (%)</i>							
Single without kids	47.5	79.1	46.5	29.8	23.6	15.7	5.9
Single with kid(s)	5.2	5.5	6.8	9.2	3.8	2.7	1.6
Couple without kids	27.6	10.2	29.6	23.5	43.5	45.8	31.5
Couple with kid(s)	19.8	5.2	17.2	37.5	29.1	35.7	60.9
<i>Economic resources</i>							
Income per adult (1 000 NOK)	336	246	348	446	485	400	512
Wealth per adult (1 000 NOK)	1,501	894	1,673	1,883	2,922	1,815	2,601
Detached house (%)	69.5	47.7	72.8	68.6	76.5	89.2	89.8
Access to second home (%)	27.2	14.8	26.5	32.3	35.1	41.4	43.4
<i>Region of residence (%)</i>							
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/Trondheim/Stavanger	11.8	14.5	11.8	21.1	16.6	7.2	15.5
Suburbs of B/T/S	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
Small cities	19.6	16.5	20.9	10.7	16.4	22.7	14.4
Other areas	24.9	18.5	25.4	8.1	15.4	34.6	14.0
# of households	2,560,495	812,007	980,296	28,843	13,568	640,465	85,316
<b>Panel B. Individual characteristics</b>							
Age (mean)	48.4	47.1	51.4	42.0	50.8	46.8	43.0
Women (%)	49.8	53.6	50.3	49.8	46.9	46.9	48.3
<i>Immigrant (%)</i>							
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
Immigrant parents	1.5	2.5	1.3	3.3	1.1	1.0	1.9
<i>Educational attainment (%)</i>							
< High school	34.1	39.4	35.5	17.0	22.1	31.9	17.0
High school	28.9	20.7	27.3	27.0	27.5	36.4	31.3
College/university	32.4	29.7	33.4	52.5	48.8	29.8	50.3
Unknown	4.5	10.2	3.8	3.5	1.5	1.9	1.4
<i>Travel to work characteristics</i>							
Distance (km)	41.0	47.1	39.5	36.6	34.8	41.2	36.1
Road toll (%)	35.2	39.6	36.0	55.2	41.8	29.1	51.4
Road toll, amount (NOK)	18.8	23.2	18.7	28.6	20.8	15.6	25.7
Bus lane (%)	31.6	44.6	33.0	51.3	41.4	22.1	41.9
Km Bus land	0.62	0.82	0.62	1.04	0.81	0.47	0.90
# individuals	4,169,963	971,825	1,542,627	50,134	24,879	1,389,153	191,345
# individuals with workplace information	1,986,717	296,625	724,892	32,152	14,901	789,109	129,038

Note: Sample: Full sample in 2017. Car ownership is by the end of 2017. Travel to work information is for individuals with a job record in 2014 (last year with workplace information). Kids are defined as children living at home below 18 years. Access to second home means that the household members, their parents or children own a second home (cabin). Detached house includes semi-detached or terraced house, but not flats. Income is measured after tax, and includes labor income, capital income and public transfers (such as social security benefits). 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. Immigrants are split in two by country of origin. High income countries include Europe, North America and Oceania. These variable definitions are used throughout the paper.

### 3.2.1 Car ownership across socio-economic groups

This section (Figure 2 to 4) displays associations between various socio-demographic characteristics and car ownership as listed in Table 1. Each figure panel has a common structure as we first present the distribution of characteristics for all *households* (Figure 2) or all *individuals* (Figure 3 and 4) – 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).<sup>15</sup> The relative sizes of these five categories are displayed in Figure 1 in the previous subsection.



**Figure 2. Car ownership and household demographics, 2017.**

Panel A of Figure 2 shows that while car ownership generally increases with family size, car type also differs. 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.

<sup>15</sup> In this section, all non-BEV vehicles including PEVs are counted as “ICEV”s.

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 Panel C, we show that 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 income is on average 28 % higher for those with a BEV. This also holds for wealth (Panel D), but the difference is negligible among one-car households.<sup>16</sup>

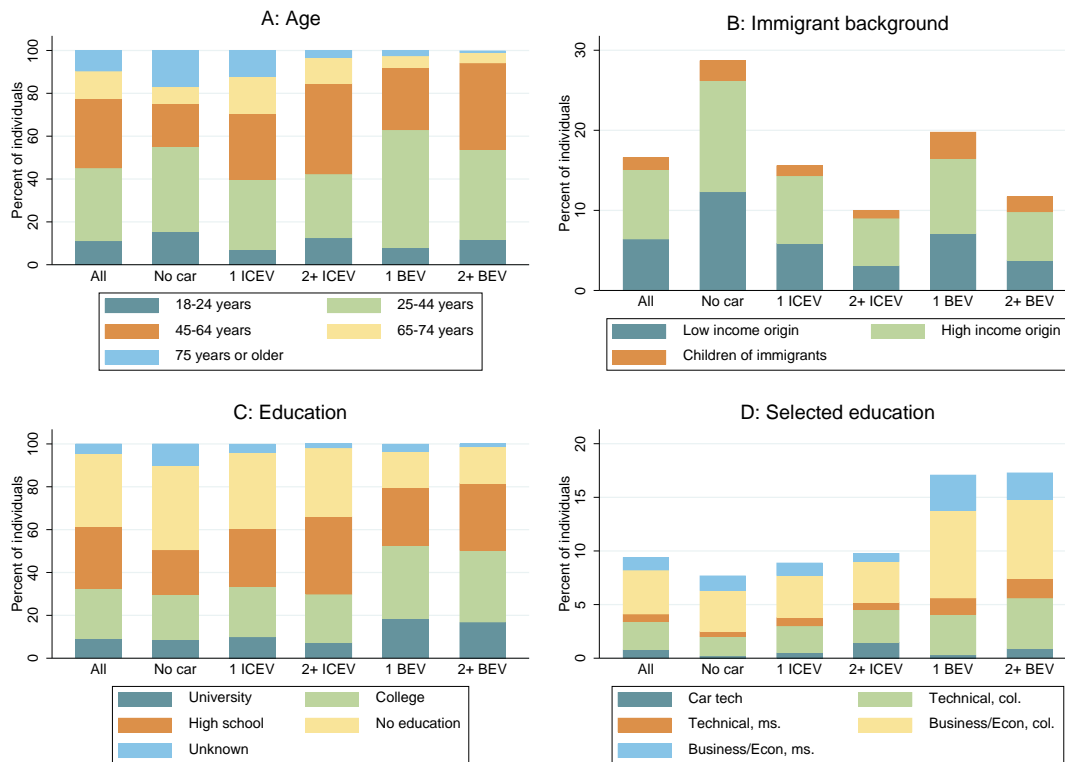
Turning to the individual characteristics in Figure 3 and 4, we still define car ownership based on the household that the individual belongs to.<sup>17</sup> Panel A in Figure 3 shows that BEV owners tend to be in the age group 25-44 years old and very few are above 65. About 16.6% of adults are immigrants or children of immigrants, but they constitute close to 30% of those without a car (Panel B). They are also underrepresented in multicar households. Perhaps most notable is the high share with immigrant parents among BEV owners.

