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Bonus Slopus: Examining the Effect of Removing Bonus Incentives for Electric Vehicles on Adoption

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Abstract:
In the global battle against climate change, the pursuit of sustainable transportation, particularly through the adoption of electric vehicles (EVs), has become a central focus. This thesis investigates the specific case of Sweden and delves into the repercussions of removing the climate bonus subsidy for EVs, exploring its immediate and potential long-term impacts on the market. The paper contextualizes the significance of EVs in climate change mitigation, emphasizing their transformative role in the transportation sector. As Sweden has a prominent leadership role in EV adoption, the study aims to provide valuable insights into the consequences of subsidy removal in this unique context. Employing a Difference-in-Difference design and drawing on a dataset spanning from May 2021 to October 2023, the study compares the share of newly registered passenger EVs in Sweden compared to a counterfactual scenario using Danish market trends. The results indicate a statistically significant decrease in the share of EV registrations post-subsidy removal, supporting the hypothesis that the climate bonus removal adversely affected EV demand. However, the failure of the parallel trends assumption calls into question the internal validity of the results, although comparability and direction purposes maintain their importance. The Swedish case is particularly intriguing due to its historical policy measures, a robust EV market, and its signaling effects on global EV adoption. The study not only aligns with theoretical expectations but also contributes to existing literature by offering nuanced insights into Sweden's unique EV landscape. The findings emphasize the crucial role of subsidies in influencing consumer behavior and shaping the trajectory of EV adoption.

Keywords: BEV, ICEV, PHEV, Green Transition, Climate Change Mitigation, Bonus Malus, Incentives

JEL: H20, H23, H24, H60, O31, O38

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1. Introduction

In the global effort to combat climate change, individuals and businesses are actively exploring diverse strategies to reduce their carbon footprints. While personal choices vary from dietary changes to alternative modes of transportation, businesses adopt initiatives ranging from large-scale campaigns to adjustments in production processes. Despite the differences in approach, the shared objective is a universal one – the reduction of carbon emissions. Given that the transportation sector significantly contributes to global emissions, it has emerged as a primary focus for climate change mitigation efforts (Allen, 2018). Notably, the introduction of electric vehicles (EVs), particularly with Tesla's groundbreaking roadster, has transformed from a niche concept to a mainstream solution in numerous markets. The association between EVs and climate change mitigation has grown synonymous, with major manufacturers leading a substantial green transition toward cleaner and more sustainable transportation.

Recognizing the pivotal role of EVs in reducing CO2 emissions, achieving widespread adoption becomes imperative for effective climate action (Skippon & Garwood, 2011). However, the transition to EVs, like any new technology, comes with its challenges. Companies investing in cutting-edge technology and substantial research and development efforts often necessitate higher prices to cover these costs. Consequently, EVs have initially presented a higher cost compared to traditional internal combustion engine (ICE) cars (GreenCars, 2023).

As governments across borders try to find ways to mitigate climate change, subsidising EVs and taxing ICEs have been popular policy measures, as it brings costs of ownership closer (Diamond, 2009; Hardman, 2019; Liu et al., 2021). The incentives are meant to even out the playing field and yield comparative costs until the EV industry is at a similar stage of maturity as the ICE industry – where they are then to reduce incentives when costs are comparable in themselves. However, some argue that this a costly, inefficient way to reduce emissions, and that the EV industry is already at a comparable stage of maturity to other vehicles. Many previous econometric studies evaluating similar subsidy programs have found that the impact on the proliferation of environmentally friendly cars to be relatively small and constitute an expensive means to achieve environmental benefit**.** (Diamond, 2009; Beresteanu & Li, 2011; Huse & Lucinda, 2014). The Swedish National Audit Office, tasked with auditing the government, authorities and companies, stated in a report related to the Bonus Malus policy in 2020 that it "[…] has reviewed the government's policy instruments and the review shows that the policy instruments for the purchase and ownership of green cars are not effectively designed and appear to be costly in comparison with other measures used today to reduce the transport sector's carbon dioxide emissions"[1] (Riksrevisionen, 2020).

