NTNU

Master thesis

The Norwegian Electric Car Controversy

- the arguments and some empirical illustrations

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PREFACE

This master's thesis marks the completion of a five-year education in economics and the end of five wonderful years at NTNU, Trondheim.

Several persons have contributed to this master's thesis. First, I would like to thank my head supervisor, Professor Anders Skonhoft and co-supervisor, Associate Professor Jan Morten Dyrstad for their time and constructive feedback throughout the process.

I would also like to extend a big thank you to James Odeck at the Norwegian Public Road Administration, who invited me to work with them on this master's thesis and who proposed the topic of electric vehicles.

I would also like to thank my co-students at NTNU for a social and fun time throughout my five years in Trondheim. It has been a pleasure to be part of such a friendly and competent group of people.

And finally, a special thanks to my parents, Anne Line and Thor Olav, for valuable input, and to my two brothers, Sigvart and Johannes, for moral support and great banter.

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ABSTRACT

In this master's thesis I have reviewed and discussed some of the arguments made in the Norwegian EV policy debate. Further, I have applied binary choice models on a cross-sectional data set of 1,722 Norwegian EV-owners, to shed some light on certain research questions raised by economists in the field.

The highlighted questions in this master's thesis include to what extent the policy has stimulated the EV being an additional car to the household, and have EV privileges had any significant effect on EV owners' propensity to drive more or use less public transport after acquiring an EV.

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1 Introduction

Electric Vehicles (EVs) are considered to be an environmental friendly substitute to the conventional petrol or diesel motorised car, and the Norwegian government has stimulated both EV purchases and usage, with the aim to reduce greenhouse gases (GHG). As a result, EVs have become increasingly popular in Norway over the last decade. Norwegians have the highest EV per capita count, and the sales are growing by the year. It is especially in and around the larger cities that car owners have made the investment. Previous studies have suggested that users are young, highly educated and with a car already in the garage (Hjorthol, 2013) .

To achieve increased use of EVs, the incentives range from subsidized purchase price to privileges given through free toll roads, free parking, and access to bus lane. Norway does not have its own production of EVs, but through government policies and subsidises, they have managed to keep the import price at a competitive level to conventional cars. EVs are powered by electric energy, and with Norway having most of its electric energy produced from renewable sources such as hydropower, Norway has an advantageous position when it comes to using EVs as a mean to reduce emission of GHG.

The government's support to EV owners has created a heated debate in the research environment onto what extent this policy has been successful. How beneficial are in fact EVs to the environment and do the arguments for policy interventions hold in a cost-benefit analysis, are questions that have been raised. The participants in the debate have not provided a clear answer to these questions; rather the contrary, it is fair to say that the debate has revealed contrasting views on the achievements of the EV policy.

In this master's thesis I will present the debate and provide some empirical illustrations of key questions of the discussion. Through reviewing earlier literature and reports on the EV policy, some important aspects of the debate are highlighted. For the empirical part, I will use a survey conducted among EV users, provided by the Institute of Transport Economics (TØI). This is a cross-sectional data set, which will be used to examine some pivotal arguments raised in the debate.

One question is to what extent the Norwegian car policy schedule makes households convert from conventional car ownership to having EVs only, or if it results in the EV being just an additional car in the household's car park. Other key questions are whether EV owners, given the incentives that reduce driving costs, drive more and use less public transport. Thus, in the empirical part, I will investigate to what extent the policy incentives are associated with i) only owning EVs; ii) increased driving after acquiring this type of car; and iii) to what extent it results in reduced use of public transport.

The data I have had available for this study does not provide clear-cut answers to the questions raised; the ambition here is nevertheless to shed light on some of the main point in the dispute by these empirical illustrations.

The master's thesis is divided into nine sections. In Section 2, I give an introduction to the characteristics of the Norwegian EV market, and give a presentation of the EV privileges. Main theories behind the EV policy are presented in Section 3, including the reasoning behind the treatment of a good with new technology and network externalities. In 4, I highlight some of the main controversies of the EV discussion, among Norwegian and international researchers, and give an introduction to my empirical illustrations. In Section 5 and 6, I describe and discuss the data set and the methods of estimation that will be applied in my empirical investigation. Results are presented in Section 7, whereas results are connected to the controversies concerning the EV policy in Section 8.

2 Policy interventions

2.1 Norway as an EV-nation

Over the last two decades, Norway has become a leading nation in terms of establishing EV policies that stimulate sales and market shares of EVs. Within a short time span, Norway has set the stones for an electrification of the car pool and surpassed nations that produce EVs. Instead of penalising those that drive petrol or diesel cars, the government decided to reward EV-drivers with a range of beneficial goods and economic gains to stimulate this type of conveyance.

Besides EV purchase being subsidised, relative to other types of cars, by exemption of the large registration fees normally applying in Norway and the VAT, privileges include free parking in the inner city, exemptions of fees on ferries and toll roads, access to bus lanes, reduced annual vehicle licence fee and financial support for charging stations.

2.1.1 EV in numbers

Having the largest number of EVs per capita, Norway has been named the world's EV nation with Oslo as the EV capital city of the world.

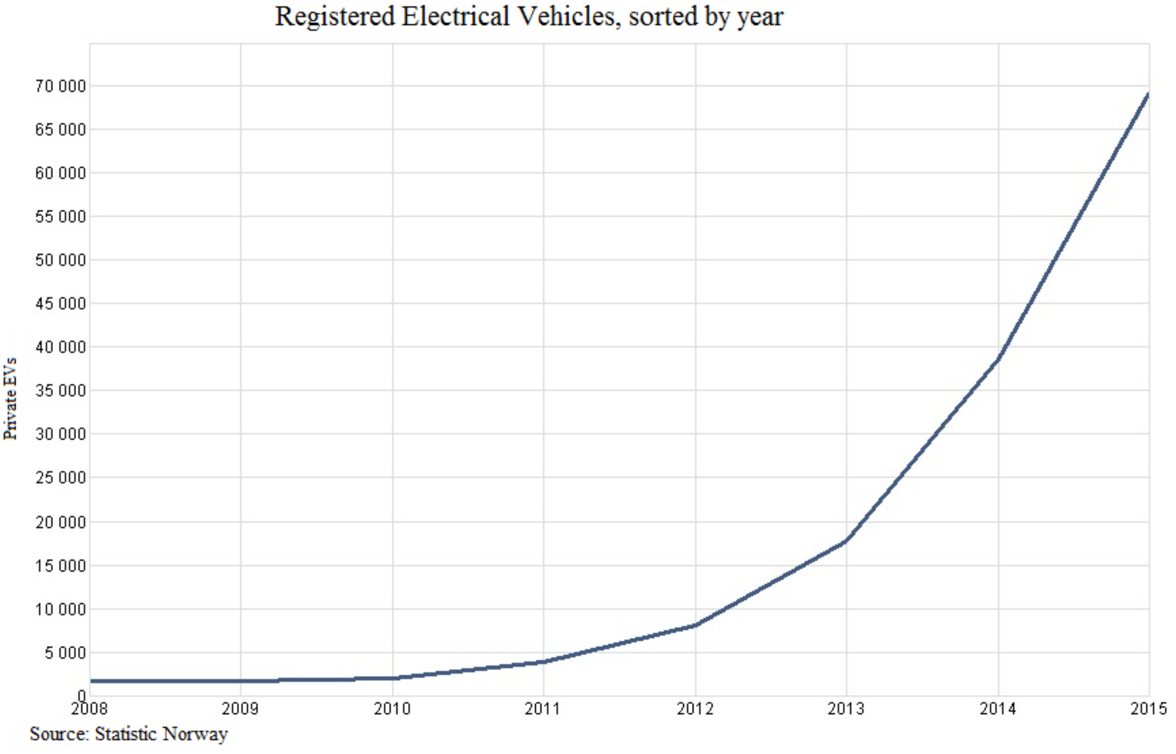

Figure 2-1: Registered vehicles by year, 2008-2015.

Figure 2-1 shows how the number of registered EVs has had an exponential growth in recent years. Despite Norway being a small country, 6.1 percent[1] of all EVs worldwide was located in Norway in 2014 (Global EV Outlook, 2015).

According to OFV[2], there were 25 788 newly registered EVs in Norway in 2015, which is a growth of 42.5 percent from the year before (OFV, 2016a). EVs had a market share of 18.7 percent in terms of newly purchased vehicles in March 2016 (OFV, 2016b).

Out of the 2.53 million cars in the Norwegian car pool at the end of 2015, about 2.6 percent were electric, as shown in figure 2-2, compared to 0.08 percent worldwide in 2014 (Global EV Outlook, 2015).

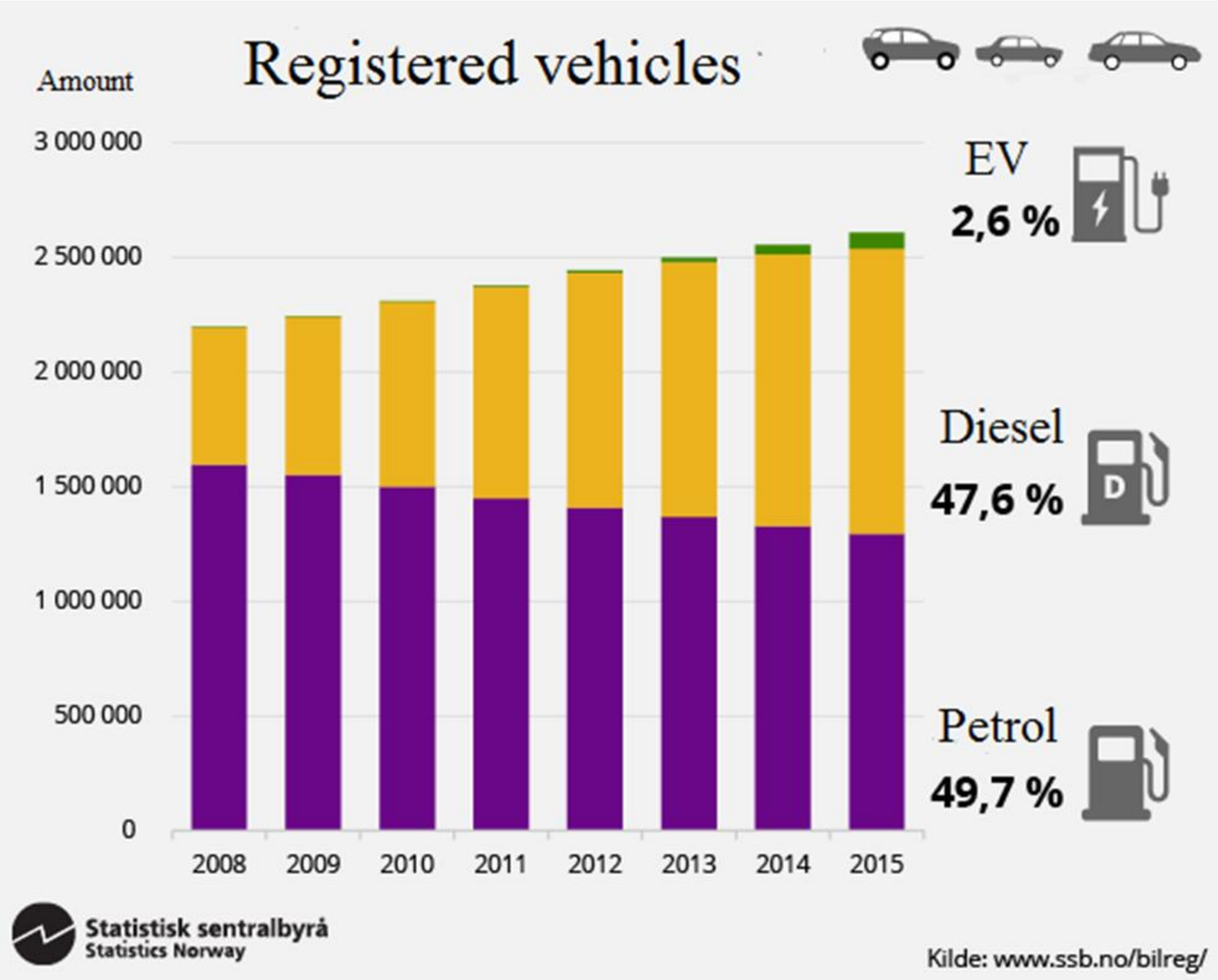

Figure 2-2: Registered vehicles in Norway by type in years 2008-2015. Adopted by SSB[3].

[1] 40,887 out of 665,000 EVs in total
[2] Opplysningsrådet for veitrafikk (Information Bureau for Road Traffic).
[3] Statistics Norway

These figures reflect that Norway is one of the leading EV nations. In the report "Handlingsplan for elektrifisering av veitransport, 2008" (Ministry of Transport and Communication, 2009), a ten percent market share as of 2020 was proposed by the government, which forms the future goal of the policy. According to NEVA[4], growth in sales is predicted to stabilise in 2016 (NEVA, 2015).

2.1.2 Exemptions from taxes

Every new vehicle registered in Norway is due to a one-time payment. The fee is based on vehicles specifications such as the type of vehicle, weight, motor power and CO^2-emission. The fee amounts to a large share of the retail price. EV owners are exempted from this fee, as well as paying the VAT (25 percent of the goods value).