Figure 3 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 investigate whether field of education also matters for car ownership, we have selected three types of education (Panel D). First, car mechanics with a vocational upper secondary education are overrepresented among multicar 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.

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<sup>16</sup> See Table 1 and its note for the definition of wealth.

<sup>17</sup> In Figure 6 and 7, this implies that we give two-person households twice as much weight as one-person households.



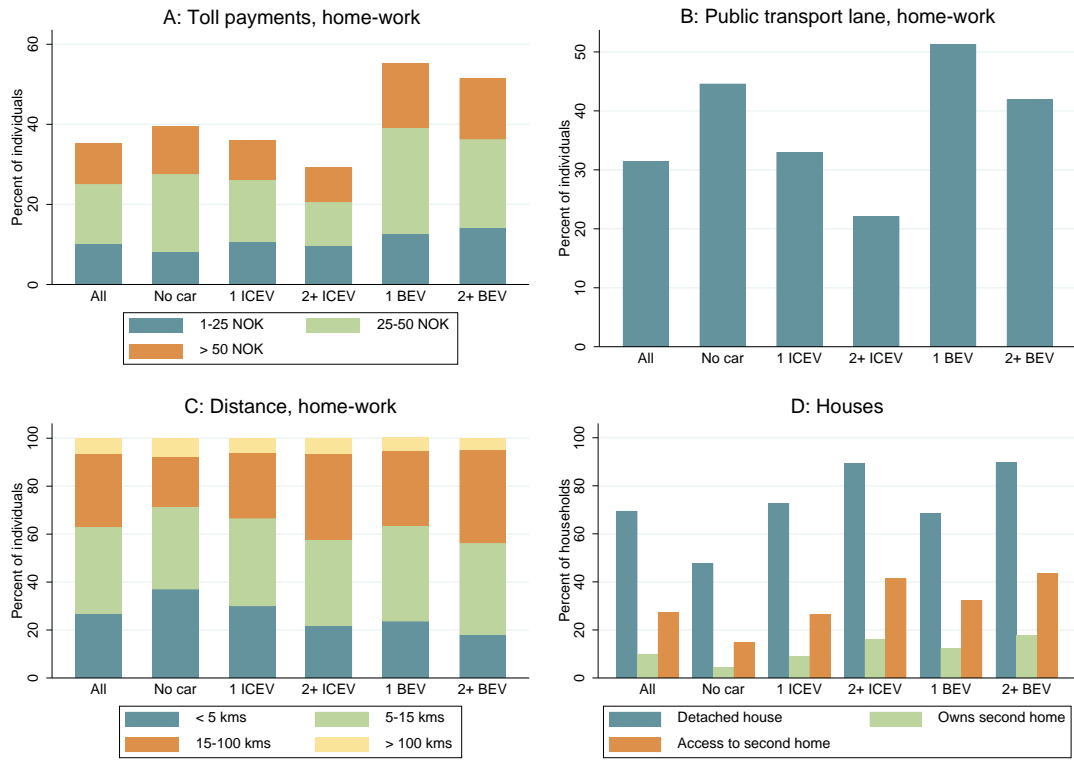
Note:

Note: Since panel B and D show selected categories as the shares of the total population, they do not sum to 100%.

**Figure 3. Household car ownership, economic resources and education. Individuals, 2017.**

Figure 4 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 travel to work. The toll is typically between 25 and 50 NOK (2.5 to 5 Euro) per trip, but BEVs are exempt. 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 the presence of 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.

We find that living in a detached house and having access to a secondary home is approximately equally common among BEV and ICEV owners (Panel D) when we compare to households with the same number of cars.



Note: Toll payments relate to the one-way work trip (the average payment of “to” and “from” work). Detached house includes semi-detached or terraced house, but not flats. “Owns second home” (cabin) 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. Categories in Panel D are not mutually exclusive.

**Figure 4. Car ownership and drivers of travel demand. Individuals, 2017.**

Figure 5 provides more details on car ownership (Panel A and B) and buyers of new cars (Panel C and D) 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). In Panel A and B, we split according to the size of the car. For electric cars, the average number of BEVs per adult is strongly increasing in income throughout the income distribution and this pattern is found for small as well as large cars.<sup>18</sup> As expected, the income gradient is less steep for the typical small BEV than for large BEVs. Note that the two scales are different. In the lower end, only one in hundred households owns a BEV (small or large) compared to just above 8% in the top income decile. Total ICEV ownership is constant when

<sup>18</sup> In 2017, the only available BEVs in the ‘large car’ segment were Tesla Model S and Tesla Model X.

exceeding median income, but ownership of small cars is decreasing while ownership of large cars is increasing - presumably because households switch to more expensive cars.

Turning to new car purchases in Panel C and D, the gradients are much more similar for buyers of BEVs and ICEVs.<sup>19</sup> This is also the case in Panel D, where we show the total value (including taxes) of new cars purchased per household.<sup>20</sup> In general, the income gradient (i.e. the relative difference between two income deciles) is stronger for value (Panel D) than for number of new cars (Panel C), because richer households tend to buy more expensive cars.