The Swedish context is particularly interesting due to the country's role as a leader in BEV adoption. This leads to signaling effects from Swedish policy which are important for the rest of the world. Although the cost efficiency of the Bonus Malus system has been critized, and the Swedish government having stated that the stage of the EV market is comparable to the ICEV market (Regeringen, 2023), previous research finds that subsidies still have a significant effect on adoption. Hence, the immediate and long-term effects of the climate bonus removal are interesting to analyze.

Governments, such as the one in Sweden, are looking into removing subsidies and costly incentives, at times where other economic priorities may rank higher. Thus, while the effects of subsidies for EVs and fuel price taxation are long documented and researched, there is still a large

[1] Translated from Swedish: "Riksrevisionen har granskat regeringens styrmedel och granskningen visar att styrmedlen för köp och ägande av miljöbilar inte är effektivt utformade och framstår som kostsamma i jämförelse med andra åtgärder som används idag för att minska transportsektorns koldioxidutsläpp"

gap in understanding how the removal of such subsidies and taxes affect the market. This effect is crucial to understand when societies move forward into the future of transportation and climate change mitigation: Are we undoing the progress we have made in the transition to electric vehicles, or are consumer preferences changed for good?

This paper aims to address this gap by evaluating the effect of Sweden's removal of the climate bonus ("Klimatbonusen") EV subsidy. The transition towards sustainable transportation is a global imperative, and understanding the repercussions of discontinuing incentives is paramount for policymakers and stakeholders. The knowledge gap in the existing literature becomes apparent when exploring the effects of subsidy removal on EV adoption. While numerous studies have investigated the impact of incentives on electric vehicle uptake (Diamond, 2009; Beresteanu & Li, 2012; Hardman, 2019; Liu et al., 2021), the focus on the specific removal of a substantial bonus remains underexplored, especially in the Swedish context. This thesis aims to address this gap by offering a comprehensive analysis that the immediate effects as well as delving into the potential long-term implications of such policy decisions.

This paper examines several dimensions of the Swedish context, considering factors such as consumer preferences, market dynamics, and policy influence. Through the examination of data spanning the pre- and post- policy period, this study provides valuable insights into how the removal of the climate bonus shapes the trajectory of pure EV adoption in Sweden.

I employ a Difference-in-Difference design, comparing the share of newly registered passenger vehicles of BEVs - the only vehicle eligible for the climate bonus since May 2021 - with shares of ICEs and Hybrids that were not granted the bonus from May 2021– October 2023. The findings indicate a statistically significant difference in the share of newly registered passenger BEVs from the counterfactual, demonstrating that the removal of the climate bonus has had a negative impact on the demand for BEVs. Like previous studies of a similar nature, the estimated effect is relatively small, with an average decrease in the share of BEVs of approximately 0.122 %-points.

The Danish EV market is used as a counterfactual with a parallel trend. I use a panel data set of 32 NUTS-3 regions in Sweden (21 Counties) and Denmark (11 Provinces) with monthly time series data that ranges from May 2021 until October 2023. Registration is chosen both due to data availability and due to the volatile nature of order book data, as it represents pre-sales orders made by customers. While it indicates interest, it doesn't guarantee actual ownership or adoption, as customers might change their minds or face delays in delivery. Furthermore, to control for various differing other policy and macroeconomical trends, the research focuses on the share of BEV registrations, rather than the count. Using shares provides a normalized measure that accounts for the growth or decline in the overall vehicle market, gives a clear indication of the relative policy efficiency.

The remainder of this paper is organized as follows: In Section 2, I present historical policy incentives aimed at increasing the share of and provide an overview and background to the Swedish and Danish EV markets. Section 3 includes a review of previous economic and policy research on vehicle incentives. Section 4 and 5 describes the theory, model, data, and methodology used to evaluate the market share data on BEVs. The paper concludes with a presentation of the study's results, discussion as well as limitations and suggestions for further research in sections 6 to 8.