EV owners are also privileged in the sense that they pay a reduced yearly fee. Where owners of petrol motorised and diesel motorised vehicles pay 3135 and 3655 NOK per year, respectively, EV owners only have to pay 445 NOK (NTA[5], 2016).

2.1.3 Lower operating costs

It is favourable to drive an EV in Norway compared to other types of cars. The low operating cost of EVs can be illustrated with a numerical example. Tesla Model S is one of the most popular EVs in Norway, and consumes approximately 24 kWh per 100 kilometres (U.S. Department of Energy, 2016). It is reasonable to assume a cost of 0.75 NOK kWh for a representative household, which will give the price of 18 NOK per 100 kilometres.

The low operating cost of EVs becomes evident when compared to the operating cost of a representative petrol car. Assuming that a conventional car consumes 7 litres of fuel per 100 kilometres, priced at 13 NOK per litre, the operating cost of conventional cars amount to 91 NOK per 100 kilometres. These calculations suggest that the operation cost per 100 kilometres for EVs is five times lower than for conventional cars. Moreover, does the comparison not account for the other costs that conventional cars are exposed to, such as toll roads and parking.

[4] Norwegian Electric Vechicle Association (Elbilforeningen)
[5] Norwegian Tax Administration

2.1.4 Phasing out the incentives

EVs low operating cost and favourable policies are considered the main reasons for Norway having such a high number of EVs per capita. The generous EV policies have been gradually implemented over the last 15 years and have been integrated in “Klimaforliket”, which is a political conciliation that was made to specify and enhance efforts to improve the environment (Ministry of Climate and Environment, 2012). Figure 2-3 shows the year the different incentives were introduced, together with the developments in sales from 1997 to 2013.

The cost of running these favourable policies has mounted as the number of EV units has grown, and, as a consequence, the Norwegian government has been forced to phase out some of the incentives.

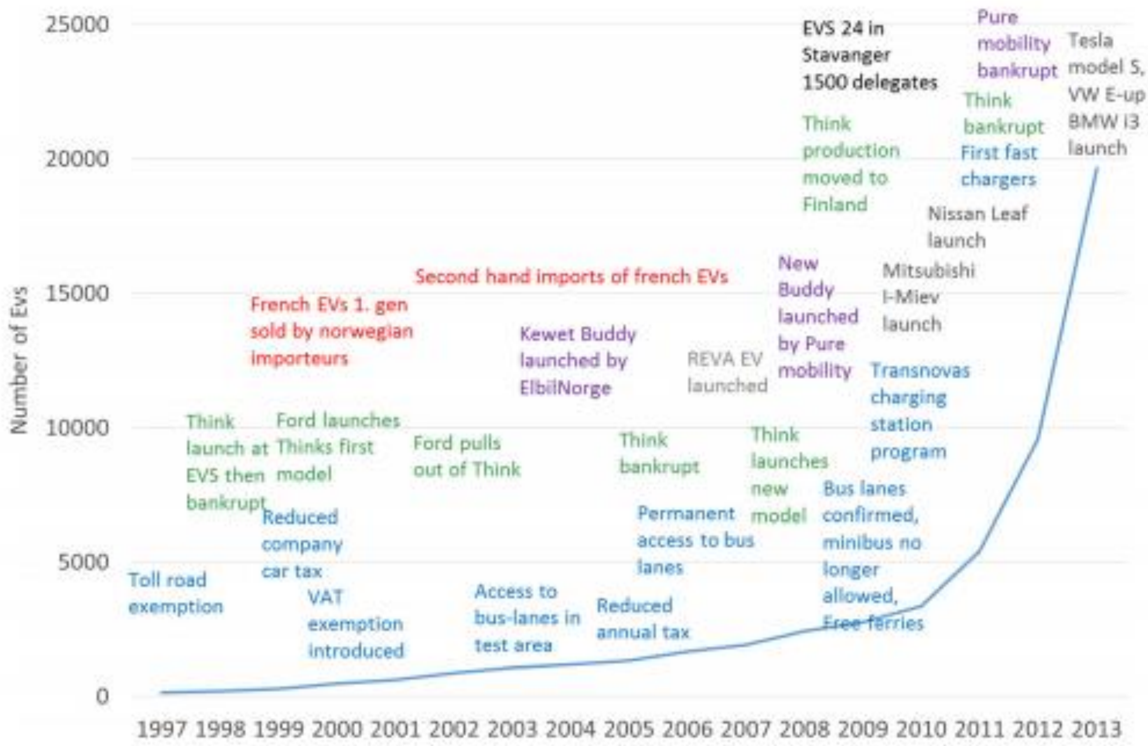

Figure 2-3: Development in incentives and the supply market combined with EV sales in the years 1997-2013. Adopted from Bonnema et al. (2015).

As of November 2015, there were 210 toll gates in Norway financing 60 projects, and these gates all have the goal to accelerate the development of road infrastructure (Norwegian Public Road Administration, 2016). Up until May 2015, EVs freely passed through, but in May, there was an agreement between the Government and their coalition partners to diminish this type of support. It is no longer decided at the national level to what extent EVs pay toll fees, but it is determined by the county authorities.

The Government has also made it more practical to drive EVs, through tailoring the traffic and making it more EV friendly. This includes access for EVs to bus lanes, which has been especially popular in Norway's larger cities and their respective suburbs.

One of the locations where EV owners have enjoyed this benefit is the road Ring 3 around Oslo and E18 from Vækerø to Filipstad, where there have been periods with up to 85 percent of the vehicles in the bus lane being EVs (Norwegian Public Road Administration, 2014). In May 2015, it was decided that EVs were denied access to bus lanes in rush hours, unless there are two or more persons in the car (Dagens Næringsliv, 2015a).

2.2 EV as an instrument in Norwegian climate politics

In the Government's plan of action to electrify road transportation from 2009, they announced the Norwegian authorities' ambitions to have four percent of the car population electrified by 2015, and increasing it to ten percent by 2020 (Norwegian Ministry of Transportation and Communication, 2009). If successful, this will have large impacts on the Norwegian infrastructure, and it will affect power usage and emission of GHG. One negative consequence is that it may also lead to reduced public revenue, in particular if the current policies are kept unchanged after the planned revision in 2017.

Jørgensen et al. (2010) have made predictions on the effect of the EV expansions on the economy. The prognoses for year 2020 are presented under the assumptions that EV technology has improved to the extent that the range for EVs matches that of conventional cars. This means that the reduction in driving performed by conventional petrol cars corresponds directly to the rise in driving done by EVs, with EVs having fully replaced conventional cars. EVs will then provide ten percent of the total driven kilometres in Norway in 2020.

The ten percent equals approximately 3.5 billion kilometres in total, which according to Jørgensen et al. (2010), means that the entire electric car pool needs approximately 0.53 TWh each year. However, this only represents an approximately 0.44 percent rise in the national power usage, assuming that an EV requires 15 kWh to travel 100 kilometres. The power usage will amount to about ten percent of an average household consumption in Norway, which likely the national power grid can handle, according to Jørgensen et al. (2010).

Jørgensen et al. (2010) predict that EV's entry into the market will in 2020 give a reduction in national GHG-emission of 441,000 ton of CO^2. Such a reduction in emission of CO^2 corresponds to 0.8 percent of the total Norwegian emission in 2014 (SSB, 2015). The yearly public budgetary cost, given no changes in economic policies for EVs in 2017, is estimated to be approximately 4 billion NOK (Jørgensen et al.) in 2020, which would mean that the cost of reducing 1 ton of CO^2 emission will be 9,070 NOK.[6] This is a high emission cost, which suggests that using EVs as a mean to reduce emission of CO^2 is fairly expensive.

[6] 4,000,000,000/441,000

3 Externalities and the intervention arguments

3.1 Forming an EV policy

Before I present some of the main arguments of the Norwegian EV debate, I present the main theoretical public economics reasoning behind the EV policy.

Holland et al. (2015) have listed factors to be considered when deciding on EV tax or subsidy levels. Subsidises should reflect the total benefit to the economy. When stimulating EVs sales there might be intricate benefits or losses that must be taken into account when deciding the level of public involvement, which the debate in Norway may also reflect. For example, there might be technological response to subsidising EVs that help justify the grant.

By making EVs more attractive and hence more consumed, it will indirectly influence the individual demand for EVs in all foreseeable future, and this is an additional consideration that involves the dynamics of networking. Greaker and Midttomme (2014) developed a model with a network effects with one “dirty” and one “clean” good, and applied it to the Norwegian car market. One result was that the optimal tax not only should account for the damages inflicted by consuming the good, but also the change in probability for other individuals to consume the good. I will return to this shortly, in Section 3.2.

It is not obvious how emissions from EVs should be accounted for. The electricity used by EVs may have been produced far away from where the vehicle is actually driven, and the emission are traced back to where the electricity production took place. In contrast, the emission from conventional cars follows the car. This is important because there might be large discrepancies in emission from one EV to another, despite being used in the same area. This creates a challenge when determining the appropriate taxation or subsidies.

In an experiment by Holland et al. (2015) in the US, it was found that 91 percent of local pollution damages associated with EVs was transferred to a different state than the EV is driven. In comparison, 18 percent is exported by conventional vehicles. This raises an argument for having a centralisation of the tax-setting, to ensure that policies and taxes account for the damages that also occur outside local government’s jurisdictions.

Another consideration is that EVs can generate benefits through less reliance on oil and insulation from oil price shocks. Norway has been severely affected by the reduction in the oil price in 2015, especially in areas where oil production is a big part of the economy and infrastructure.

3.2 Network externalities

Optimal governmental policies also depend on the networking effect. EV is an example of a good that has network externalities. This means that the good's value is affected by the number of consumers (Moen and Riis, 2011, p. 226). In the case of EV, additional consumers can give authorities incentives to build supplementary charging stations, which in turn will make EVs more attractive and raise demand. This means that for every EV that is sold, there might be a utility gain not only for the purchaser, but for all existing users through external effects.

The idea that joining a network leads to benefits for all participants in the network became popular in economic literature in mid 1980s by contributions such as Katz and Shapiro (1985). Lopoatka and Page (1999) mentioned the old telephone or fax machine as classical network goods. These types of goods have the impact of additional users internalised to a great degree, where the value of being the sole user is extremely low, but it may also apply to EVs.

3.2.1 Characterisations of a networking good

When examining networking goods, we assume that not only price (*P*) impacts the demand, but also how many that already own that good (*n*), and we also include a vector *X* which is a set of other variables which influence demand. For an individual *j*, demand can then be written as

$$EV_j = d_j(\overset{\div}{P}, \overset{+}{n}, X) \tag{4.1}$$

For EVs, examples of the *X* variables can be EV privileges, commercials or trends.

The first consumers may have a willingness to pay that is lower than the actual price, as the Figure 3-1 displays, but they might have expectations of a higher level of utility in the future (Moen and Riis, 2011, p. 228). Since information on potential buyers' is always imperfect, there is no guarantee to get returns on the investments in the future (Lopoatka and Page, 1999).

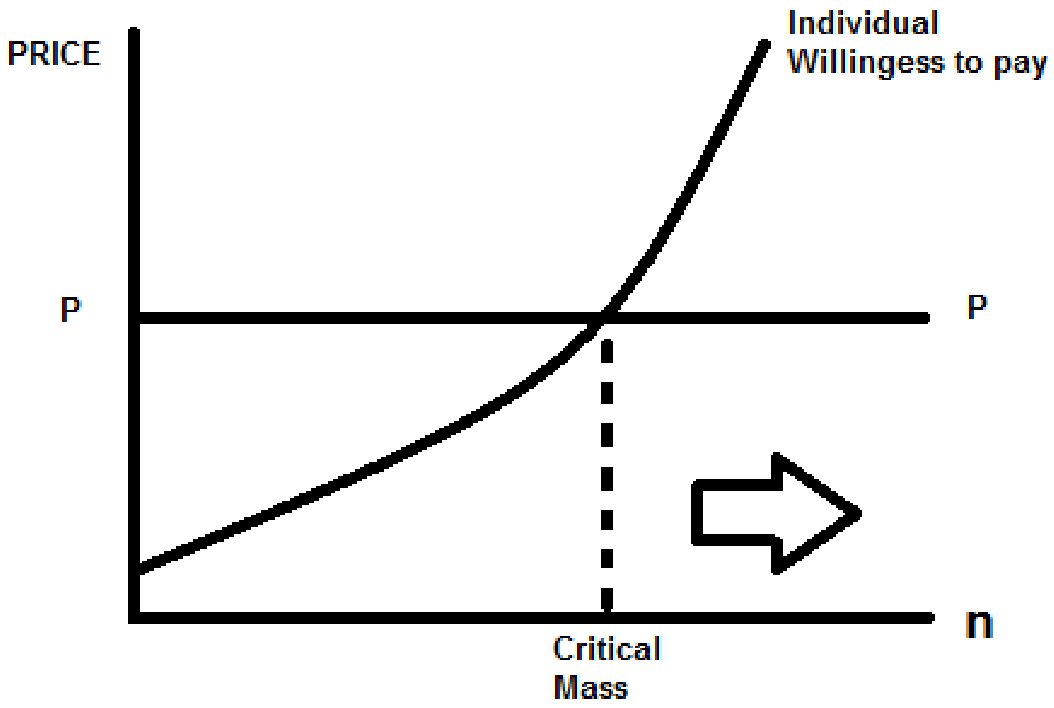

Figure 3-1: Willingness to pay for a good with network externalities

As Figure 3-1 shows, there is an amount of sold units where the willingness to pay exceeds the price level. This intersect is called the critical mass, and beyond this point more individuals will consume the good, which in turn will further increase the gain for others by increasing the demand for EV infrastructure. (Moen and Riis, 2011, p. 229)

3.1.2 EV as a networking good

The networking benefits of EVs in Norway have been many. There have been large investments in charging stations (Ministry of Transport and Communications, 2009), both publicly and privately financed, to meet the increasing demand for them. It has been established unions and organisations of interest, like NEVA, that have great impact on political decisions through lobbying and media presence. Unions of interest are just one of the many benefits of a big market mass.