When considering the entire income distribution, the income gradient is stronger for buyers of BEVs than for ICEVs in both panels.<sup>21</sup>

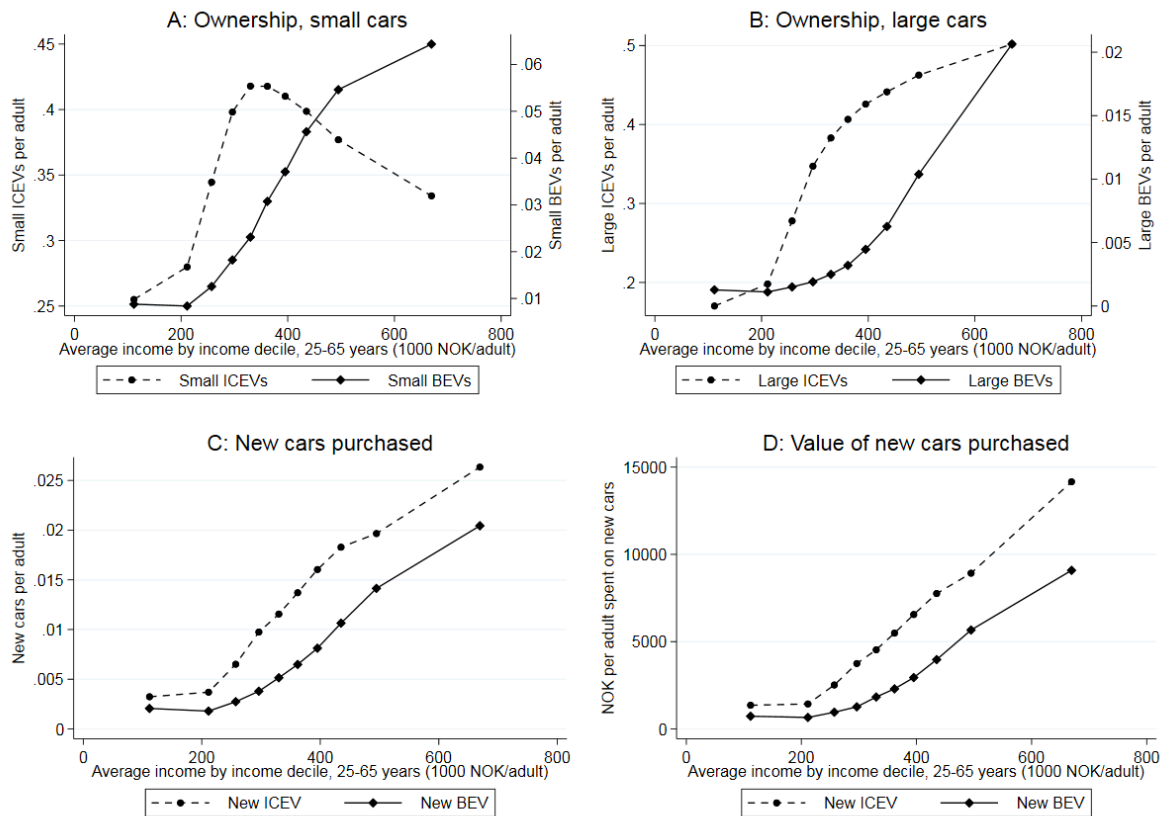
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<sup>19</sup> Household car ownership is defined at the end of the year. New cars are here defined as cars that are bought new during the year, regardless of whether they are bought by the same household.

<sup>20</sup> On average, new BEVs are cheaper than new ICEVs (due to the tax exemptions). Moreover, the price variation for ICEVs is larger, as the variation in car models offered on the market is larger.

<sup>21</sup> 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.





Note: The category Large BEVs include Tesla S and Tesla X, while Small BEVs include all remaining BEVs. Small/large ICEVs are defined as cars with lower than/higher than median weight (1420 kg). This is approximately the weight of the median Tesla without the weight of the battery, so we believe these categories should be comparable.

**Figure 5. Car ownership and new car purchase across the income distribution. Number of cars or total value of cars per household, 2017.**

### 3.2.2 BEV 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.

In Figure 6 we display the development over time (from 2012 to 2017) for selected household characteristics. The solid lines represent all BEVs, while the dotted ones are split into small and large vehicles. First, in Panels A and B we compare mean economic resources of BEV households, relative to ICEV households. Numbers higher than 1 imply that BEV households have higher income or wealth than ICEV households. As for income, the BEV

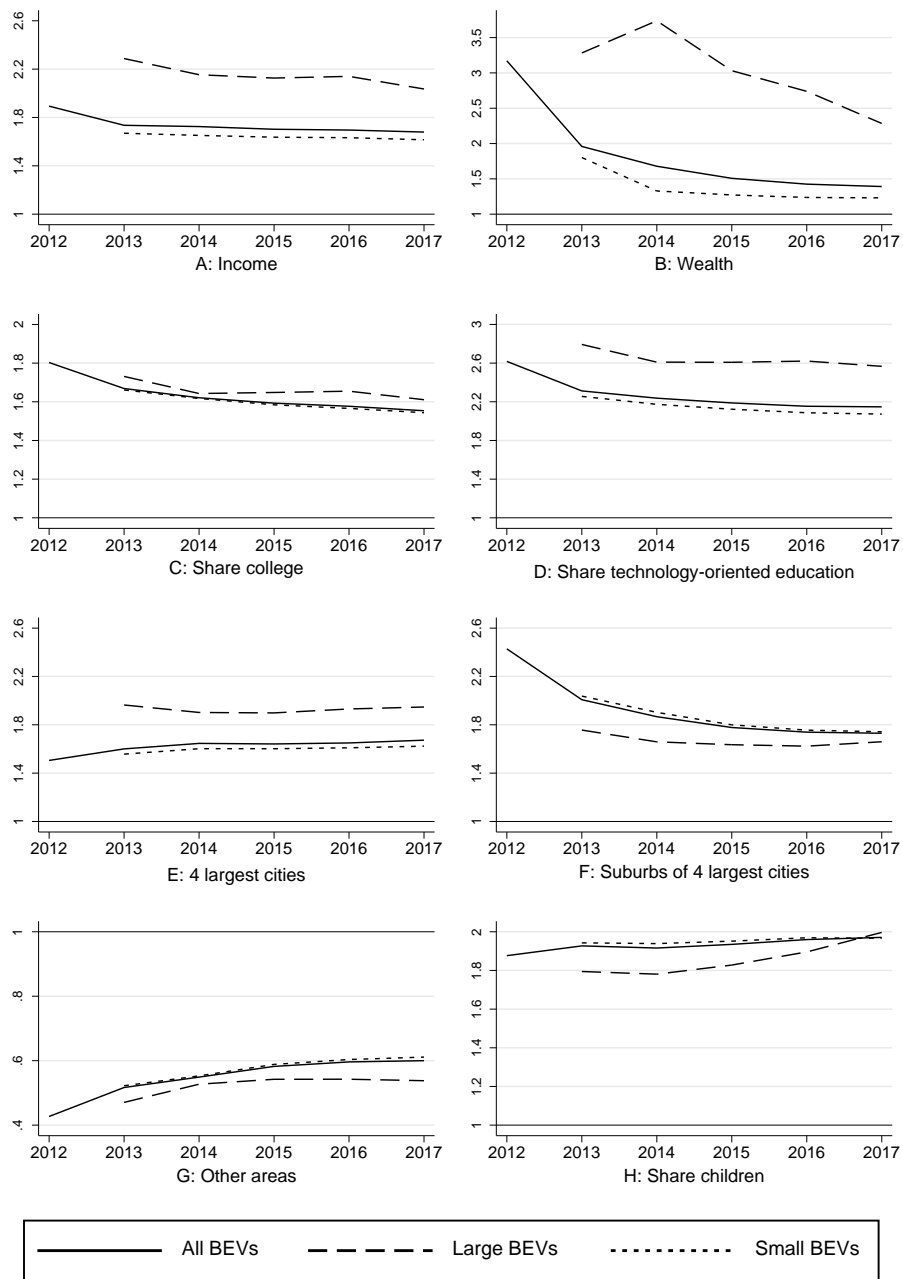
household earned about 75% more than ICEV owners did in 2013. Wealth of BEV households was about two times that of ICEV owners in 2013 (Panel B).