2. Historical Background

2.1 Types of Vehicles

There are different types of vehicles, and looking specifically at the private car market, vehicles are categorized based on drive train and fuel type. As the Bonus Malus system was aimed primarily on increasing the share of battery electric vehicles, it is important to understand the categories.

2.1.1 Internal Combustion Engine Vehicles (ICEV)

An Internal Combustion Engine (ICE) car is powered by a liquid fuel such as diesel or petrol that is burnt (combusted) to generate mobility. ICEVs have been used for over a century to convert the chemical energy released from the combustion of fossil fuels into mechanical energy that propels vehicles (Blackridge Consulting).

2.1.2 Battery Electric Vehicle (BEV)

Battery Electric Vehicles (BEVs) represent a departure from traditional vehicular propulsion, relying exclusively on electricity and devoid of an ICE, fuel tank, and exhaust system. Instead, they integrate one or more electric motors powered by a substantial onboard battery. User recharging of the battery occurs mainly through an external outlet. The versatility of BEVs extends across various vehicle types, encompassing cars, buses, motorcycles, scooters, and marine vessels (Aptiv, 2021).

2.1.3 Hybrid Electric Vehicle (HEV)

Hybrid Electric Vehicles (HEVs) constitute a well-established category of hybrid vehicles incorporating dual power sources - an ICE and a larger battery-driven electric motor. These vehicles initiate motion under electric power, transitioning seamlessly to gas power at higher speeds. An integrated computer system manages the optimal allocation of electricity or gas. In contrast to fully electric vehicles (EVs), HEVs do not necessitate user involvement in the charging process. The application of "regenerative braking" facilitates a modest recharge of the electric battery during braking events. Notably, the Toyota Prius stands as a representative model within this category (Aptiv, 2021).

2.1.4 Plug-in Hybrid Electric Vehicle (PHEV)

Plug-in Hybrid Electric Vehicles (PHEVs) assume an intermediary position between BEVs and HEVs, featuring an externally rechargeable electric motor, akin to BEVs. Concurrently, they integrate a fuel-based ICE, reminiscent of HEVs. A distinctive feature of PHEVs is their capability to cover a considerable distance solely on electric power - around 30-50 kilometers - attributed to an enlarged battery size and the capacity to recharge from the electrical grid. Prominent examples of PHEVs include variants of the Toyota Corolla and RAV4, the Volvo XC40, and the BMW 3-Series (Aptiv, 2021).

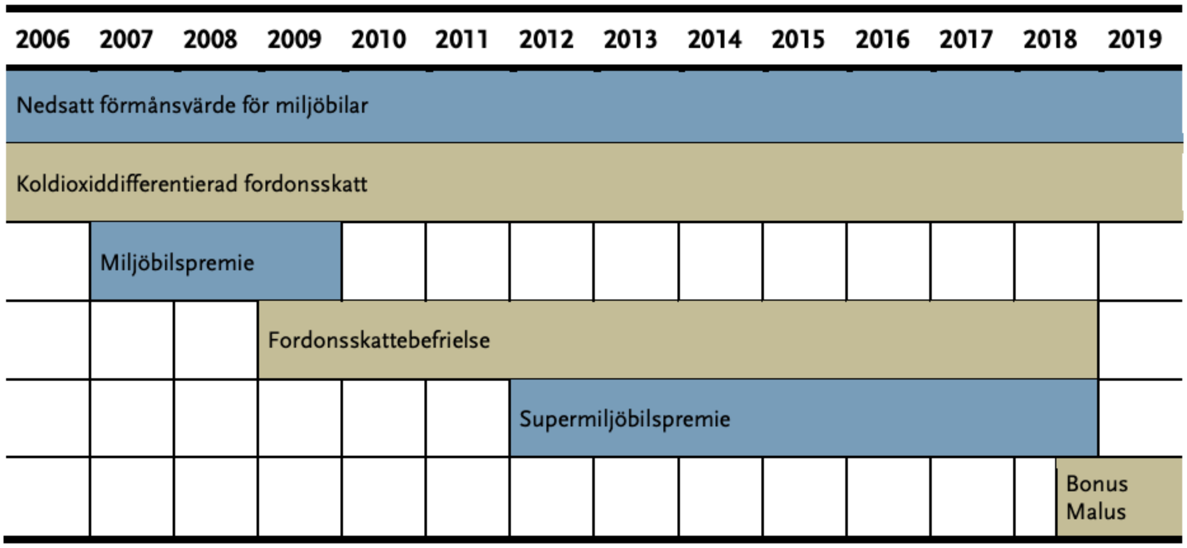
2.2 Historical Policies to Foster EV Adoption