There are also aspects of the expansion that can have a negative effect on individual demand for EV. Having a growing stock of EV can cause more traffic, especially if EVs are not replacing conventional cars. The issue to traffic is levitated, if having an EV stimulates to less driving, but this is suggested by Figenbaum et al. (2014), not to be the case. Traffic congestion is a negative externality of the EV expansion, which the Norwegian government has addressed through giving EVs access to bus lanes. As this privilege will be phased out in the future and with more EVs on the road, it might cause EV consumptions by others to have a negative effect on individual willingness to pay.

This suggest that there is a level of EV consumption that causes the $d_j\,'$ to be negative with respect to n in (4.1) Whether the growth in the EV stock in Norway has reached its maximum is however unclear at the time of writing.

3.3 More on introductions of new technology

How do we see new technology diffuse in the population? Not all individuals in a society adopt new technology at the same time. Rather than establishing a timeline, Rogers (1983) differentiated between five groups of adopters, who were characterised by their socio-economic status, personality and also communicative behaviour.

The first group of adopters of new technology were named “Innovators” by Rogers. To these people, boldness is almost as an obsession, and they are always eager to try new ideas and technologies. In a study by Figenbaum et al. (2014), “Innovators” are defined as individuals with EV(s) as their only vehicle or “pure EV household”. They were estimated to make up for only 3 percent of the car owners, as shown in Figure 3-2, which was based on a survey among NAF-members in Norway from 2014.

The second group of adopters has Rogers named “Early Adopters”. Early Adopters are often more integrated in the society than Innovators, and are considered leaders and role models to a greater degree. Figenbaum et al. (2014) defined this group as individuals with both EV(s) and conventional car(s), and they amounted to 10 percent of the car owners.

The third group was called “Early Majority”, characterised by adopting technology right before the average member of society. Members of this group are often interacting with their peers, but do not have leadership qualities themselves. Figenbaum et al. (2014) define this group as car owners who are considering buying an EV the next time they buy a vehicle. This s a relatively large group, around 30 percent.

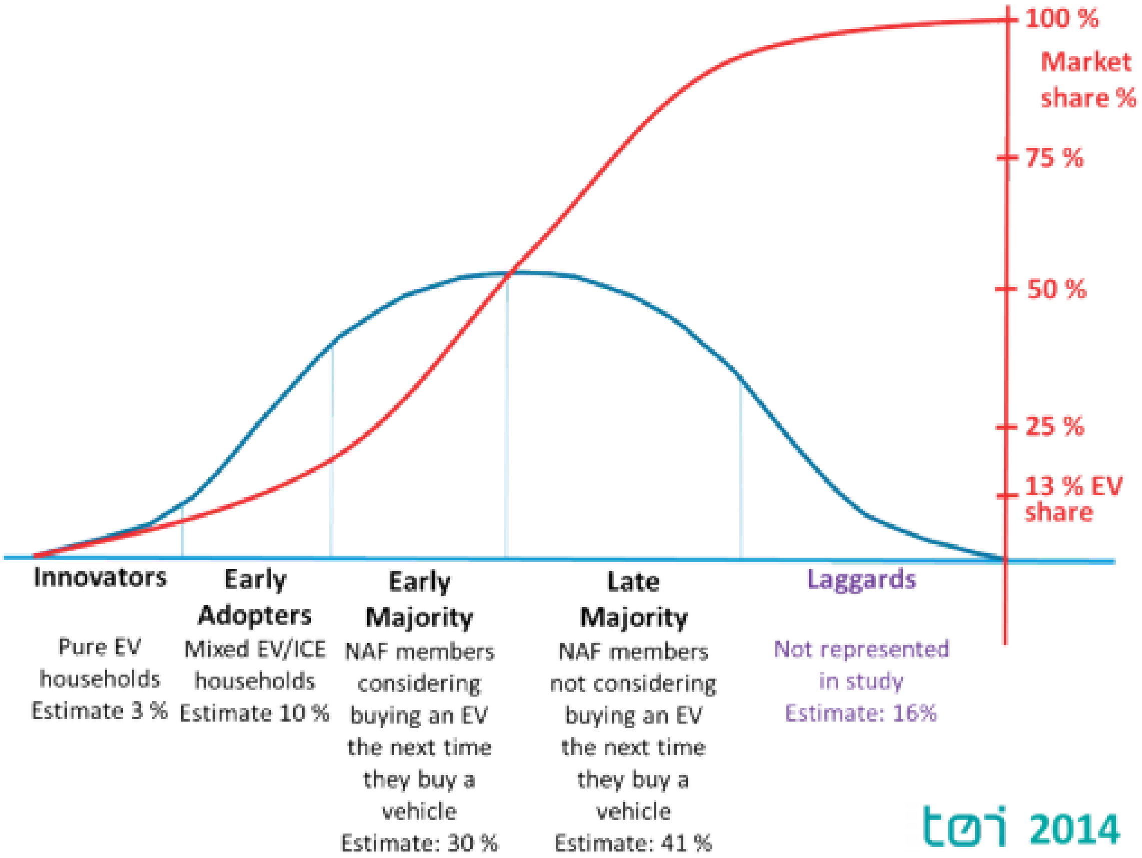

Figure 3-2: Vehicle purchase groups in Norway and market share. Blue line denotes successive groups consumers that adopt EV and red line denotes the market share of EV compared to total vehicle market. Adopted from Figenbaum et al. (2014, p. 104).

The fourth group was named "Late Majority", and members of this group were adopting technology by following the average member. To them, adoptions are either an economic necessity or the answer to network pressure. They are not easily persuaded, and often require that most of their social group have already made the adoption before they do. Figenbaum et al. (2014) defined this group as individuals who were not considering EV the next time they buy a vehicle. They are important because they make up such a large part of the population, estimated to 41 percent by Figenbaum et al. (2014).

The last group has Rogers named "Laggards". Individuals in this group are the last to adopt innovations, and they are characterised by being socially isolated, tradition-oriented and often low on resources. Laggards are so suspicious of new technology, that when they finally decide to react, it may have been replaced by even more recent ideas. Figenbaum et al. (2014) estimated this group to 16 percent.

According to Figenbaum and Kolbenstvedt (2015), the early adopters were crucial when the Norwegian car park was going to be electrified. The early adopters were consisting of relatively young men, with high education and income. The majority lived in or close to large cities, where the EV incentives were most profitable.

Figenbaum and Kolbenstvedt (2015) also emphasised the effects of networking in the EV diffusion. In their study, 40 percent of EV owners in Oslo had friends who already had purchased an EV and 36 percent had friends who considered doing so. This could be an important reason for the expansionary growth in areas with large population density.

4 A controversial policy

As a newcomer to this field, one is struck by the lack of agreement among Norwegian economists regarding the success of the EV policy. In this Section I will present some of the controversies found in the literature. In the empirical part of the thesis, I will follow-up on some of the aspects of the debate, and my research questions are introduced at the end of this Section.

4.1 Debate on EV emission

Holtsmark and Skonhoft (2014) argue that the amount of resources spent to make consumers choose EVs do not add up from a social economic perspective. On the basis that the Government keeps the current EV policies, Skonhoft and Holtsmark estimate a cut of 43 000 ton of CO^2 every year. This is a small fraction of the total emission, which was around 52 million ton of CO^2 back in 2013. Holtsmark and Skonhoft used data from Statistic Norway in their calculations.

Lasse Fridstrøm (TØI) states that Holtsmark and Skonhoft have undervalued the EV's contribution, and arrive at a larger reduction of CO^2 with the use of data from Nissan statistic bank for EVs. In a featured article in *Dagens Næringsliv* (2015b), Fridstrøm argues that the estimated cut of CO^2 is 145 000 tons each year, which is about three times as much as reported by Holtsmark and Skonhoft (2015).

	Holtsmark and Skonhoft, 2014	**Fridstrøm, 2014**	**My calculations**
Data from year	2013	2013	2015
Average emission from new cars	110 g/km CO^2	176 g/km CO^2	124 g/km CO^2
EV average driving range	7,800 km/year	16,500 km/year	13,100 km/year
Cuts in CO^2 when switching to an EV	0.86 ton per car each year	3 ton per car each year	1.62 ton per car each year
CO^2 - emission avoided with 50.000 EVs	43,000 ton each year	145,000 ton each year	81,000 ton each year
Share of total emission in Norway	0.08 percent	0.27 percent	0.15* percent

Table 4-1: Emission calculations from Holtsmark and Skonhoft, Fridstrøm and my own calculations. Modified table from Dagens Næringsliv (2015b) *- computed total emission for 2015 from SSB (2016a)

Table 4-1 displays that there is a disagreement in the CO^2 emission per kilometre for new cars and different estimations in average driving range for EVs which leads to the disagreement concerning the estimates of emission cuts.With a CO^2 cut of 145,000 instead of 43,000 the price per avoided ton of CO^2 will fall considerably.

In the third column, I have updated the figures to 2015 figures, by using data from The Norwegian Information Counsel for Road Traffic (OFV). They report that in March 2016 the average CO^2-emission for sold cars were 117 g/km for petrol and 131 g/km for diesel (OFV, 2016b). According to NEVA (2016) there are about 50 percent petrol cars and 47 percent diesel cars in the 2015 Norwegian car pool, so I will assume that the CO^2-emission is 124 g/km for an average conventional car.

Data from Statistics Norway suggest that average driving range for an EV is 13,100 km per year (SSB, 2016b). Assuming that replacing a conventional car with an EV will not affect the amount of driven kilometres, each EV will cut CO^2-emission by 1.62 ton each year.[7] With current policies adjusted for 50,000 EV units, the estimate of yearly emission cut is 81,000 ton CO^2 each year. Thus, my estimate places itself between the estimates of the two opposing sides.

CO^2-emission is not the only negative effect of driving which can be reduced or avoided by switching to EV. In an article by Fridstrøm and Østli (2014) it is argued that the subsidisations of EVs will benefit other health outcomes too. This improvement in health is a consequence of the reduction in NOx emission, where EVs have a lower output of NOx than combustion engines, and, in particular, this happens when diesel engines are replaced.

4.2 Debate on policy appropriation

4.2.1 Dispute in the research field

Another line of arguments questions the working of the policy initiative, i.e., to what extent the policy works as intended.

Holtsmark (2012) and Holtsmark and Skonhoft (2014) state that the privileges are so favourable that it contributes to more driving, often at the cost of public transport or cycling, both which are considered more climate friendly than EVs. This argument is strengthened by evidence presented in Frøyen et al. (Prosam, 2009), who find that the incentives have affected public transportation in a negative manner. Holtsmark (2012) adds to this point by referring to the short range of EVs, which gives incentives to own an additional car, which in turn encourage more private driving. He has also gone so far as characterising the EV incentives as targeted tax relief for wealthy households (TV 2, 2013).

[7] 124 g/km x 13,100 km

Odeck and Aasness (2015) further expand on the adverse effects of the EV incentives. Exemptions from toll roads have given a large reduction in public income, and access to bus lanes has resulted in greater travelling time for users of public transport. They have illustrated the problems by using a case study in Oslo, and have estimated a public loss in income of approximately 95 million Euro in 2020. This a considerable amount, considering that nearly 60 percent of the income from toll roads goes to maintenance of public roads and other transportation investments, and as financing must be found through other sources, with associated welfare losses.

Odeck and Aasness (2015) conclude that other countries should not adopt Norwegian policies. This is also related to the fact that other countries have a higher usage of electricity that is produced with a larger GHG-emission than Norway does. Frøyen et al. (Prosam, 2009) also propose to terminate the incentives used to stimulate the EV expansion, especially in areas close to the larger cities, while Holtsmark (2012) suggests terminating most of the subsidised privileges of EVs altogether.

Interestingly, Figenbaum and Kolbenstvedt (2013) state that other countries should adopt the Norwegian policies. Hannisdahl et al. (2013) support this my stating that the incentives will become an important instrument in the work to obtain lower GHG-emission and to keep EVs attractive. Their calculations suggest that it is possible to maintain the Norwegian incentives by increasing tax rates and toll road charges for petrol and diesel cars.

Along a similar line of reasoning, Fridstrøm and Østli (2014) justify the support because it gives economic of scale advantages to the EV producers, which in turn will give a lower import price and result in EVs becoming more accessible to the public. The argument that Norwegian market will contribute with scale effects is contradicted by Bjertnæs (2016): he points to Norway's marginal role in terms of total EV sales.

4.2.2 Various other policy assessments

The Norwegian Green Tax Commission (NOU 2015:15) was a committee consisting of specialists with expertise in climate economy and public economics. The committee was appointed by the Government to propose new tax bills that will fund green project and direct taxation towards environment damaging activities.