Panels C to H display the relative share of education, place of residence and number of children for BEV owners relative to ICEV owners. In Panel C, we see that the share of BEV owners that has completed college was 80% higher compared to that of ICEV owners in 2012.

When we compare BEV owners over time, we see that the pioneers are a particularly selected group, but after the initial phase, BEV owners become more similar to ICEV.<sup>22</sup> This convergence can be due to the increase in the magnitude of BEV ownership and how diffusion of new technology spreads (from early adopters to the rest of the population), but also can be the result of the change in the supply side of BEVs over time, in that the supply of BEVs has become better and BEVs have become more similar to other cars.

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<sup>22</sup> 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. Income 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 6. BEV owner characteristics relative to ICEV owners.**

## 4 Regression results

In this chapter, we aim to shed light on two separate questions using regression analysis. The first section presents the conditional association between demographics and car ownership status of households. In the second section, we attempt to figure out whether BEVs come in addition to a household's existing car(s), or as a replacement for it.

### 4.1 Socio-economic gradients

Many of the socio-economic characteristics of typical BEV owners 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. In this section, we examine the conditional association between each characteristic and car ownership in a multinomial logit (MNL) regression model, including a larger set of socio-economic characteristics. 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 Table 2, we present average marginal effects from the estimated MNL model, with the same six alternatives of car ownership: No car, single car (ICEV, BEV, PHEV) and multicar (2+ICEV, 2+BEV).<sup>23</sup> While Table 1 included the entire sample, Table 2 is based on the sub-sample of couples in 2017. The estimated coefficients and corresponding standard errors can be found in Appendix B, Table A2. Since the shares are uneven across categories, we present marginal effects in percent rather than percentage points; i.e. we report average marginal effects *scaled* with the respective sample means reported in the bottom row.<sup>24</sup> For

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<sup>23</sup> 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 included in the “2+ BEV” category if they also own at least one BEV and in the “2+ ICEV” category otherwise.

<sup>24</sup> That is  $(dP_j/dX_k)/P_j$ , i.e. the relative change in the average probability of choosing the  $j$ th alternative ( $P_j$ ) from a marginal increase in the value of the  $k$ th attribute ( $X_k$ ).

example, the estimate 0.346 in the 2+ BEV 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 constant.<sup>25</sup> With few exceptions, all effects are statistically significant.

The patterns described by Figures 1-6 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 secondary home are more likely to own several cars. 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 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 strongly relates to economic resources. Moving one decile up in the income distribution for males is associated with a significant higher probability (11.3%) of owning a BEV or a PHEV. BEV ownership is positively associated with female income as well, but less so compared to that of men. The effect of wealth on multicar BEV is also positive, but weaker than for income.

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<sup>25</sup> 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.

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

	No car	1 ICE	2+ ICEV	1 PHEV	1 BEV	2+ BEV
Children	-0.358***	-0.016***	0.046***	-0.163***	0.143***	0.346***
<u>Economic resources</u>						
Income decile, male	-0.077	-0.017	0.011***	0.155***	0.075***	0.113***
Income decile, female	-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, female	-0.055	-0.000	0.008***	0.051***	-0.001	0.028***
Detached house	-0.499***	-0.186***	0.221***	-0.100***	-0.090***	0.444***
Access second home	-0.067***	-0.080***	0.074***	-0.166***	0.039**	0.092***
<u>Region of residence</u>						
Suburbs of O/B/T/S	-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***
<u>Immigrant</u>						
High income country, m	0.050***	0.056***	-0.040***	-0.147***	-0.047	-0.108***
Low income country, m	0.108***	0.003	-0.044***	-0.353***	0.072*	0.129***
Immigrant parents, m	0.073***	-0.015	-0.078***	-0.008	0.731***	0.324***
High income country, f	0.026***	0.016***	-0.020***	-0.126***	0.061**	0.001
Low income country, f	0.193***	0.131***	-0.165***	-0.058	0.214***	-0.015
Immigrant parents, f	-0.021	0.022*	-0.073***	0.144	0.587***	0.237***
<u>Education</u>						
Secondary, male	-0.077***	0.002	-0.008***	0.143***	0.110***	0.121***
Tertiary, male	0.165***	0.079***	-0.159***	0.193***	0.268***	0.248***
Secondary, female	-0.040***	-0.080***	0.050***	0.014	0.118***	0.169***
Tertiary, female	0.072***	-0.038***	-0.038***	0.080**	0.268***	0.288***
<u>Selected educations</u>						
Car mechanics, male	-0.389***	-0.267***	0.344***	-0.424***	-0.496***	0.059**
Car mechanics, female	-0.217	-0.211***	0.203***	0.771	-0.050	0.144
Technical, col., male	-0.189***	-0.074***	0.075***	-0.0301	0.0314	0.229***
Technical, univ., male	-0.101***	-0.031***	0.040***	-0.084	-0.152***	0.124***
Business/econ, col., m	0.108***	-0.062***	0.014***	-0.004	0.196***	0.050***
Business/econ, univ., m	0.184***	0.017*	-0.075***	0.0671	0.159***	0.064***
Technical, col., female	-0.043	-0.039**	0.038***	0.083	-0.008	0.033
Technical, univ., female	0.028	0.070***	-0.060***	-0.134	-0.086	-0.018
Business/econ, col., f	0.009	-0.021***	0.009*	0.021	0.060*	0.034**
Business/econ, univ., f	0.100***	0.053***	-0.078***	0.079	0.043	0.028
<u>Age</u>						
25-44, male	-0.739***	-0.020*	0.128***	0.522***	-0.251**	0.435***
45-64, male	-0.924***	-0.125***	0.285***	0.308**	-0.599***	0.406***
65-74, male	-1.19***	0.041***	0.241***	0.491***	-0.800***	0.168***
75+, male	-0.977***	0.164***	0.096***	0.307**	-0.758***	0.093