In the pursuit of advancing sustainable transportation, both Sweden and Denmark have implemented various policies over the years to promote the adoption of Electric Vehicles (EVs). This section provides an overview of the historical policy landscape in these two countries, shedding light on the measures undertaken to encourage the transition towards cleaner and more environmentally friendly modes of mobility.

2.2.1 Swedish EV Policy

The Swedish parliament ("Riksdag") has adopted target to reduce greenhouse gas emissions by 70% from domestic transport to 2030 compared to 2010 (prop. 2016/17:146). Sweden employs various policy instruments aimed at steering transportation and the passenger car market in desirable directions. These policies, driven not only by fiscal considerations but also by the aim to address undesirable effects like greenhouse gas emissions, pollutants, noise, congestion, and accidents, as well as promote desirable effects such as rapid technological development, are crucial. The primary tools utilized include taxes and fees associated with vehicle usage, such as fuel taxes or congestion charges, strategically designed to counteract the undesired effects. Policies facilitating the purchase and ownership of environmentally friendly cars are grounded in the necessity of promoting new, low-carbon technologies to mitigate the climate impact of the transportation sector. The provision of support for the purchase of environmentally friendly cars is occasionally attributed to the buyer's "shortsightedness," meaning the inability to fully consider all relevant future costs associated with increased fuel taxes at the time of car purchase (RIR 2020:1).

Figure 1: Timeline of Historical Swedish Policies



(RIR 2020:1)

2.2.1.1 Swedish Direct EV Subsidies

The purpose of Swedens historical subsidies for environmental cars have largely been the same for the Environmental Car Premium ("Miljöbilspremien"), the Super Environmental Car Premium ("Supermiljöbilspremien"), and the Climate Bonus ("Klimatbonusen"): to promote increased sales and usage of new cars with low environmental impact (1§ SFS 2007:380; 1§ SFS 2011:1590; 1§ SFS2017:1334). Furthermore, the subsidies aimed to reduce the climate effect from the Swedish transport sector (prop 2017:18:1 - 6.5.3). The subsidies have entailed payouts of differing amounts depending on certain carbon dioxide conditions, with an increasing payout amount for vehicles with lower emissions (starting with the Super Environmental Car Bonus).

In an amendment to the climate bonus, (April, 2021) the maximum bonus for PHEVs decreased by 10 000 sek, whereas it increased the bonus from a maximum of 60 000 sek to a maximum of 70 000 sek (SFS 2021:200; Bergman, 2021). In 2022, the maximum allowed CO2 emissions to qualify for the bonus went from 60 g/km to 50 g/km (SFS 2022:801). Later, on November 8th, 2022, the climate bonus ceased entirely, and all vehicles purchased after the date were ineligible to receive a payout (Transportstyrelsen, 2022). The Swedish government stated that this was due to that the cost of owning and driving a climate bonus vehicle is starting to be comparable to owning and driving a petrol or diesel car (Regeringen, 2023).

In Table 1 , the various subsidies and their conditions are shown. The table is inherited from RIR 2020:1 and modified.