The committee's evaluations were based on overall normative framework, and their mandate from the Norwegian Parliament was to contribute to better resource utilisation and simultaneously achieve the goals that were presented in “Klimaforliket”. The committee kept a strong emphasis on cost-efficiency, to make sure Norway uphold the climatic principles and simultaneously ensure a healthy economic future.

Among the 80 initiatives, there was a recommendation to remove the economic advantages of buying an EV. The committee states that EVs have managed to obtain a foothold in the market, and that future EV owners still have advantages, in terms of exemptions from road fees and CO^2 taxes. If implemented, owners will get compensated through temporary subsidies. According to the committee, the benefits should better reflect the environmental benefits of driving an EV. The committee also recommended that taxes connected with conventional cars are raised by 12–17 billion NOK.

The committee’s recommendations have already been heavily criticised by participants of interest. Lobby organisations such as The Norwegian Automobile Union (NAF) and NEVA have argued against the changes, and claim that this will end the EV development. They are also supported by The Information Bureau for Road Transportation (OFV) who thinks EVs should pay for the damages they cause to the environment eventually, but that the timing is wrong (Aftenposten, 2015).

4.2.3 International studies

Even though the Norwegian policy is the main topic of this master’s thesis, let me also briefly mention some findings from abroad.

DeShazo (2016) proposes four specific design choices policymakers should consider when forming EV incentives. His study on Californian car fleet suggests amplifying incentives around actual sales rather than usage, focus more on EVs rather than hybrids, and argue for making it cheaper and easier to retire old vehicles. It is also argued that policies should be directed towards low and moderate income consumers, as lower-income consumers tend to drive more polluting cars, have higher total driving range and have lower propensity to buy an EV. All these considerations are aimed to help improve the cost effectiveness of incentives and lower GHG emission.

As mention earlier, Holland et al. (2015) have assessed EV policies in the US. By developing a theoretical discrete choice model of new vehicle purchases, they estimate the environmental benefits of EVs. Employed on US data, they find there are great variations in EV adaptability within in the country.

4.3 Research questions aiming to examine some aspects of the EV policy

To reduce the emission of GHG, the Government has a clearly stated aim to stimulate increased usage of EVs at the cost of conventional cars (Ministry of Transport and Communication, 2009). In order to achieve this, they have invested heavily into making it cheaper to acquire an EV and in making it easier and cheaper to use, through various privileges already mentioned. However, as discussed, the policy initiatives are controversial, and experts do not agree on effects of policies and to what extent they are well-funded. By employing data collected among a sample of EV owners, I will empirically investigate to what extent the policy incentives are associated with i) only owning EVs; ii) increased driving after acquiring this type of car; and iii) to what extent it results in reduced use of public transport.

4.3.1 Only owning EV

Some EV owners seem to have responded to the EV incentives by having fully converted to vehicles with less GHG emission, i.e., they report to rely on having an EV only and no additional, conventional car. Others report that they both have an EV and a petrol and/or a diesel car. In my first model specification, I want to examine the empirical association between the sample's evaluation of a set of EV policy incentives and only owning EV(s), after accounting for a set of personal characteristics and indicators for driving demand.

The estimated associations might provide some interesting suggestions for what the policy-makers should look for when deciding on future policy and privileges, given that an increase in usage of EVs and less of conventional cars are goals for the Government. Further, the results should give some insight into characteristics of households who only rely on EV(s).

4.3.2 Extended driving range

I want to further assess the implications of governmental policies. If the policies work as intended, with the aim of reducing GHG-emission, then acquiring an EV should not increase the total driving range for EV owners. At best, it should stimulate to less driving and support alternative ways of travelling. As the presentation of the discussion among economists revealed, the total amount of driving after the introduction of subsidies is a controversial issue. In my analysis, I want to investigate the empirical association between the sample's evaluation of a set of EV policy incentives and possible increase in their driving range after becoming an EV user.

4.3.3 Less use of public transport

Related to the previous point, one potential side effect of the EV incentives is that EVs become so convenient to use that EV travels replace more environmental friendly travelling, like cycling and/or public transport. Thus, this third research question will investigate the empirical association between the sample's evaluation of a set of EV policy incentives and the EV owner's usage of public transport after acquiring an EV, after accounting for a set of personal characteristics and factors influencing their driving demand.

5 Data

5.1 Introduction

To study the research question introduced in Section 4.3, I will use data provided by the Institute of Transport Economics (TØI). It is a cross-sectional data set that was deducted from survey conducted in February 2014 among 1,722 members of NEVA. Every respondent is in possession of an EV. NEVA is a lobby organisation that offers all EV buyers a free membership for the first year, and approximately 40 percent of all EV owners were members in 2014.

The aim of the survey was to get information on the usage and experiences among the NEVA members with respect to both EVs and conventional cars, as well as getting an assessment of their overall satisfaction and expectation of EVs. In addition to assessing the members' valuations and practises, the participants provided information on personal characteristics such as gender, age, place of residence and income.

The survey was part of a newsletter sent out to 9,051 NEVA members, where members were asked to participate in an online survey. The 1,722 responses thus constituted a response rate of 19 percent and amounted to 8 percent of the total number of registered Norwegian EV owners in 2014. The respondents were 18 years or older, and each one of them represented their own household. Personal identification information was excluded, as well as the last digit of their postal code. All regions in Norway were represented, and all individuals were equally weighted in the data set.

5.2 Earlier data application

Let me first briefly mention that there are two reports and one master's thesis that have previously used the same data set or the same type of data. Figenbaum et al. (2014) give an insight in Norwegian households' experiences, travel patterns and opinion on EVs through descriptive statistical presentation of the survey.

Another report using the same type of data is Bjerkan et al. (2015). They discuss the importance of incentives for promoting EVs in Norway. Based on information from 3400 EV survey participants, they find that EV owners are particularly responsive to purchasing cost incentives. According to the report, the combination of incentives and privileges are important, as only ten percent of the respondents stated that only one policy instrument was sufficient for them buying an EV.

The data set was also used in a master's thesis by Hilde Bjørdal in 2014, which discussed to what extent the EV incentives contributed to the Norwegian Government's defined objectives with respect to city planning. In her study, she found that the incentives were counterproductive when trying to build a city infrastructure based around sustainable transportation and less traffic in and around the city.

5.3 Evaluation and limitations with the data set

Ideally, I would have liked access to a broader data set with information on all types of car owners, i.e., data not restricted to EV owners only. Such a data set would provide possibilities for a more comprehensive investigation of the incentive effects on being an EV owner, by having conventional car owners as a control group, and thus expand the possible research areas.

One obvious challenge with the data set at hand, is that it may be contaminated by self-selection bias. This possibility is a consequence of EV owners having a choice when it comes to survey participation. Further, and somewhat related, it is a concern that the NEVA members may have acted strategically, for example by not reporting correctly or by answering in certain ways to protect what they see as their self-interest. If they assume that the results could have consequence for future EV policies, this could be an incentive to make EVs look better than they actually are.

Another potential problem is measurement error. Many of the survey questions ask for the respondents' experiences. This means that the analyses are not based on objectively registered driving ranges or registered income, but rely on the respondents' self-reports. This would cause inaccuracies if there are discrepancies between the respondent's answers and facts. Further, the questionnaire asks for information that may not be available to the respondents at the time of survey or she/he could remember incorrectly ("recall bias"). Also, with every respondent representing their respective household, the respondent may not account for the opinions of his or her fellow household members.

The sample also has some advantages. One advantage with online surveys is that the collection period is often short, which means that all respondents are assumed to be exposed to the same policies. Also, online surveys usually take less time to complete, which might have lowered the barriers for participation and increased the response rate.

Further, having eight percent of all EV owners and eighteen percent of the NEVA member base responding to the survey, the sample may be sufficient to obtain an insight into the research questions raised. Furthermore, 1722 is a sufficiently high number of observations to conduct the wanted regression analyses.

5.4 Descriptive statistics

In the following tables I will present descriptive statistics for the variables that are included in the analyses. I have categorised the variables into four different groups i) "dependent variables", ii) "personal characteristics", iii) "driving demand variables" and iv) "policy variables".

5.4.1 Dependent variables

Recall that the first research question relates to associations of having only EVs, see Section 4.3. "EnesteElbil" will be used as a binary dependent variable which takes the value 1 for respondents who only have EV(s), and 0 for EV owners with additional conventional cars. As Table 5-1 shows, there are 26 percent of the study observations who only rely on EV(s).

Variable	N	Mean
EnesteElbil	1,722	0.26
KjorerMer	1,722	0.23
LengerForsikret	1,722	0.18
MindreKollektivt	1,722	0.16

Table 5-1: Descriptive statistics of the dependent variables in the data set

"KjorerMer" is a dummy variable that is 1 if the respondent stated he or she is driving more after having acquired an EV, and 0 otherwise, and Table 5-1 shows that 23 percent of the owners reported driving more. "LengerForsikret" is a dummy that variable that takes the value 1 if the respondent has extended their insured driving range after acquiring an EV, 0 otherwise. This was the case for 18 percent of the study observations. "KjorerMer" and "LengerForsikret" will be employed as dependent variables for examining the second research question.

The third research question concerns the use of public transport. "MindreKollektivt" is a dummy variable that takes the value of 1 if the respondent reported using less public transportation after acquiring an EV, 0 otherwise. Table 5-1 shows that 16 percent of the asked reported using less public transport.

5.4.2 Personal characteristics

Respondents' attributes and characteristics are reported in Table 5-2. They are included as control variables in the empirical investigations. As Table 5-2 shows, the average age of the sample was 46 years, with 76 percent being male, as reported by the variables "Alder" and "Mann". The average household size was slightly above 3 persons, at 3.24, denoted by "Hustandsstr". 15 percent of the asked participants reported to be a member of an environmental group, denoted by the dummy variable "Miljoorg".

Variable	N	Mean	Variable	N	Mean
Alder	1,722	46.39	**Hustandsstr**	1,722	3.24
Mann	1,722	0.76	**Miljoorg**	1,722	0.15
LavInntekt	1,722	0.13	**StorBy**	1,722	0.39
MedInntekt	1,722	0.38	**By**	1,722	0.21
HoyInntekt	1,722	0.43	**Tettsted**	1,722	0.30
IkkeOnsker	1,722	0.07	**AnnetBosted**	1,722	0.10

Table 5-2: Descriptive statistics of personal characteristics

The continuous variables "Alder" had a standard deviation of 11.3, with a minimum value of 0 and maximum value of 90. The issue with the minimum age being 0 is further discussed in Section 5.5.2. The other continuous variable "Hustandsstr" had a standard deviation of 1.35, with the lowest reported value at 1 and a largest reported value at 14.

Income is divided into three groups where "LavInntekt" includes units with a household gross income below 600,000 NOK, "MidInntekt" denotes income between 600,000 and 1,000,000 NOK and "HoyInntekt" includes people with income above 1,000,000 NOK. 13 percent reported to be in the low income group, 38 percent in the mid income and 43 percent in the high income group. 7 percent of the respondents did not to declare their income, denoted by "IkkeOnsker"

The respondents were also divided into groups based on their place of residency. "StorBy" includes people living in one of the three largest cities in Norway (Oslo, Bergen, Trondheim), which was the case for 39 percent of the respondents. 21 percent reported living in another city than the three mentioned ("By"), whereas 30 percent lived in a town ("Tettsted"). The remaining 10 percent lived in rural areas, denoted by "AnnetBosted".

5.4.3 Driving demand variables

Table 5-3 presents descriptive statistics for variables that relates to the demand of travelling.

Variable	N	Mean
Jobbdistanse	1,519	26.29
IngenJobbdistanse	1,722	0.00
KortJobbdistanse	1,722	0.34
MidJobbdistanse	1,722	0.43
LangJobbdistanse	1,722	0.11
NyElbil	1,722	0.60

Table 5-3: Descriptive statistics of driving demand variables

The average distance to work or school was 26.29 kilometres, with 250 km being the longest reported travel distance and shortest at 0 km, cf. the continuous variable “Jobbdistanse”. Distance to work/school had a standard deviation of 22.15, and was reported by 1,519 of the participants.

“Jobbdistanse” is divided into four groups. “KortJobbdistanse” is a dummy for travel distance greater than 0 and less than 16 kilometres, which applied to 34 percent of the sample. “MedJobbdistanse” comprises participants with a travel distance greater than 15 and less than 45 kilometres, which was the case for 43 percent. “LangJobbdistanse” include individuals who had 45 kilometres or more in travel distance, which amounted to 11 percent. “IngenJobbdistanse” is a dummy variable that take the value of 1 if the respondents had no travel distance to work or school. This applied to only 4 individuals, and I will get back to this in Section 5.6.1

“NyElbil” is a dummy variable that takes the value of 1 if the respondent’s newest EV had been in his or her possession in less than a year, and 0 otherwise. This applied to 60 percent of the sample.

5.4.4 Policy variables

The policy variables are meant to reflect the potential influence of the incentives that policy makers have introduced to increase the usage of EVs, i.e. factors that were important to the EV owners when they decided to buy and use the EV. This category also includes whether the EV replaced other cars.