25-44, female	-0.358***	-0.039***	0.077***	-0.0254	-0.190***	0.320***
45-64, female	-0.519***	-0.103***	0.191***	-0.143	-0.396***	0.266***
65-74, female	-0.792***	0.092***	0.108***	0.190	-0.445***	0.0836**
75+, female	-0.220***	0.221***	-0.123***	-0.048	-0.126	-0.091*
<i><u>Travel to work characteristics, distance</u></i>						
5-15 km, male	-0.272***	-0.117***	0.151***	-0.127***	-0.093***	0.150***
15-100 km, male	-0.357***	-0.226***	0.244***	-0.275***	-0.101***	0.328***
>100 km, male	-0.279***	-0.235***	0.302***	-0.330***	-0.320***	-0.082***
5-15 km, female	-0.234***	-0.159***	0.177***	-0.213***	-0.056**	0.163***
15-100 km, female	-0.297***	-0.264***	0.269***	-0.272***	-0.0214	0.260***
>100 km, female	-0.169***	-0.238***	0.297***	-0.360***	-0.353***	-0.188***
<i><u>Travel to work characteristics, other</u></i>						
Road toll 1-25 kr, male	-0.119***	0.058***	-0.063***	-0.0140	0.183***	0.231***
Road toll 25-50 kr, male	0.154***	0.080***	-0.157***	0.107***	0.365***	0.240***
Road toll>50kr, male	0.0269*	0.068***	-0.159***	0.181***	0.500***	0.481***
Road toll 1-25 kr, f	-0.109***	0.064***	-0.084***	-0.045	0.221***	0.315***
Road toll 25-50 kr, f	0.131***	0.102***	-0.170***	0.104**	0.332***	0.237***
Road toll>50kr, female	0.013	0.085***	-0.186***	0.087	0.561***	0.584***
Bus lane, m	0.204***	0.069***	-0.109***	0.058*	0.123***	-0.034***
Bus lane, f	0.185***	0.089***	-0.117***	0.067*	0.069***	-0.064***
<i><u>Employment sector</u></i>						
Government, 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***
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***
Mean <sup>a</sup>	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. O/B/T/S: the cities Oslo/Bergen/Trondheim/Stavanger. Car mechanics: a vocational upper secondary education in car mechanics. <sup>a</sup>The mean corresponds both to the observed market shares and the predicted market shares, as these are identical due to the alternative-specific constants (ASCs).

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 use 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 sole car or in combination with other cars. The effect of being a public employee tends to be negative both for single women and for those living with a partner, but is mixed for men.

We split travel to work distance in 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 in the model).

Single person households are common, but less than 2% of these households own a BEV. Results for single person households are presented in Table A1 in the Appendix, and show similar patterns as for couples.

BEVs have only been on the market for a short time, and thus have only been an option for those that have considered buying a new car during the last couple of years. The fact that BEV owners share certain characteristics could be due to that our analysis partly captures characteristics of households with new cars in general.



Table 3 gives a final illustration of the heterogeneity in car ownership across households. Based on the MNL estimates (see Table A2 in Appendix B) we predict the set of ownership probabilities at the household level and for three selected types of households. As can be seen from Table 3, predicted and observed market shares are slightly different, which is due to focusing on very narrowly defined sub-populations. In Table 3 there is only one constant term per alternative, meaning that predicted market shares only will reproduce observed market shares when considering the whole sample. If we had included sub-population specific constant terms for categories A, B and C, predicted and observed market shares would have been identical. Thus, Table 3 illustrates the degree of over/under-prediction for specific sub-populations.

In the pro-BEV-household (A), both adults have tertiary (university/college) education, age between 25 and 44, live in a 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%). In sum, our estimates predict that four out of ten households with these characteristics own a BEV.

**Table 3. Predicted car ownership share by household type. Per cent.**

	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 bus lane, 15-50 km distance		Male employed with no toll or bus 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
BEV	7	4	1	1	0	0
ICEV	30	41	21	15	27	30
No car	5	8	2	1	4	2
PHEV	1	2	1	1	0	0
Households	399		769		540	

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.

Focusing on car ownership in general, we can compare our findings with the findings of previous studies based on administrative register data. In line with the descriptive statistics of Gillingham et al. (2015b) from Denmark, we find that car ownership increases strongly with age among young adults, while the differences between the remaining age groups are smaller.<sup>26</sup> The positive relationship with income is also similar to that shown by Gillingham et al. as well as by Pyddoke (2009). Like Pyddoke, we also find that car ownership is lower in urban areas and highest in the most rural areas. This relationship appears to be even stronger in our regression results than in the bivariate relationship reported by Pyddoke. Finally, like Gillingham and Munk-Nielsen (2019), we find that a longer work distance increases the probability of owning more than one car.

## 4.2 Do BEVs substitute ICEVs?

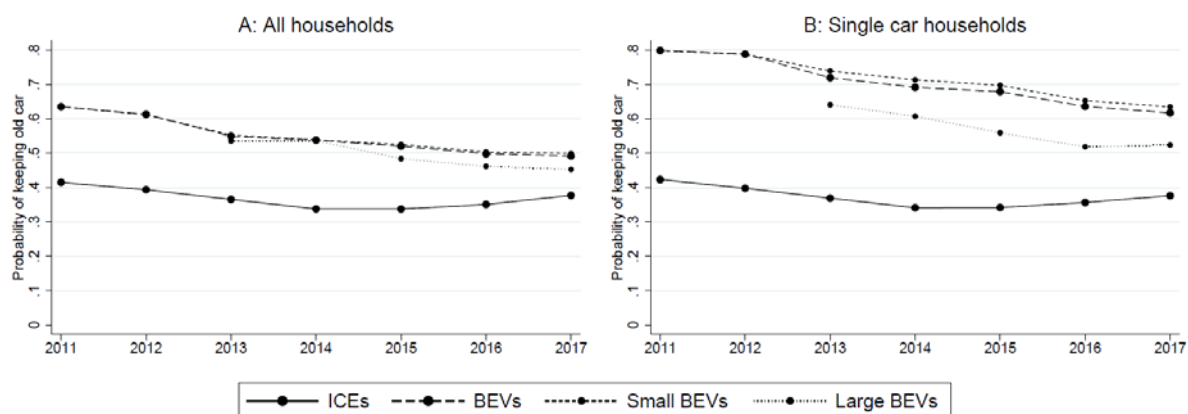
The adoption of the BEVs involves household decisions along a number of different margins. One important choice is the total number of cars owned and, in particular, whether a new BEV replaces an ICEV or not. Here we study this empirically at the household level within an event study framework. As households do not necessarily sell their old car at the same day as they purchase a new car, 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

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<sup>26</sup> An important difference, however, is that the share that owns two or more cars is substantially lower in Denmark.

car registration for the analysis, and track the car transaction(s) of the household within this period.