Table 1, Swedish Historical Environmental Car Subsidies

	Environmental Car Premium	Super Environmental Car Premium	Climate Bonus
Target Group	Physical Persons	Pysical and Legal Persons	Physical and Legal Persons
CO2 Conditions	120 g/km[1]	50 g/km[2]	50 - 60 - 70 g/km[3],
Premium	10 000 sek	20 000[4]–40 000[5] sek	10 000[6]-60 000[7] sek, 10 000-70 000[8] sek
Payout	6 months after purchase	When registering new vehicle	6 months after purchase

(RIR 2020:1; SFS 2021:200)

1) Applies to requirements for gasoline, diesel, and plug-in/electric hybrids. For gas, electric, and ethanol cars, fuel efficiency requirements applied instead. 2) Mainly electric cars and plug-in hybrids meet this limit. 3) Primarily electric cars and plug-in hybrids meet this limit. However, gas cars also receive a bonus. The higher figure in parentheses is in line with budget proposal for 2020. 4) Refers to other super environmental cars. 5) Until 2016, all super environmental cars received 40,000 kronor. From 2016, only zero-emission cars received the highest bonus. For legal entities, the bonus could be lower, as it could be a maximum of 35 percent of the price difference between the super environmental car and the closest comparable car. 6) Refers to, among other things, gas cars. For legal entities, the bonus may be lower, as it can only be a maximum of 35 percent of the price difference between the climate bonus car and the closest comparable car. 7) Refers to zero-emission cars. Subsidies are granted according to the formula 60,000 – (833 × grams per kilometer). From 2020, 833 was replaced with 714 (RIR 2020:1). 8) As per SFS 2021:200, a vehicle emitting 0 g/km is eligible to receive a bonus of up to 70 000 sek.

2.2.1.2 Lower Vehicle Tax for Environmental Cars

The first use of tax to actively reduce carbon emissions from Swedish roads came from the Road Traffic Tax Act ("Vägtrafikskattelagen", SFS 2006:227). Carbon dioxide differentiation was introduced to reduce carbon dioxide emissions and create effective economic incentives so that car buyers are more likely to choose fuel-efficient cars (prop. 2005/06:1 – 5.5.6). The Swedish Parliament introduced a vehicle tax exemption for the first five years upon the purchase of passenger cars emitting a maximum of 120 grams of carbon dioxide per kilometer in 2009 (prop 2009/10:41). Subsequent amendments were made to the Road Traffic Tax Act (SFS 2006:227). The objective was to continue stimulating the purchase of environmentally friendly cars after the conclusion of the environmental car premium. In 2013, the conditions for the vehicle tax exemption were tightened, and it was extended to include motorhomes, light trucks, and light buses. The tax exemption for new cars ceased with the introduction of the bonus-malus system in 2018 (RIR 2020:1).

In July 2018, as part of the Bonus Malus system, a vehicle tax - malus - was introduced in the budget proposition of 2018 (prop. 2017/18:1). In sum, the vehicle tax to be paid per year were to be based on CO2 g/km emissions. Although BEVs and PHEVs were to pay a set sum of 360 sek per annum, petrol and diesel cars paid a higher vehicle tax based on how much CO2 g/km they emit for the first three years. The first proposition, stemming prop. 2017/18:1, set one threshold value for ICE vehicles with emissions between 95 g CO_2 /km and 140 g CO_2 /km, who were to pay a vehicle tax of 82 sek per g CO_2 /km. For instance, a vehicle emitting 120 g CO_2 /km would pay a vehicle tax of 120 x 82 = 9 840 sek the first three years. For an ICE vehicle emitting more than 140 g CO_2/km, the vehicle tax is 107 sek per g CO_2/km. Furthermore, diesel vehicles are subject to a further environmental addition of 250 sek per year, and an additional fuel addition of 13,52 sek per g CO_2/km per year (Ekonomifakta, 2022). In Table 2, the full set of rates and tax amounts is presented.