Variable	N	Mean	Variable	N	Mean
Erstatning	1,722	0.69	**BetydningDrift**	1,722	0.81
BetydningSikkerhet	1,722	0.29	**BetydningKollektiv**	1,722	0.30
BetydningMiljo	1,722	0.64	**BetydningBom**	1,722	0.66
BetydningPris	1,722	0.55	**BetydningFerge**	1,722	0.18
BetydningAarsavgift	1,722	0.53	**BetydningParkering**	1,722	0.40

Table 5-4: Descriptive statistics for policy variables

Looking at Table 5-4, we see that 69 percent of the respondents reported that they replaced one or multiple cars with the EV they bought, denoted by the dummy variable "Erstatning". Further, there is a set of dummy variables which represent which policy incentives were important when the respondents decided to purchase an EV. These variables are based on a likert scale from 1 to 5, where 1 is "not important" and 5 is "very important". This scale variable has been converted to a variable that takes the value 1 if the factor was important or very important to the individual, 0 otherwise. In addition, there is one binary variable reflecting the respondents' assessment of how important safety was for their EV purchase.

Table 5-4 shows that environmental aspects were important to 64 percent. Price, yearly fee and operational cost were important to 55, 53 and 81 percent, respectively. Access to bus lanes was important for 30 percent of the sample, whereas free toll roads, ferry and parking were important to 66, 18 and 40 percent, respectively. 29 percent of the sample reported that car safety was important or very important when deciding to buy an EV.

5.5 Minor data modifications

5.5.1 First time car owners

To investigate the changes in travel patterns for car owners who have invested in EVs, I wanted to exclude observations for whom an EV was their first car. Some of the questions were tailored to respondents who already owned a car, like changes in travel patterns after acquiring an EV. Travel patterns may have greatly changed for first time car owners, but as the effects of going from not being a car owner to being a car owner is not the main focus here, first time car owners were dropped from the data set. By this, the sample size was reduced by 60 observations.

5.5.2 Punching errors

In the data set the minimum age is 0, which could be a typing mistake or a misinterpretation. Either way, any respondent with a reported age below 18 years was dropped, which applied to two individuals. Also, three respondents reported that they were using both more *and* less public transport after acquiring an EV. To avoid misunderstandings, these three observations were also dropped from the analyses.

5.6 Missing data

5.6.1 Workplace distance

Table 5-3 displays a variable stating the respondents' distance from their home to their work place/school. "Jobbdistanse" has missing values and there are only 1,519 observations with recorded distance, compared to the full sample size of 1,722 individuals. The missing values amounts to over ten percent of the total observations. This may be problematic for two reasons. Firstly, the exclusion may cause selection bias in analysis, see, for example, Woolridge (2013, p. 314). Secondly, fewer observations imply less statistical power to the analyses.

The reason behind many missing observations might be related to the fact that many of these respondents do not have a place to work or a school to go to, and they may have left the question unanswered. If so, their response should have been "0", and not missing. I will therefore assume that pensioners and other individuals, who are not employed in school or work, do not have any distance to work or school. By replacing "missing" values with ”0" for every senior and everyone who is not employed in work or school, the number of missing observations is reduced from 190 to 107.

The 107 respondents that have stated they are employed or a student, without reporting their travel distance, were dropped from the analyses. If the reason for missing values is non-random, this could have caused biased results, but it does not seem to be the case. Being employed, but not reporting distance to work, may suggest that the respondent is self-employed, but the share of self-employed is approximately the same in this group as in the rest of the sample.

5.6.2 Income

Table 5-2 displays that 7 percent chose not to report their income levels, and they are therefore treated as missing observations. There may be multiple reasons for not reporting income. The respondents may feel uncomfortable sharing private information, or they are not particularly proud of their income level, it being relatively high or low. If the latter is the most important reason, then the no-income group might consist of more members who should have belonged to the low and high income group rather than medium income. These observations are treated as missing, and dropped from the used data set.

6 Model specification and methods of estimation

6.1 Model specification

6.1.1 Only Owning EV

As discussed in 4.3.1, one of the Government's overall goal is less reliance on conventional cars. In my first empirical illustration, I want to examine the association between only owning EV(s) and various explanatory variables that affect the probability or willingness to do so. To examine the associations, I will use the variable "EnesteElbil" as the dependent variable. "EnesteElbil" is a dummy on whether the respondent owns only electric car(s), and no additional conventional car(s).

$$EnesteElbil = PersonalCharacteristics + DrivingDemandVariables + PolicyVariables \quad (6.1)$$

More detailed versions of the model illustrations from (6.1) to (6,4), which includes all variable names and meanings, can be found in Appendix 9.2B.

6.1.2 Extended Driving range

Next, I discuss the relationship between EV acquisition and more or less driving, which also has been a controversial topic among researchers. There are some variables in the data set that may serve as indicators of potential changes in driving range after requiring an EV. The first variable is called "KjorerMer", and is a dummy variable indicating whether the respondent has answered that he or she has increased driving after acquiring an EV.

$$KjorerMer = PersonalCharacteristics + DrivingDemandVariables + PolicyVariables \quad (6.2)$$

The second variable is called "LengerForsikret", and is a dummy variable indicating whether the respondent has increased the insured driving range after acquiring an EV.

$$LengerForsikret = PersonalCharacteristics + DrivingDemandVariables + PolicyVariables \quad (6.3)$$

6.1.3 Less use of public transport

Recall that one of the "EV controversies" concerns EVs becoming so convenient to use that EV travels replace travels that used to be performed by what are considered to be more environmental friendly, like cycling or public transportation. To examine this, I use the variable "MindreKollektivt" as a dependent variable, which is a dummy variable for whether the respondent has reported to be using less public transportation after acquiring an EV, or not.

$$MindreKollektivt = PersonalCharacteristics + DrivingDemandVariables + PolicyVariables \quad (6.4)$$

6.2 Methods of estimation

In the empirical specifications (6.1) – (6.4), the dependent variables take the form of a binary variable. Binary choices, or multiple discrete choices, imply that the conventional linear regression models are generally inappropriate to use (Verbeek 2012, p. 206).

The main difference from having a continuous variable as a dependent variable is that the parameters in binary models must be interpreted as a change in probability of an occurrence. The parameters will indicate how the variables affect the individual choices between two discrete alternatives or likelihood of being part of a designed group (Verbeek 2012, p. 207).

6.2.1 Linear probability model (LPM)

The simplest model for limited dependent variables is called the linear probability model (LPM) and it assumes that the dependent variable (*y*) is a linear function of the explanatory variables (*x*). An advantage of the LPM model is that is easy to obtain predictions. Thus, it is often used in applied work, see, for example, Angrist and Pischke (2008).

Assuming a model with a binary dependant variable, y, and a single explanatory variable, x_{i2}, the LPM model is given by

$$y_i = \beta_1 + \beta_2 x_{i2} + \varepsilon_i = x_i'\beta + \varepsilon_i \quad (6.5)$$

Where ε_i denotes the error term, x_{i1} is an interception term ($\equiv 1$) which makes $x_i = (x_{i1}, x_{i2})'$.

Standard assumptions are fulfilled which implies that $E\{\varepsilon_i \mid x_i\} = 0$. This ensures that the expected value of the error term is zero and that the factors are exogenous. This implies that

$$\begin{aligned} E\{y_i \mid x_i\} &= 1 \cdot P\{y_i = 1 \mid x_i\} + 0 \cdot P\{y_i = 0 \mid x_i\} \\ &= P\{y_i = 1 \mid x_i\} = x_i'\beta \end{aligned} \quad (6.6)$$

LPM model implies that $x_i'\beta$ is a probability that should lie between 0 and 1. This is only possible with certain restrictions that are difficult to achieve in practice. The first problem is that by assumption, the error term can only take two possible values, because the dependent variable will either take the value of 1 or 0 (Verbeek, 2012, p. 207) This leads to a non-normal distribution where the error term will take the value of $1-(x_i'\beta)$ with probability P, or $(-x_i'\beta)$ with probability $1-P$.

The non-normal distribution also means that heteroscedasticity will be an issue, as the variance will not be constant given the explanatory variables. The probably most important problem is that the LPM is able to predict irrational probabilities, not inside the interval [0,1] (Verbeek, 2012, p. 207). These problems call for using alternative models to estimate relationships.

6.2.2 Logit and probit

To overcome the problems with non-normal distribution and heteroscedasticity, there exist a class of binary choice models that are designed to handle discrete alternatives. They will estimate the probability that $y_i = 1$, often by departing from an underlying latent variable model. In general, we have

$$P\{y_i = 1 | x_i\} = G(x_i, \beta) \tag{6.7}$$

For some function of G(.). The equation says that the probability of having $y_i = 1$ depends on the vector x_i, containing some individual characteristics. The function G(.) in (6.7) should take only values in the interval [0,1], and it is often restricted to the form of $G(x_i, \beta) = F(x_i'\beta)$, where the F(.) function is chosen to have a distribution form. Common choices are the standard forms, which is either the standard normal distribution function or the standard logistic distribution function, which are referred to as the probit and the logit model, respectively.

The probit model is built on the standard normal distribution function, and is given by

$$F(w) = \int_{-\infty}^{w} \frac{1}{\sqrt{2\pi}} \exp\left\{-\frac{1}{2}t^2\right\} dt = \Phi(w) \tag{6.8}$$

The logit model is built on the standard logistic distribution function, and is given by

$$F(w) = L(w) = \frac{e^w}{1+e^w} \tag{6.9}$$

The LPM model in (6.5) is related to these two models, but probabilities are set to 0 and 1 respectively if $x_i'\beta$ exceeds the lower or upper limit, and they also do not suffer from heteroscedasticity like the former. Probit and logit models are commonly applied in econometrics and often show similar results in empirical work (Verbeek 2012, p. 208).

6.3 Estimation

Conventionally, probit and logit models are estimated by the maximum likelihood estimation (MLE). It builds on the assumptions that the distribution of an observed endogenous variable is known, except for a finite number of unknown parameters. These parameters are estimated by giving the values that give the observed value the highest probability, hence the name maximum likelihood (Verbeek 2013, p. 180).

Because MLE is based on the distribution of y given x, the heteroscedasticity in the variance is automatically accounted for, and assuming a random sample of size n, the MLE can be written as

$$L(\beta) = \prod_{i=1}^{N} P\{y_i = 1 | x_i; \beta\}^{y_i} \, P\{y = 0 | (x_i; \beta)]^{1-y_i} \qquad (6.10)$$

When y is 1, the second part of the expression equals 1, so we get $P\{y_i = 1 | x_i\}$. When y is 0, we get $1 - P\{y_i = 1 | x_i\}$. The log-likelihood function for individual i, is obtained by taking log of (3.10)

$$\ell_i(\beta) = \sum_{i=1}^{N} y_i \log[G(x_i\beta] + \sum_{i=1}^{N} (1 - y_i) \log[1 - G(x_i\beta)] \qquad (6.11)$$

and one can find the log-likelihood for the entire sample by summing across all observations (Wooldridge 2013, p. 564).

The general theory for MLE for random samples implies that under general assumptions, MLE is consistent, asymptotically normal and efficient, which implies that asymptotic tests, such as t tests, are applicable (Wooldridge 2013, p. 564).

6.4 Testing

Lagrange multiplier and score test are possible ways to test restrictions under the null-hypothesis, but they are less used in empirical work compared to the Wald test. The Wald test requires that estimation of only the unrestricted model, and uses a transformed statistic of the F-statistic with the same asymptotic chi-squared distribution (Wooldrige, 2013, p. 564).

If both unrestricted and restricted model are easy to estimate, then the likelihood ratio (LR) test is easy to apply. Where the F test is based on difference in sum of squared residuals, the LR test is based on differences in log likelihood between the restricted and unrestricted model. Dropping variables generally leads to a smaller log-likelihood, so the question is whether there is drop is large enough to conclude that the dropped variables were important. The LR statistic is given by

$$LR = 2(\ell_{ur} - \ell_{r}) \tag{6.12}$$

Since the log-likelihood of unrestricted model is generally larger then restricted, the parenthesis is strictly positive. LR is two times the difference, and the multiplication is needed for LR to have an approximately chi-square distribution (Wooldrige 2013, p. 565).

6.6 Goodness-of-fit

A goodness-of-fit measure is a statistic indication on how well the model approximates observed data, and is denoted as R^2. For linear models, R^2 is a measurement on how much of the model is explained by the included variables. In the case of the dependent variable being binary, the goodness-of-fit can be explained based on the connection between calculated probabilities and observed frequencies, in other words, the models ability to forecast observed response (Verbeek, 2012, p. 212).

There is no single measurement of goodness-of-fit in binary choice models, as seems to be established for linear regression methods. The two most common measurements are both defined as differences between a model with only a constant term and a model where all parameters are included (Verbeek 2012, p. 212).

The goodness-of-fit measurement is called $pseudo-R^2$. It is defined as

$$pseudo-R^2 = 1 - \frac{1}{1 + 2(\log L_1 - \log L_0)/N}, \tag{6.13}$$

where L_1 denotes the maximum log-likelihood value of the full model, L_0 denotes the same for the very restricted model and N denotes the number of observation. (6.13) expresses that if the smaller difference between the two likelihoods, the smaller $pseudo-R^2$ will be. McFadden (1975) made an alteration to this method of estimation. The alternative measurement, the $McFaddenR^2$ is given by,

$$McFaddenR^2 = 1 - \log L_1 / \log L_0, \tag{6.14}$$

which takes values in the interval [0,1], since $\log L_1 \leq \log L_0 < 0$. In practice, the two estimators usually take values well below 1 (Verbeek, 2013, p. 212-213).