Our ambition is not to estimate a 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.



Note: Data include the most recent purchase from January 1<sup>st</sup> 2011 until July 1<sup>st</sup> 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. Observed proportion keeping the old car. By year of purchase and type of car acquisition.**

Figure 8 shows the share of the households that kept their old car(s), within the +/- 120 day 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 proportion of housing keeping existing car(s) can be explained by household characteristics that affect car consumption in general. The outcome of the linear probability

model is whether the household kept their old car or not.<sup>27</sup> As our main focus is the comparison between new BEV and ICEV buyers, we restrict the sample to households that have bought a new car in the period 2011-2017, and owned at least one car prior to the purchase. Over this period, 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. The final Model (3) has the following specification:<sup>28</sup>

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

and Models (1) and (2) are simplified versions where some of the parameters are restricted to zero. By interacting the BEV dummy with year dummies and household characteristics, we show how the effect of buying an electric vehicle on the probability of keeping the old one changes over time and across households.

Model (1) in Table 4 displays the estimated conditional 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, pp) that one-car BEV households in 2017 kept their car compared to an ICEV household. For households who buy a large BEV, there is a small negative coefficient suggesting that they are slightly more similar to ICEV buyers. For multicar households who buy a new car, however, there is no difference in the probability of keeping the old car among those who buy a BEV and those who buy ICEVs. This can be seen from the large negative coefficient of the interaction effect (-25.4 and -25.9 for two and three car households respectively), which completely outweighs the main BEV coefficient of 25.6. The positive

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<sup>27</sup> In this section 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 rather than a binomial logit model.

<sup>28</sup>  $y_i$  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;  $\gamma_{age}$  is age fixed effects for the oldest household member;  $\gamma_{inc}$  is income percentile fixed effects;  $\gamma_{car}$  is age fixed effects of the newest car owned; and finally  $\gamma_n$  is neighborhood fixed effects.

year\*BEV interactions indicate that compared to the main BEV effect in 2017, the difference between BEVs and ICEVs were even larger in the years preceding 2017.

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

	Sample share	(1)		(2)		(3)	
		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)
<u>BEV * initials cars (base one):</u>							
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)
<u>BEV* Year (base 2017):</u>							
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)
<u>BEV*Household char.:</u>							
BEV*Children	8.41 %					-3.05	(0.503)
BEV*Single	1.80 %					-11.2	(0.733)
BEV*Access 2 <sup>nd</sup> home	2.31 %					0.67 <sup>ns</sup>	(0.615)
<u>Common controls:</u>							
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 2nd home	14.2 %			4.20	(0.232)	4.10	(0.251)
Year dummies:		6		6		6	
Age dummies:		0		83		83	
Income percentile dummies:		0		99		99	
Car age dummies:		30		30		30	
Neighborhood dummies:		0		12,756		12,756	
Adjusted R <sup>2</sup>		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: <sup>ns</sup> 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 pp is partly explained by selection on household characteristics. In Model (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 households with similar characteristics (i.e. include household characteristics as controls in Model 2), the additional probability that a BEV buying one-car

household kept their car in 2017 drops down to 20.1 pp (from 25.6 pp). 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 Model (2).

Finally, in Model (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 pp 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.

## 5 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 studies. Such data from the country with the highest market share 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.

In this paper we show that socioeconomic characteristics are strong predictors of the car portfolio. In particular, battery electric vehicle (BEV) ownership is increasing in wealth, income and education. Households with kids and households living in large cities are more likely to own BEVs. While early BEV owners in particular differed from other car owners, over time BEV owners have become more similar to other car owners. We document a strong association between BEV ownership and BEV privileges on the travel to work (road toll

exemptions and bus lane access), where road toll 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, conditional on a rich set of socioeconomic characteristics.

Based on the multinomial logit models, we estimate the BEV ownership probabilities for different types of households. In households with children where both adults have tertiary education and are age between 25 and 44 years old, who live in a house located in the suburb of a larger city, we predict that four out of ten households own a BEV. Whereas for households without children at home, aged 45-64 years old, living in rural areas, less than high school education, just one employed adult and without road tolls on the travel to work, we predict the probability of BEV ownership to be 2% as of 2017.

For transport and environmental externalities, the degree of substitution between BEVs and ICEVs is vital. Using a simple event study 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 one-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 vehicle ownership and travel behavior.

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# Appendices

**Table A1. Car ownership and individual characteristics, single person households.**

*Average marginal effects (dP<sub>i</sub>/dX<sub>j</sub>)/P<sub>i</sub>.*

	No car		ICE		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 second home	-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***
<u>Immigrant</u>						
High income country	0.265***	0.158***	-0.213***	-0.177***	-0.271***	-0.006
Low income country	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***
<u>Selected educations</u>						
Car mechanics	-0.337***	-0.197***	0.282***	0.225***	0.008	-0.162
Technical, college	-0.074***	0.022	0.056***	-0.027*	0.176***	0.058
Technical, university	-0.001	0.053**	-0.002	-0.065**	0.078	0.240
Business/econ, college	0.001	0.005	-0.004	-0.007	0.097**	0.050
Business/econ, university	0.095***	0.098***	-0.082**	-0.116***	0.074	0.242***
<u>Travel to work char.</u>						
Distance 5-15K	-0.175***	-0.164***	0.142***	0.179***	0.129***	0.163***
Distance 15-100K	-0.259***	-0.241***	0.204***	0.262***	0.371***	0.329***
Distance >100 km	-0.189***	-0.168***	0.166***	0.199***	-0.245***	-0.412***
Road toll 1-25 kr	-0.022***	-0.052***	0.005	0.044***	0.430***	0.556***
Road toll 25-50 kr	0.081***	0.089***	-0.084***	-0.113***	0.513***	0.555***
Road toll>50kr	0.047***	0.056***	-0.065***	-0.097***	0.829***	1.34***
Bus lane	0.125***	0.126***	-0.104***	-0.138***	-0.034	-0.130***
<u>Employment sector</u>						
Government	-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 A2. Multinomial logit estimates. Car ownership. Couples.**