Table 2, Malus Vehicle Taxes, the First Three Years, July 2018 – Mars 2021

Propulsion Type	Emissions	Vehicle Tax per Year	Environmental Addition per Year	Fuel Addition per Year
EV/PHEV	< 95 g CO_2/km	360 sek	0 sek	0 sek
Petrol	95-140 g CO_2/km	82 sek per g CO_2/km	0 sek	0 sek
Petrol	> 140 g CO_2/km	107 sek per g CO_2/km	0 sek	0 sek
Diesel	95-140 g CO_2/km	82 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km
Diesel	> 140 g CO_2/km	107 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km

(Ekonomifakta, 2022)

In April 2021, the CO_2 based vehicle tax for ICE vehicles increased whereas the EV/PHEV set amount stayed the same. The lower bound rate – vehicles emitting from 95 g CO_2/km to 140 g CO_2/km – increased from 82 to 107 sek per g CO_2/km, and the higher bound rate – vehicles emitting more than 140 g CO_2/km – increased from 107 to 132 sek per g CO_2/km (Ekonomifakta, 2022). In Table 3, the full set of updated rates and tax amounts is presented.

Table 3, Malus Vehicle Taxes, the First Three Years, April 2021 – May 2022

Propulsion Type	Emissions	Vehicle Tax per Year	Environmental Addition per Year	Fuel Addition per Year
EV/PHEV	< 95 g CO_2/km	360 sek	0 sek	0 sek
Petrol	95-140 g CO_2/km	107 sek per g CO_2/km	0 sek	0 sek
Petrol	> 140 g CO_2/km	132 sek per g CO_2/km	0 sek	0 sek
Diesel	95-140 g CO_2/km	107 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km
Diesel	> 140 g CO_2/km	132 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km

(Ekonomifakta, 2022)

In June 2022, the threshold values reduced so that the EV- and PHEV tax rate applied to vehicles emitting less than 75 g CO_2/km. The lower bound for ICEs dropped from vehicles emitting more than 95-140 g CO_2/km to 75-125 g CO_2/km, and the higher bound dropped from vehicles emitting over 140 g CO_2/km to 125 g CO_2/km (Ekonomifakta, 2022). In Table 4, the full set of rates and tax amounts is presented.

Table 4, Malus Vehicle Taxes, the First Three Years, June 2022 – October 2023

Propulsion Type	Emissions	Vehicle Tax per Year	Environmental Addition per Year	Fuel Addition per Year
EV/PHEV	< 75 g CO_2/km	360 sek	0 sek	0 sek
Petrol	75-125 g CO_2/km	82 sek per g CO_2/km	0 sek	0 sek
Petrol	> 125 g CO_2/km	107 sek per g CO_2/km	0 sek	0 sek
Diesel	75-125 g CO_2/km	82 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km
Diesel	> 125 g CO_2/km	107 sek per g CO_2/km	250 sek	13,52 sek per g CO_2/km

(Ekonomifakta, 2022)

2.2.1.3 Lower Benefit Value for Environmental Cars

Lastly, another type of policy instrument that is used to incentivized environmentally friendly vehicles is the reduced benefit value. The usage of an employer's vehicle for private use is a benefit, and something that is commonly taxed. It is deemed a benefit when an employee uses the vehicle for private trips more than 10 times or 100 kilometers per year. The benefit value, which is the value that is taxed, is calculated based on vehicle list price, additional equipment, vehicle tax, and environmentally friendliness (Skatteverket,).

For environmentally friendly company cars, the taxable value can be reduced under specific conditions. This regulation was introduced through the parliament's decision on the government proposition in 1999 regarding the taxation of environmentally friendly company cars and added to the Income Tax Act (Inkomstskattelagen, 1999:1229). The foundations of benefit value taxation have been intact since. If the car's list price exceeds the list price of the closest comparable conventional car, the taxable value should be reduced to a level equivalent to the list price of the closest comparable car. For gas, electric, and plug-in hybrid cars, the taxable value, calculated as above, should also be reduced by 40 percent compared to the closest comparable car. The reduction is capped at a maximum of 10,000 SEK per year and is time-limited, with conditions for reduction having changed over time (RIR 2020:1).