6.7 Marginal probability

When reporting results from logit and probit models, it may be easier to interpret results by addressing marginal probabilities. To obtain the magnitudes of partial effects, it is convenient to have a single scale factor that can be multiplied with each coefficient. One commonly uses sample averages to get the partial effect of the "average" person in the sample. This is often referred to as partial effect of the average or PEA (Wooldridge, 2013, p.567).

A challenge in that respect, given a data set with mostly discrete variables as explanatory variables, that results do not really apply to anybody in the sample. It can therefore be more intuitive to compare and report differences in estimated probabilities for two designed individuals, with different characteristics, for example, the difference in probabilities for an individual only owning EV(s) and who lives far away from his or her work, compared to a person who lives nearby.

7 Results

7.1 Only owning EV(s)

In this Section I will present and discuss the results from regressing the empirical specifications described in Section 6.1.

The dependent variable in the first empirical illustration is a dummy variable for only having EV(s) and no additional conventional car, see Section 6.1.1. Tables 7-1 to 7-3 show the regression results from this specification, with the three different estimation methods, which were discussed in Section 6. LPM was estimated by ordinary least squares, while the Logit and Probit models were estimated by maximum likelihood.

Since the variance is $\pi^2/3$ in logistic distribution, it means that the coefficients in logit models are roughly $\pi/3$ larger than those obtained in probit estimations, while the LPM coefficients are about four times lower (Verbeek, 2012, p.215). The results in according to each estimation method are predominantly the same. Given that results are less dependent on the choice of estimation method, I base the discussion on the logit estimates from specification (2), which had a pseudo R-squared value of 0.187. To control for heteroscedasticity, the t- and z statistics are based on robust standard deviations.

Given the large number of exogenous variables, I will present the results in three separate tables. The full set of results can be found in Appendix 9.2D.

7.1.1 Personal characteristics

Table 7-1 shows that the two personal characteristics that are positively associated with only owning EV(s) is living in one of three largest cities in Norway ("Storby") rather than in the countryside and being part of an environmental organisation ("Miljoorg"). The characteristics that are negatively associated are age ("Alder"), household size ("Hustandsstr"), and having medium ("MedInntekt") or high income ("HoyInntekt") rather than low income. Gender does not seem to have significant effect on the probability of only owning an EV.

Specification	(1)	(2)	(3)
Dependent Variable	**EnesteElbil**	**EnesteElbil**	**EnesteElbil**
Estimation Method	**LMP**	**Logit**	**Probit**
Alder	-0.00450***	-0.0305***	-0.0174***
	(-4.00)	(-4.03)	(-4.08)
Mann	-0.0285	-0.157	-0.125
	(-1.09)	(-0.91)	(-1.28)
Hustandsstr	-0.0399***	-0.290***	-0.166***
	(-4.70)	(-4.45)	(-4.56)
MedInntekt	-0.239***	-1.239***	-0.724***
	(-6.15)	(-5.67)	(-5.73)
HoyInntekt	-0.296***	-1.623***	-0.927***
	(-7.50)	(-6.90)	(-6.89)
StorBy	0.138***	0.943**	0.490**
	(3.65)	(3.21)	(3.02)
By	0.0811*	0.599*	0.309
	(2.10)	(1.99)	(1.84)
Tettsted	0.0577	0.425	0.196
	(1.61)	(1.47)	(1.23)
Miljoorg	0.124***	0.765***	0.439***
	(3.83)	(4.07)	(4.03)
N	1450	1450	1450

Table 7-1: Regression results of LMP, logit and probit. Personal characteristics. t and z statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results in Table 7-1 show that the older you get, the more prone you are to having additional conventional cars. There is no obvious reason for age being negatively associated with only owning EV(s) by itself, but age may be slightly positively correlated with other explanatory variables in the data set with a negative association to the dependent variable. These variables include household size (family size) and income. Larger households may have a high total household driving range, so that EVs, with their relatively short driving range, may not be sufficient for their travelling needs.

Table 7-1 also shows that having medium and higher income is negatively associated with only owning EV(s). This supports the claim of some researcher such as Holtsmark, that EVs are subsidies, additional cars for the wealthy households to enjoy.

Living in a city is positively associated with only owing EVs, which is not a surprising result in itself. Cities in Norway have a better developed infrastructure for EV compared to rural areas, with over half of the Norwegian charging stations being located in and around Norway's three largest cities (Ladestasjoner, 2016). Public policies directed towards people in cities, less developed infrastructure and longer traveling distances may be explanations underpinning the finding of lower probability in rural areas, compared to cities.

Another reason, and somewhat related, is the externality effect. EV has not been adopted to the same degree in households in rural areas as in more crowded areas. Figenbaum and Kolbenstvedt (2015) emphasise the importance of knowing someone who already owns an EV, which is less likely in rural areas, recall the discussion of critical mass in Section 3. Less flow of information and experiences with EV may lead to scepticisms, which in turn leads to households being less susceptible to fully rely on EV.

Being part of an environmental group is also positively associated, which may be explained by the fact that many look at EVs as a more environmental friendly alternative to conventional cars. Being engaged in an environmental group indicates that the car owner is environment-conscious, which is an obvious reason for only using the EV for transport.

7.1.2 Driving demand variables

Table 7-2 shows that having a distance to work/school over 15 kilometres is negatively associated with only relying on EV (“MidJobbdistanse”, “LandJobbdistanse”), compared to having no distance to work. Having to travel 15 kilometres or less to work has no significant effect on the probability of only owning EV (“KortJobbdistanse”). Living further away from the work place or school is negatively associated, which makes sense, in that long daily trips cumulate large total driving ranges, which makes it less convenient to only rely on EV(s).

Specification	**(1)**	**(2)**	**(3)**
Dependent Variable	**EnesteElbil**	**EnesteElbil**	**EnesteElbil**
Estimation Method	**LMP**	**Logit**	**Probit**
KortJobbdistanse	-0.0648	-0.442	-0.246
	(-1.12)	(-1.41)	(-1.33)
MidJobbdistanse	-0.106	-0.714^{*}	-0.399^{*}
	(-1.85)	(-2.24)	(-2.12)
LangJobbdistanse	-0.166^{**}	-1.268^{**}	-0.720^{**}
	(-2.68)	(-3.19)	(-3.18)
NyElbil	0.0533^{*}	0.366^{*}	0.194^{*}
	(2.45)	(2.34)	(2.19)
Constant	0.632^{***}	0.621	0.503
	(5.93)	(0.89)	(1.27)
N	1450	1450	1450

Table 7-2: Regression results of LMP, logit and probit. Driving demand variables. t and z statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Having owned an EV for less than a year is positively associated with only owning EV(s) denoted by “NyElbil”, which can be explained by that newer EVs often have improved technology and longer maximum driving ranges. Newer cars are therefore better substitutes for conventional cars.

7.1.3 Policy variables

Table 7-3 shows the results of the policy variables' association with "EnesteElbil". There was a positive estimate for having replaced one or multiple cars when buying an EV ("Erstatning"). This result was not surprising, considering that EVs are relatively new to the market, and replacing one or multiple cars most likely would mean getting rid of conventional car(s) of some sort.

Specification	**(1)**	**(2)**	**(3)**
Dependent Variable	**EnesteElbil**	**EnesteElbil**	**EnesteElbil**
Estimation Method	**LMP**	**Logit**	**Probit**
Erstatning	0.215***	1.814***	0.949***
	(10.84)	(7.90)	(8.23)
BetydningSikkerhet	0.0483*	0.291	0.170
	(2.02)	(1.89)	(1.90)
BetydningMiljo	0.00663	0.0616	0.0242
	(0.30)	(0.39)	(0.27)
BetydningPris	-0.00652	-0.0422	-0.0202
	(-0.29)	(-0.26)	(-0.22)
BetydningAarsavgift	-0.0190	-0.0890	-0.0466
	(-0.78)	(-0.53)	(-0.48)
BetydningDrift	0.00583	0.0371	0.00160
	(0.19)	(0.17)	(0.01)
BetydningKollektiv	-0.00765	0.0164	-0.00217
	(-0.32)	(0.09)	(-0.02)
BetydningBom	-0.0194	-0.185	-0.0875
	(-0.78)	(-1.09)	(-0.90)
BetydningFerge	0.000591	-0.000287	0.00521
	(0.02)	(-0.00)	(0.04)
BetydningParkering	0.0120	0.0512	0.0259
	(0.49)	(0.30)	(0.27)
N	1450	1450	1450

Table 7-3: Regression results of LMP, logit and probit. Political variables. t and z statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7-3 also shows that there is no significant association between the respondents' evaluations of the different policy incentives and only owning an EV, which may be a surprising result. There may be a number of reasons for these insignificant results. One reason may be model misspecification, i.e., too many incentives and privileges are employed, this is further discussed and investigated in Section 7.6. Another reason is that there is the concern about EV owners not wanting to admit to be influenced by incentives and privileges, as discussed in Section 5.3.

7.1.4 Robust I

As a robustness test, I will further investigate independence from conventional cars, with logit estimation on a somewhat smaller data set. In this estimation, all the respondents who did not report any distance to work/school or income are excluded. The full set of results from this regression can be found in Appendix 9.2D, while the statistically significant variables are listed in Table 7-4, see specification (4). Results from the original estimations is included for comparison (specification (2)).

		Robust I		Robust II	
Specification	**(2)**	**(4)**	**(5)**	**(6)**	**(7)**
Dependent variable	**EnesteElbil**	**EnesteElbil**	**KjorerMer**	**Lenger-Forsikret**	**Mindre-Kollektivt**
Estimation method	**Logit**	**Logit**	**Logit**	**Logit**	**Logit**
Alder	-0.0305***	-0.0317***			-0.0297***
	(-4.03)	(-3.97)			(-3.42)
Mann					-0.419*
					(-2.46)
Hustandsstr	-0.290***	-0.284***		-0.134*	
	(-4.45)	(-4.32)		(-2.17)	
MedInntekt	-1.239***	-1.233***			
	(-5.67)	(-5.27)			
HoyInntekt	-1.623***	-1.621***			
	(-6.90)	(-6.58)			
StorBy	0.943**	1.037**			
	(3.21)	(3.17)			
By	0.599*	0.683*			
	(1.99)	(2.05)			
Miljoorg	0.765***	0.744***			
	(4.07)	(3.78)			
MidJobbdistanse	-0.714*				
	(-2.24)				
LangJobbdistanse	-1.268**				
	(-3.19)				
Erstatning	1.814***	1.730***	-0.566***	-1.378***	-1.187***
	(7.90)	(7.43)	(-4.06)	(-9.40)	(-7.47)
BetydningMiljo					0.359*
					(2.04)
BetydningKollektiv					0.540**
					(2.98)
BetydningParkering					0.504**
					(2.68)
NyElbil	0.366*	0.375*			
	(2.34)	(2.30)			
Sample size	1450	1372	1450	1450	1450
Pseudo R-squared	0.187	0.177	0.034	0.095	0.111

Table 7-4: Summary of the significant variables discussed in Section 7. z statistics in parentheses, * p < 0.05, ** p < 0.01, *** p < 0.001

Most importantly, the same characteristics as reported in tables 7-1 to 7-3 have a significant effect on probability for only owning EV(s), except for distance to work/school. Both when including *and* excluding the missing values for distance to work/school, variables such as age, income, household size are negatively associated with the relying only on EV(s).

Also when it comes to the policy variables, there are no large differences between the two samples. Replacing an EV is still the only positively characteristic associated with only owning EV(s), and respondents claim that the benefits do not influence choices.

7.2 Extended driving range

7.2.1 Result

The result of the logit estimation of "KjorerMer" can be found in Appendix 9.2D, and a summary can be found in Table 7-4, specification (5).

Results based on this specification show that when using "KjorerMer" as a dependent variable, it turns out that the only significant characteristic is the variable which represent the individual having replaced one or multiple cars when acquiring an EV. Having replaced car(s) is negatively associated with reporting to drive more, which is expected, given that the amount of cars the households dispose was unchanged or in some cases reduced. This also may indicate that the incentives for using EVs are not extremely strong compared to using conventional cars, if replacing a conventional car with a EV does not lead to more driving.

Other variables, such as valuing incentives or being part of an environmental organisation do not seem to have any significant effect on the probability. The model estimation has a low pseudo R-squared at 0.034, which suggests that there are other factors which are not included in the model specification that has explanatory power. For example, there can be unobserved personal changes in and around the time of acquiring an EV that led to changes in travel patterns, such as new work place or moving, that the model does not account for.

7.2.2 Robust II

To see if there are any major differences in the results when switching the proxy for extending driving range from “KjorerMer” to “LengerForsikret”, I have presented the results of logit estimation with “LengerForsikret” as a dependent variable. A short summary of the results can be found in specification (6) in Table 7-4, and all results are reported in Appendix 9.2D. “LengerForsikret” is a dummy variable which takes the value of 1 for respondents who have increased their insured driving range after acquiring an EV.

The results in specification (5) and (6) in Table 7-4 show that the two specifications give relatively identical results. Using increased insured driving range as a proxy for increased driving range suggests an even stronger association between replacing a car and increasing driving range, than already seen.