	No car	1 ICE	2 ICE	1 PHEV	1 BEV	2 BEV
Children		0.439*** (0.009)	0.551*** (0.009)	0.327*** (0.029)	0.619*** (0.021)	0.876*** (0.013)
<i>Economic resources</i>						
Income decile, male		0.083*** (0.002)	0.125*** (0.002)	0.266*** (0.006)	0.185*** (0.005)	0.237*** (0.003)
Income decile, female		0.040*** (0.002)	0.083*** (0.002)	0.116*** (0.006)	0.095*** (0.004)	0.125*** (0.003)
Wealth decile, male		0.077*** (0.001)	0.099*** (0.001)	0.115*** (0.004)	0.044*** (0.003)	0.087*** (0.002)
Wealth decile, female		0.069*** (0.001)	0.098*** (0.002)	0.125*** (0.005)	0.069*** (0.003)	0.107*** (0.002)
Detached house		0.485*** (0.008)	1.018*** (0.009)	0.632*** (0.029)	0.606*** (0.021)	1.258*** (0.015)
Access second home		0.020** (0.008)	0.209*** (0.009)	-0.052** (0.023)	0.147*** (0.018)	0.228*** (0.011)
<i>Region of residence</i>						
Suburbs of O/B/S/T		0.549*** (0.011)	1.021*** (0.012)	0.491*** (0.032)	0.416*** (0.023)	0.876*** (0.015)
Five other cities		0.547*** (0.012)	0.943*** (0.013)	0.461*** (0.038)	0.129*** (0.029)	0.602*** (0.018)
Other areas		0.861*** (0.01)	1.577*** (0.011)	0.585*** (0.032)	-0.223*** (0.027)	0.642*** (0.016)
<i>Immigrant</i>						
High income country, male		-0.019 (0.014)	-0.135*** (0.016)	-0.239*** (0.053)	-0.131*** (0.035)	-0.215*** (0.023)
Low income country, m		-0.131*** (0.017)	-0.195*** (0.019)	-0.561*** (0.083)	-0.053 (0.043)	-0.016 (0.03)
Immigrant parents, male		-0.112*** (0.031)	-0.194*** (0.037)	-0.094 (0.124)	0.493*** (0.058)	0.209*** (0.048)
High income country, f		-0.021 (0.014)	-0.065*** (0.015)	-0.172*** (0.049)	0.025 (0.033)	-0.042** (0.021)
Low income country, f		-0.131*** (0.016)	-0.499*** (0.018)	-0.334*** (0.066)	-0.053 (0.039)	-0.322*** (0.027)
Immigrant parents, f		0.039 (0.031)	-0.071** (0.035)	0.16 (0.116)	0.517*** (0.058)	0.250*** (0.047)
<i>Education</i>						
Secondary, male		0.104*** (0.01)	0.103*** (0.01)	0.263*** (0.032)	0.234*** (0.027)	0.254*** (0.016)
Tertiary, male		-0.141*** (0.011)	-0.434*** (0.012)	-0.029 (0.036)	0.078*** (0.029)	0.016 (0.017)
Secondary, fem		-0.013 (0.011)	0.142*** (0.011)	0.096*** (0.034)	0.214*** (0.029)	0.295*** (0.017)
Tertiary, female		-0.123*** (0.011)	-0.128*** (0.011)	0.002 (0.033)	0.220*** (0.028)	0.244*** (0.017)
Age 25-44, male		0.625*** (0.021)	0.881*** (0.026)	1.313*** (0.203)	0.482*** (0.076)	1.286*** (0.085)
Age 45-64, male		0.759*** (0.024)	1.334*** (0.029)	1.358*** (0.207)	0.381*** (0.081)	1.537*** (0.087)
Age 65-74, male		1.274*** (0.03)	1.634*** (0.034)	1.887*** (0.211)	0.454*** (0.094)	1.600*** (0.09)
Age 75+, male		1.043*** (0.034)	1.089*** (0.039)	1.343*** (0.218)	0.169 (0.117)	1.109*** (0.101)
Age 25-44, female		0.332*** (0.017)	0.500*** (0.02)	0.374*** (0.104)	0.223*** (0.055)	0.797*** (0.05)
Age 45-64, female		0.477*** (0.022)	0.866*** (0.024)	0.477*** (0.111)	0.219*** (0.062)	0.983*** (0.053)
Age 65-74, female		1.048*** (0.029)	1.152*** (0.031)	1.165*** (0.12)	0.529*** (0.083)	1.141*** (0.061)
Age 75+, female		0.364*** (0.033)	-0.004 (0.036)	0.118 (0.136)	0.058 (0.111)	0.012 (0.083)
<i>Selected education</i>						
Car mechanics, male		0.365***	1.115***	0.176	-0.032	0.850***



	(0.045)	(0.044)	(0.129)	(0.105)	(0.052)
Car mechanics, female	0.115	0.630**	0.965	0.314	0.580*
	(0.292)	(0.284)	(0.639)	(0.567)	(0.343)
Technical, col., male	0.199***	0.394***	0.270***	0.320***	0.545***
	(0.019)	(0.019)	(0.046)	(0.036)	(0.023)
Technical, univ., male	0.110***	0.204***	0.067	-0.021	0.289***
	(0.03)	(0.031)	(0.071)	(0.056)	(0.036)
Business/econ, col., m	-0.183***	-0.105***	-0.124***	0.071**	-0.063***
	(0.017)	(0.018)	(0.046)	(0.033)	(0.022)
Business/econ, univ., m	-0.202***	-0.330***	-0.164**	-0.06	-0.174***
	(0.025)	(0.028)	(0.069)	(0.047)	(0.033)
Technical, col., female	0.024	0.118**	0.151	0.058	0.114*
	(0.048)	(0.05)	(0.123)	(0.09)	(0.058)
Technical, univ., female	0.019	-0.134*	-0.202	-0.143	-0.089
	(0.065)	(0.071)	(0.172)	(0.116)	(0.078)
Business/econ, col., f	-0.029	0.005	0.016	0.054	0.032
	(0.018)	(0.019)	(0.048)	(0.034)	(0.022)
Business/econ, univ., f	-0.080***	-0.245***	-0.066	-0.086*	-0.127***
	(0.027)	(0.03)	(0.076)	(0.05)	(0.035)
<i>Travel to work</i>					
<i>characteristics, distance</i>					
5-15K, male	0.256***	0.587***	0.276***	0.277***	0.585***
	(0.014)	(0.014)	(0.038)	(0.03)	(0.019)
15-100K, male	0.288***	0.863***	0.285***	0.430***	0.940***
	(0.016)	(0.017)	(0.044)	(0.034)	(0.021)
>100 km, male	0.164***	0.797***	0.082	0.029	0.371***
	(0.027)	(0.027)	(0.074)	(0.055)	(0.034)
5-15 km, female	0.179***	0.582***	0.153***	0.281***	0.566***
	(0.014)	(0.014)	(0.035)	(0.029)	(0.018)
15-100 km, female	0.175***	0.818***	0.218***	0.438***	0.806***
	(0.017)	(0.018)	(0.045)	(0.035)	(0.022)
>100 km, female	0.017	0.635***	-0.109	-0.183***	0.076*
	(0.033)	(0.034)	(0.102)	(0.07)	(0.045)
<i>Travel to work</i>					
<i>characteristics, other</i>					
Road 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)
Road 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)
Road toll>50kr, male	0.012	-0.256***	0.124**	0.431***	0.389***
	(0.021)	(0.022)	(0.055)	(0.039)	(0.025)
Road toll 1-25 kr, f	0.192***	0.035*	0.095*	0.366***	0.445***
	(0.021)	(0.021)	(0.052)	(0.038)	(0.025)
Road toll 25-50 kr, f	-0.083***	-0.418***	-0.091**	0.148***	0.023
	(0.017)	(0.018)	(0.045)	(0.032)	(0.021)
Road toll>50kr, female	0.041*	-0.281***	0.053	0.480***	0.469***
	(0.025)	(0.026)	(0.067)	(0.044)	(0.03)
Bus lane, m	-0.193***	-0.423***	-0.223***	-0.139***	-0.339***
	(0.012)	(0.013)	(0.034)	(0.024)	(0.016)
Bus lane, f	-0.154***	-0.415***	-0.195***	-0.176***	-0.355***
	(0.013)	(0.014)	(0.036)	(0.026)	(0.017)
<i>Employment sector</i>					
Government, 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)
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)
Constant	-2.046***	-4.404***	-8.675***	-6.004***	-8.593***
	(0.028)	(0.033)	(0.208)	(0.087)	(0.091)

Note: Reference category; Non-immigrant couple, in Oslo/Bergen/Trondheim/Stavanger, less than high school, aged 18-24, both employed in private sector with travel to work distance <5 km, no road toll nor bus lane.

**Table A3.**  
**Multinomial logit**  
**estimates. Single**  
**person**  
**households.**

	No car		ICE		BEV	
	Male	Female	Male	Female	Male	Female
Children			1.114*** (0.014)	0.572*** (0.009)	1.588*** (0.029)	0.929*** (0.026)
<u>Economic resources</u>						
Income decile			0.154*** (0.001)	0.202*** (0.002)	0.256*** (0.005)	0.243*** (0.006)
Wealth decile			0.141*** (0.002)	0.139*** (0.001)	0.130*** (0.004)	0.012*** (0.005)
Detached house			0.640*** (0.006)	0.678*** (0.006)	0.833*** (0.023)	0.933*** (0.026)
Access second home			0.255*** (0.008)	0.249*** (0.007)	0.526*** (0.022)	0.506*** (0.025)
<u>Region of residence</u>						
Suburbs of O/B/S/T			0.680*** (0.009)	0.777*** (0.009)	0.472*** (0.027)	0.517*** (0.03)
Five other cities			0.608*** (0.01)	0.726*** (0.01)	0.026 (0.035)	0.005 (0.039)
Other areas			0.874*** (0.008)	0.972*** (0.008)	-0.218*** (0.029)	-0.326*** (0.033)
<u>Immigrant</u>						
High income country			-0.628*** (0.01)	-0.456*** (0.012)	-0.722*** (0.042)	-0.280*** (0.047)
Low income country			-0.510*** (0.011)	-0.884*** (0.014)	-0.507*** (0.049)	-0.488*** (0.051)
Immigrant parents			-0.399*** (0.022)	-0.390*** (0.024)	0.409*** (0.054)	0.172** (0.068)
<u>Education</u>						
Secondary			0.101*** (0.007)	0.243*** (0.008)	0.267*** (0.027)	0.391*** (0.034)
Tertiary			-0.238*** (0.009)	0.044*** (0.008)	0.252*** (0.031)	0.504*** (0.033)
Age 25-44			-0.159*** (0.009)	-0.323*** (0.01)	-0.368*** (0.036)	-0.694*** (0.042)
Age 45-64			0.008 (0.01)	0.141*** (0.011)	-0.580*** (0.039)	-0.539*** (0.046)
Age 65-74			0.319*** (0.014)	0.221*** (0.013)	-0.794*** (0.058)	-0.989*** (0.063)
Age 75+			-0.193*** (0.014)	-0.937*** (0.013)	-1.322*** (0.072)	-2.377*** (0.078)
<u>Selected education</u>						
Car mechanics			0.877*** (0.034)	0.575*** (0.179)	0.646*** (0.083)	0.191 (0.602)
Technical, college			0.179*** (0.016)	-0.067* (0.04)	0.295*** (0.041)	0.018 (0.11)
Technical, university			-0.002 (0.031)	-0.159** (0.072)	0.078 (0.069)	0.129 (0.162)
Business/econ, college			-0.006 (0.017)	-0.016 (0.016)	0.094** (0.044)	0.042 (0.047)
Business/econ, university			-0.236*** (0.029)	-0.294*** (0.031)	-0.08 (0.068)	0.05 (0.075)
<u>Travel to work, characteristics, distance</u>						
5-15 km			0.423*** (0.012)	0.458*** (0.012)	0.417*** (0.038)	0.443*** (0.039)
15-100 km			0.627*** (0.014)	0.677*** (0.014)	0.777*** (0.041)	0.731*** (0.044)
>100 km			0.469*** (0.023)	0.484*** (0.028)	-0.001 (0.064)	-0.294*** (0.089)
<u>Travel to work characteristics, other</u>						
Road toll 1-25 kr			0.041**	0.136***	0.453***	0.603***

	(0.017)	(0.018)	(0.041)	(0.047)
Road toll 25-50 kr	-0.218***	-0.275***	0.346***	0.354***
	(0.015)	(0.016)	(0.037)	(0.043)
Road toll>50kr	-0.144***	-0.201***	0.616***	0.862***
	(0.019)	(0.022)	(0.045)	(0.052)
Bus lane	-0.310***	-0.368***	-0.245***	-0.364***
	(0.011)	(0.012)	(0.029)	(0.034)
<i>Employment sector</i>				
Government	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)
Constant	-1.788***	-2.517***	-5.622***	-5.849***

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.