A variable that was insignificant with “KjorerMer”, but was significant with “LengerForsikret”, is the household size variable. Larger households were less likely to drive more after acquiring an EV, which is interesting, but hard to explain. This may be related to large households already having large total driving range, and that the marginal utility of car travels is diminishing.

7.3 Less public transportation

The third empirical illustration focuses on the associations with less use of public transportation after acquiring an EV. A summary of the results can be found in specification (7) in Table 7-4, while the full set of regression result can be found in Appendix 9.2D.

Age is negatively associated with less use of public transportation, which suggests that the older you get, the less likely you are to change travel patterns. The negative association with age can be explained by older people tending to be more conservative and less receptive to large changes in general.

Being male is negatively associated with using less public transport, which means that females to a greater extent move away from public transport after acquiring an EV.

Place of residency did not seem to have any effect on less public transport, which is interesting considering that cities in Norway have a better developed public transportation system than most rural areas. Therefore, one might expect that there to be more fluctuation from public transport in rural areas, but this is not case, according to the results.

Having replaced one or multiple cars is negatively associated with less public transport, which is not so surprising, given that the amount of alternatives to public transport (indicated by the number of household's vehicles) is unchanged or reduced.

There are few policy variables that have significant effect on the probability for using less public transport. Having stated that access to bus lanes and free parking was of importance when buying an EV is positively associated with using less public transportation after acquiring it. This makes sense if valuing certain privileges indicates the intention of exploiting them, and if so, then valuing privileges related to the use of EVs might indicate their intention to drive more and use less public transport.

The third variable that was positively associated with using less public transport is valuing environmental advantages of the EV. One may speculate that it seems that some individuals are convinced that the environmental benefits of EVs are so great, that they surpass that of public transport, and hence consume less of it.

7.4 Marginal probability

There are multiple ways to present results from a logit regression. Tables 7-1 to 7-4 showed which variables that had a significant effect on the probability for "success" for the dependent variable and whether it was positive or negatively associated, but it did not show the magnitude of their effects. Table 7-5 shows the marginal effects for some of the explanatory variables, estimated in sample means, so-called PEA (Partial effects of the average).

Specification	**(8)**
Dependent variable	**EnesteElbil**
Estimation method	**Marginal Logit**
Alder	-.004**
	(4.11)
Mann	-0.022
	(0.91)
MedInntekt	-0.174**
	(0.593)
HoyInntekt	-0.227**
	(7.44)
StorBy	0.132**
	(3.29)
By	0.084*
	(2.01)
Tettsted	0.060
	(1.48)
Miljoorg	0.107**
	(4.15)
Erstatning	0.211**
	(11.3)
KortJobbdistanse	-0.06
	(1.46)
MidJobbdistanse	-0.10*
	(2.26)
LangJobbdistanse	-0.145**
	(4.12)
NyElbil	0.051*
	(2.37)
Sample size	1450

Table 7-5, Marginal effects * p<0.05; ** p<0.01, z-values reported in parentheses.

For the “average” individual of the sample, moving from an income level of low income to high income will lower the probability of only owning EV(s) with 22.7 percent. Individuals living in Oslo, Bergen and Trondheim have a 13.2 percent higher probability, compared to individuals living in a rural area, and individuals that are part of an environmental group have a 10.7 percent higher probability of only relying on the EV.

As discussed in Section 6.7, it can be more informative to compare and report differences in estimated probabilities for two individuals with different characteristics.

For instance, from the logit estimation from specification (8) in Table 7-4, among EV owners the probability of only using the EV is as high as 28.5 percent when the following conditions apply: living in a household of three in either Oslo, Bergen or Trondheim, having household gross income between 600,000 NOK and 1,000,000 NOK, having replaced one or multiple cars, and living more than 45 kilometres away from his work place/school.

The estimated probability for a person with the same characteristics, but who is 20 years older is 17.8 percent, which shows once again that age is negatively associated with only owning EV(s). For this person, the probability of only owning EV(s) is reduced by 10.7 percentage points (ceteris paribus).

7.6 Checking for multicollinearity

The results in Table 7-4 showed that the valuing certain policy variables had mostly an insignificant effect on the respondents' probability of only relying on EV, increasing driving range or using less public transport after acquiring an EV.

One possible explanation for this lack of statistical significance could be high correlation between the respondents' assessment of the various policy incentive variables, i.e., there might be a multicollinearity problem in the data set. Table 9.2C in the Appendix displays the correlation coefficients between these policy incentive variables. The highest correlation coefficient (0.43) is found between "BetydningAaravgift" and "BetydningDrift", whereas the coefficients for correlation between "BetydningParkering" and "BetydningAarsavgift", "BetydningBom" and "BetydningParkering" is 0.33 and 0.35, respectively.

To see if the model specification (2), (5) and (7) suffered from a multicollinearity problem, I removed "BetydningAarsavgift", "BetydningBom", "BetydningFerge", "BetydningParkering" and "BetydningDrift" from the model specifications. Results from these estimations can be found in specification (8), (9) and (10) in Appendix 9.2D. The results show that there were no large differences between the initial model specifications and the specification with less policy variables. The same policy variables were insignificant and significant for both models, which suggests that multicollinearity was not the cause of the insignificant results.

8 Implications of empirical findings

8.1 Connections to the controversy

Given the interesting and rather heated debate on the EV policy, see Section 4, it would have been useful to bring some hard evidence into the discussion. Unfortunately, the data I have had access to in this study do not fully answer to this. Nevertheless, there are some important findings that I would like to convey, which relate to the discussion and may potentially be used in the continuing evaluation of the policies.

As discussed in Section 4, it has been questioned to what extent the EV is the only car in the family, or if it just represents a convenient, additional mode of transportation for the households. Table 5-1 shows that for about one quarter of the EV owners in the sample have EV is the only type of vehicle. Section 7.1 discussed characteristics of the EV owners who have fully invested in the EV, and the results indicate that they often belong to a low-income household living in cities. This supports the claim of some economists, such as Holtsmark (2012), that the EV policy is exploited by well-off households to take advantage of subsidies and privileges by adding another car to their car park. An interesting result from Table 7-3 is that it seemed to be no connection between only relying on EV(s) and appreciating various policy incentives.

Somewhat related to the previous point, a concern, that some researchers have brought up, is that the introduction of EVs has led to a greater total driving range among EV owners. Table 5-1 displays that 23 percent of the owners report driving more after acquiring an EV, while 18 percent increased their insured driving range. Thus, these results suggest that a large number of users have actually increased their car driving. It is interesting, however, that privileges related to use of EVs do not seem to have an effect on the respondent's travel patterns. As already discussed, I am convinced that the response is reliable on this point.

The increased car driving may have come at the expense of public transportation, a problem raised by Holtsmark and Skonhoft (2015) and Frøyen et al. (Prosam, 2009). Table 5-1 shows that 16 percent of the sample reported to be using less public transport after acquiring an EV, which is a non-negligible share. Reduced public transportation is a negative adverse effect of the policy, and results in Table 7-4 suggest that valuing access to bus lanes and free parking is negatively associated with EV owners' propensity to use less public transport.

EVs' contribution to reduce emission of GHG has also been debated, see Section 4.1. Fridstrøm (Dagens Næringsliv, 2015b) and Holtsmark and Skonhoft (2015) operated with different numbers, and come to a different conclusion when evaluating the overall contribution from electrifying the car pool. By updating the figures into 2015 figures, I end up with a reduction of GHG-emission that places itself between the two opposing sides. According to my calculations, 50,000 EVs will lead to a reduction of 81,000 ton of CO^2 each year. This result supports the claim by Jørgensen et al. (2010), that it is expensive to use EVs as an instrument to reduce GHG-emission.

The results in Chapter 7 suggest that there is little connection between valuing policy incentives and the goals of the EV policy, in general. The reason for this may be that the incentives are not effective in what they are trying to achieve, or, as already discussed in Section 5.3, the respondents may not wish to admit that they are affected by the policy in order to protect their self-interest.

What does seem to have an effect, however, is car replacement. Households who replaced one or multiple vehicles had in general a higher probability of only relying on EVs, they do not tend to drive more *or* use less public transportation after acquiring an EV, which all are objectives of the EV policy. If the acquired EV replaced another car, it would mean that the old car(s) were either sold or deposed. I interpret these results as supportive of the EV policy.

The findings in Table 7-4 indicate that making it easier to replace already owned cars will improve the policy outcomes, and this result is in line with the results found by DeShazo (2016) on vehicle retirement. DeShazo points out the environmental benefits of retiring vehicles, and he states that low-income households are more likely to retire relatively older and more polluting vehicles compared to high-income households.

There is, however, no direct link between replacing a vehicle and retiring a vehicle, and there was no significant association between the propensity to replace a car and level of income in my data set (specification (11) in Appendix 9.2D). This means that DeShazo's argument of giving low-income households stronger incentives may not have a positive effect on replacement rate. Differentiated EV policy may be difficult to implement. It can, however, contribute to more overall economic equality, by giving more resources to those who have less, which may be seen as an overall goal of the Government's policies.

Lastly, removing the privileges of free parking and access to bus lanes for EVs may encourage EV owners to keep using public transport, as there is a statistical significance between valuing these incentives and using less public transportation. There are already some distances where denied access to bus lanes for EVs are in effect, and these distances have experienced less delay for buses and a higher overall satisfaction of public transport (NRK, 2016). Removing these privileges may result to additional use of public transport in the future.

8.2 Strengths, weaknesses and future research

The validity of the results in the empirical illustrations is strongly related to strengths and weaknesses of the data set, which was discussed in the Section 5.3. The main problem with the data set at hand is that it only included EV owners, which limit information on implications of changing policy. Of course, a panel data set with information about all types of car owners would have given opportunities for obtaining more clear-cut answers.

For example, an interesting research investigation for the future is to examine the supply and demand elasticities for EVs, and to include the results from this research in a review of the policy The price sensitivity of the supply and demand sides appear to be important for a better understanding of the policy implications.

Nevertheless, the empirical also shed some light on a research field that is relatively new and unexplored. This is reflected by the many disagreements among researchers. Given that it seems that the EV policy is under continuous evaluation, it is assumed that the information provided here is valuable too. Being such a new field and market, one expects that the policies are adjusted in the future, and some of the findings provided here may be used in these endeavours.

8.3 Summary

In this master's thesis I have reviewed and discussed some of the arguments made in the Norwegian EV policy debate. Further, I have applied binary choice models on a cross-sectional data set of 1,722 Norwegian EV-owners, to shed some light on certain research questions raised by economists in the field. The highlighted questions in this master's thesis included to what extent the policy has stimulated the EV being an additional car to the household, and have EV privileges had any significant effect on EV owners' propensity to drive more or use less public transport after acquiring an EV. I have also updated some of the calculations used to review the policy from earlier year into 2015-figures, to see if the evaluations still hold today.

My findings provide some suggestions on the effects of the EV policy, but no clear-cut answer on the overall evaluation. There was a large share of EV owners in the sample who possess an additional conventional car, and there was a considerable number of respondents reporting to have increased the driving range and used less public transportation. In short, this study has left some questions on the influence of the EV policy. We are most likely on the move to more EVs. To what extent the EV policy has contributed to this – or what the outcomes would have been without these policy initiatives, however, is hard to assess.

9 References and appendices

9.1 References

A lot of published articles and books have contributed to this master's thesis.

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9.2 Appendix

9.2A Variable explanation

Dependent variables

EnesteElbil – Dummy on whether respondent only have EV(s). 1 if only EV(s), 0 otherwise.
KjorerMer – Dummy on whether the respondent stated to be driving more after acquiring an EV. 1 if the case, 0 otherwise.
LengerForsikret – Dummy on whether respondent increased insured driving range after acquiring an EV. 1 if the case, 0 otherwise.
MindreKollektivt – Dummy on whether the respondent stated to be using less public transport after acquiring an EV. 1 if the case, 0 otherwise.

Personal characteristics

Alder – Respondent's age
Mann **–** Gender dummy. 1 if male, 0 if female
Hustandsstr – Number of residents in respondent's households
Miljoorg – Dummy on whether respondent is a member of an environment organisation. 1 if the case, 0 otherwise.

LavInntekt – Dummy on whether respondent's household has a combined yearly gross income lower than 600,000 NOK. 1 if the case, 0 otherwise.
MidInntekt – Dummy on whether respondent's household has a combined yearly gross income between 600,000 and 1 000,000 NOK. 1 if the case, 0 otherwise.
HoyInntekt – Dummy on whether respondent's household has a combined yearly gross income higher than 1 000,000 NOK. 1 if the case, 0 otherwise.
IkkeOnsker – Dummy on whether the respondent did not wish to declare their income. 1 if the case, 0 otherwise.

Storby – Dummy on whether respondent lives in either Trondheim, Bergen or Oslo. 1 if the case, 0 otherwise.
By **–** Dummy on whether respondent lives in a city excluding Trondheim, Bergen and Oslo. 1 if the case, 0 otherwise.
Tettsted **–** Dummy on whether respondent lives in a densely populated area outside a city. 1 if the case, 0 otherwise.
AnnetBosted **–** Dummy on whether respondent lives in a rural area. 1 if the case, 0 otherwise.

Driving demand variables

Jobbdistanse – Distance to work place/school from Home

IngenJobbdistanse – Dummy on whether the person has no travel distance to work/school. 1 if the case, 0 otherwise

KortJobbdistanse – Dummy on whether the person has travel distance to work/school greater than 0 kilometres, but less than 16 kilometres. 1 if the case, 0 otherwise.

MedJobbdistanse **–** Dummy on whether the person has travel distance to work/school greater than 15 kilometres, but less than 45 kilometres. 1 if the case, 0 otherwise.

LangJobbdistanse **–** Dummy on whether the person has a travel distance to work/school equal to 45 kilometres or more. 1 if the case, 0 otherwise.

NyElbil – Dummy on whether respondent's newest car was acquired in the last 12 months. 1 if the case, 0 otherwise.

Policy variables

Erstatning **–** Dummy on whether their EV replaced one or multiple cars in the household. 1 if the case, 0 otherwise.

BetydningSikkerhet – Dummy on whether EV safety was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise

BetydningMiljo – Dummy on whether the environmental properties of EVs were either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningPris – Dummy on whether EVs' price was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningAarsavgift – Dummy on whether EV's yearly fee was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningDrift – Dummy on whether EVs' operational cost was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

B*etydningKollektiv* – Dummy on whether EV access to bus lanes was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningBom **–** Dummy on whether free toll roads for EVs was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningFerge – Dummy on whether free pass on ferries was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

BetydningParkering – Dummy on whether free parking for EVs was either important or very important to the respondent when choosing to buy an EV. 1 if the case, 0 otherwise.

9.2B Model specifications

(1) – Linear probability model for "EnesteElbil"

(1)*EnesteElbil* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(2) – Logit model for "EnesteElbil"

(2)*EnesteElbil* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(3) – Probit model for "EnesteElbil"

(3)*EnesteElbil* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(4) – Robust I: Logit for "EnesteElbil" on a smaller sample

(4)*EnesteElbil* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(5) – Logit model for "KjorerMer"

(5)*KjorerMer* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(6) – Robust II: Logit model for "LengerForsikret"

(6)*LengerForsikret* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(7) – Logit model for "MindreKollektivt"

(7)*MindreKollektivt* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningAarsavgift + BetydningDrift
+ BetydningKollektiv + BetydningBom + BetydningFerge + BetydningParkering

(8) – Checking for multicollinearity I: Logit mode for "EnesteElbil" with fewer policy variables

(8)*EnesteElbil* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningKollektiv

(9) – Checking for multicollinearity II: Logit model for "KjorerMer" with fewer policy variables

(9)*KjorerMer* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg
+ KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningKollektiv

(10) – Checking for multicollinearity III: Logit model for "MindreKollektivt" with fewer policy variables

(10)*MindreKollektivt* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted
+ Miljoorg + KortJobbdistanse + MidJobbdistanse + LangJobbdistanse + NyElbil + Erstatning
+ BetydningSikkerhet + BetydningMiljo + BetydningPris + BetydningKollektivt

(11) – Logit model for "Erstatning"

(10)*Erstatning* = Alder + Mann + Hustandsstr + MedInntekt + HoyInntekt + StorBy + By + Tettsted + Miljoorg

9.2C Table: Correlation

Betydning-	Miljo	Pris	Aarsavgift	Drift	Kollektiv	Bom	Ferge	Parkering	Sikkerhet
Miljo	1.0000								
Pris	0.0594	1.0000							
Aarsavgift	0.0758	0.2731	1.0000						
Drift	0.0135	0.2237	0.4333	1.0000					
Kollektiv	-0.0565	-0.0227	0.1134	0.0412	1.0000				
Bom	-0.0759	0.1149	0.3447	0.3161	0.2376	1.0000			
Ferge	-0.0008	0.0835	0.2529	0.1303	0.1441	0.2574	1.0000		
Parkering	0.0671	0.0253	0.3311	0.2015	0.2613	0.3512	0.3177	1.0000	
Sikkerhet	0.1240	0.1831	0.0634	0.0605	-0.0162	0.0477	0.0763	0.0315	1.0000

9-1: Correlations between different policy incentives in the data set. N=1450.

9.2D Estimation results

Specification	(1)	(2)	(3)
Dependent Variable	EnesteElbil	EnesteElbil	EnesteElbil
Estimation Method	LPM	Logit	Probit
Constant	0.632***	0.621	0.503
	(5.93)	(0.89)	(1.27)
Alder	-0.00450***	-0.0305***	-0.0174***
	(-4.00)	(-4.03)	(-4.08)
Mann	-0.0285	-0.157	-0.125
	(-1.09)	(-0.91)	(-1.28)
Hustandsstr	-0.0399***	-0.290***	-0.166***
	(-4.70)	(-4.45)	(-4.56)
MedInntekt	-0.239***	-1.239***	-0.724***
	(-6.15)	(-5.67)	(-5.73)
HoyInntekt	-0.296***	-1.623***	-0.927***
	(-7.50)	(-6.90)	(-6.89)
StorBy	0.138***	0.943**	0.490**
	(3.65)	(3.21)	(3.02)
By	0.0811*	0.599*	0.309
	(2.10)	(1.99)	(1.84)
Tettsted	0.0577	0.425	0.196
	(1.61)	(1.47)	(1.23)
Miljoorg	0.124***	0.765***	0.439***
	(3.83)	(4.07)	(4.03)
KortJobbdistanse	-0.0648	-0.442	-0.246
	(-1.12)	(-1.41)	(-1.33)
MidJobbdistanse	-0.106	-0.714*	-0.399*
	(-1.85)	(-2.24)	(-2.12)
LangJobbdistanse	-0.166**	-1.268**	-0.720**
	(-2.68)	(-3.19)	(-3.18)
NyElbil	0.0533*	0.366*	0.194*
	(2.45)	(2.34)	(2.19)
Erstatning	0.215***	1.814***	0.949***
	(10.84)	(7.90)	(8.23)
BetydningSikkerhet	0.0483*	0.291	0.170
	(2.02)	(1.89)	(1.90)
BetydningMiljo	0.00663	0.0616	0.0242
	(0.30)	(0.39)	(0.27)
BetydningPris	-0.00652	-0.0422	-0.0202
	(-0.29)	(-0.26)	(-0.22)
BetydningAarsavgift	-0.0190	-0.0890	-0.0466
	(-0.78)	(-0.53)	(-0.48)
BetydningDrift	0.00583	0.0371	0.00160
	(0.19)	(0.17)	(0.01)
BetydningKollektiv	-0.00765	0.0164	-0.00217
	(-0.32)	(0.09)	(-0.02)
BetydningBom	-0.0194	-0.185	-0.0875
	(-0.78)	(-1.09)	(-0.90)
BetydningFerge	0.000591	-0.000287	0.00521
	(0.02)	(-0.00)	(0.04)
BetydningParkering	0.0120	0.0512	0.0259
	(0.49)	(0.30)	(0.27)
R-squared	0.188		
Adjusted R-squared	0.174		
Pseudo R-squared		0.187	0.183
N	1450	1450	1450

Table 9-2: Estimation results from specification (1), (2) and (3). t and z statistics in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Specification	(4)	(5)	(6)	(7)
Dependent Variable	EnesteElbil	KjorerMer	LengerForsikret	MindreKollektivt
Estimation Method	Logit	Logit	Logit	Logit
Constant	-0.395	-0.267	-0.433	0.451
	(-0.26)	(-0.42)	(-0.56)	(0.57)
Alder	-0.0317***	-0.0112	-0.0135	-0.0297***
	(-3.97)	(-1.61)	(-1.72)	(-3.42)
Mann	-0.162	0.119	0.0232	-0.419*
	(-0.91)	(0.75)	(0.13)	(-2.46)
Hustandsstr	-0.284***	-0.104	-0.134*	-0.0478
	(-4.32)	(-1.78)	(-2.17)	(-0.78)
MedInntekt	-1.233***	-0.195	0.460	-0.494
	(-5.27)	(-0.89)	(1.79)	(-1.87)
HoyInntekt	-1.621***	-0.283	0.319	0.0519
	(-6.58)	(-1.23)	(1.20)	(0.20)
StorBy	1.037**	-0.0540	0.0615	0.679
	(3.17)	(-0.21)	(0.20)	(1.80)
By	0.683*	0.0621	0.379	0.547
	(2.05)	(0.23)	(1.23)	(1.42)
Tettsted	0.559	-0.145	0.158	0.463
	(1.72)	(-0.58)	(0.53)	(1.28)
Miljoorg	0.744***	0.309	0.387	-0.199
	(3.78)	(1.74)	(1.95)	(-0.85)
KortJobbdistanse	0.644	0.314	0.230	0.540**
	(0.45)	(0.92)	(1.37)	(2.98)
MidJobbdistanse	0.374	0.0246	0.320	-0.0184
	(0.26)	(0.07)	(1.75)	(-0.09)
LangJobbdistanse	-0.165	-0.429	-0.327	-0.326
	(-0.11)	(-1.09)	(-1.41)	(-1.35)
NyElbil	0.375*	0.143	-0.0414	0.504**
	(2.30)	(1.01)	(-0.24)	(2.68)
Erstatning	1.730***	-0.566***	0.131	-0.310
	(7.43)	(-4.06)	(0.31)	(-0.74)
BetydningSikkerhet	0.218	0.213	0.526	-0.122
	(1.36)	(1.43)	(1.24)	(-0.29)
BetydningMiljo	0.145	-0.0330	0.516	-0.109
	(0.88)	(-0.22)	(1.14)	(-0.24)
BetydningPris	-0.00693	0.0144	-0.142	-0.0509
	(-0.04)	(0.10)	(-0.93)	(-0.30)
BetydningAarsavgift	-0.0957	0.119	-1.378***	-1.187***
	(-0.54)	(0.71)	(-9.40)	(-7.47)
BetydningDrift	-0.127	-0.157	0.0496	0.0940
	(-0.58)	(-0.79)	(0.29)	(0.51)
BetydningKollektiv	0.0183	0.179	0.0299	0.359*
	(0.10)	(1.15)	(0.18)	(2.04)
BetydningBom	-0.163	0.0141	0.0167	-0.144
	(-0.94)	(0.08)	(0.10)	(-0.84)
BetydningFerge	0.0288	0.0124	-0.236	0.0627
	(0.13)	(0.06)	(-1.30)	(0.30)
BetydningParkering	0.0739	0.182	-0.247	-0.395
	(0.42)	(1.14)	(-1.17)	(-1.75)
Psuedo R-squared	0.177	0.034	0.095	0.111
N	1372	1450	1450	1450

Table 9-3: Estimation results from specification (4), (5), (6) and (7). z statistics in parentheses.
*** $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.**

Specification	(8)	(9)	(10)	(11)
Dependent Variable	EnesteElbil	KjorerMer	MindreKollektivt	Erstatning
Estimation method	Logit	Logit	Logit	Logit
Cosntant	0.558	-0.247	0.323	1.445***
	(0.83)	(-0.40)	(0.43)	(3.45)
Alder	-0.0309***	-0.0105	-0.0290***	-0.0111*
	(-4.11)	(-1.51)	(-3.35)	(-1.98)
Mann	-0.138	0.0902	-0.443**	0.218
	(-0.81)	(0.58)	(-2.64)	(1.61)
Hustandsstr	-0.293***	-0.107	-0.0676	-0.0224
	(-4.50)	(-1.83)	(-1.10)	(-0.47)
MedInntekt	-1.226***	-0.209	-0.500	0.118
	(-5.63)	(-0.96)	(-1.93)	(0.63)
HoyInntekt	-1.589***	-0.318	0.0627	0.206
	(-6.84)	(-1.39)	(0.24)	(1.09)
StorBy	0.907**	-0.0451	0.740*	-0.378
	(3.13)	(-0.18)	(2.01)	(-1.77)
By	0.588*	0.0691	0.634	-0.164
	(1.97)	(0.26)	(1.68)	(-0.72)
Tettsted	0.410	-0.140	0.530	-0.216
	(1.43)	(-0.56)	(1.49)	(-1.00)
Miljoorg	0.776***	0.312	-0.162	-0.0989
	(4.15)	(1.78)	(-0.71)	(-0.61)
KortJobbdistanse	-0.428	0.312	-0.305	
	(-1.37)	(0.92)	(-0.73)	
MidJobbdistanse	-0.729*	0.00789	-0.168	
	(-2.30)	(0.02)	(-0.40)	
LangJobbdistanse	-1.290***	-0.474	-0.225	
	(-3.31)	(-1.21)	(-0.49)	
NyElbil	0.364*	0.135	-0.0705	
	(2.34)	(0.96)	(-0.42)	
Erstatning	1.809***	-0.570***	-1.178***	
	(7.93)	(-4.10)	(-7.50)	
BetydningSikkerhet	0.285	0.220	0.0849	
	(1.85)	(1.49)	(0.47)	
BetydningMiljo	0.0702	-0.0237	0.392*	
	(0.44)	(-0.16)	(2.25)	
BetydningPris	-0.0792	0.0326	-0.201	
	(-0.52)	(0.24)	(-1.23)	
BetydningKollektivt	-0.0277	0.248	0.604***	
	(-0.17)	(1.66)	(3.58)	
Psuedo R-squared	0.186	0.032	0.102	0.007
N	1450	1450	1450	1450

Estimation results from specification (8), (9), (10) and (11). z statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$