2.2.2 Danish EV Policy

The regulations for the Danish vehicle market are far more complicated than for the Swedish market, but this does not inherently mean that it fails to hold parallel trends in the shares of BEV adoption for the selected period. Firstly, laws have been changed rather often, making it difficult for even the manufacturers to understand and list correct prices for their vehicles (Berggreen, 2021). Even some of the larger dealerships must include disclaimers that their interpretation of the tax rates may be wrong (Andersen & Martini). This has mainly to do with how vehicles are taxed in Denmark - particularly, the registration tax.

2.2.2.1 Danish Registration Tax

The vehicle registration tax is paid the first time a car or motorbike is registered in Denmark, and for domestic purchases, it is often taken care of by the dealer - that is, they will pay the registration tax and include it in the list price. Now, to the complicated bit. Since 2021, private cars have been taxed at the following rates for registrations: 25% of the first DKK 65 800; 85% of DKK 65 800-204 600; 150% of the rest (Motorstyrelsen). Hence, if an ICE vehicle priced at DKK 400 000 is purchased, the initial tax will be 25% x 65 800 + 85% x 204 600 + 150% x 195 400 = DKK 483 460. If this was not complicated enough, there are also some additions and deductions to be made.

There is a CO_2 surcharge added to the vehicle registration tax based on the number of grammes of CO2 the car emits per kilometre. In Table 5, the rates are presented.

Table 5, Danish CO_2 Surcharge on Vehicle Registration Tax

Emissions Level	Registration Tax Add
< 121 g CO_2/km	DKK 253 per g CO_2/km
121-155 g CO_2/km	DKK 506 per g CO_2/km
> 155 g CO_2/km	DKK 961 per g CO_2/km

(Motorstyrelsen)

The Danish system also includes a base deduction of DKK 21 900 (2022 level), which applies to all vehicles (Motorstyrelsen).

Furthermore, whereas the bonus in Sweden was rather easy to understand, the Danish bonus equivalent continues the trend of being very complicated. Firstly, all zero-emission vehicles (emitting 0 g CO_2/km - such as BEVs) are granted a special deduction from the taxable value at DKK 1 300 per kWh of battery capacity used for propulsion, up to a maximum of 45 kWh (or DKK 58 500). *The battery deduction is a deduction from the taxable value, and therefore not a direct deduction on the car* (Andersen & Martini). This deduction has and will be written down gradually, as opposed to Sweden's total removal, to amounts of DKK 900 in 2023 and DKK 500 in 2024, after which it laps as from and including 2025.

In addition to this, a special basic deduction is granted for the calculated tax on zero-emission vehicles. On registration in 2022, zero-emission private cars are subject to a basic deduction of DKK 167 500 from the vehicle registration tax. Lastly, only 40% of the calculated tax will be payable if the vehicle is registered before 2026, from which the tax will be phased in gradually until it has been fully phased in during 2035. (Motorstyrelsen).

For low-emission vehicles (emitting between 0 and 50 g CO_2/km), the same battery deduction applies as for zero emission vehicles. Furthermore, low-emission vehicles have the same tax calculation as normal cars, but only only 50% of the calculated tax will be payable if the vehicle was registered in 2022, 55% in 2023, 60% in 2024 and 65% in 2025. The tax is phased at 3%-points per year after this until 2030, after which it will be phased at 4%-points until 2035, when it is fully phased in. Lastly, low emission cars registered in 2022 are subject to a basic deduction of DKK 48 750 from the vehicle registration tax (Motorstyrelsen).

Table 6, Eq.1, and Eq.2 further illustrates the registration tax calculations.

Table 6, Danish Registration Tax, Summary

Tax	
Vehicle Registration Tax Rates	25% of value < DKK 65 800
	85% of value DKK 65 800 – 204 600
	150% of value > DKK 204 600
CO_2 Surcharge	< 121 g CO_2/km → DKK 253 per g CO_2/km
	121-155 g CO_2/km → DKK 506 per g CO_2/km
	> 155 g CO_2/km → DKK 961 per g CO_2/km
Base Deduction	DKK 21 900
Battery Deduction	DKK 1300 per kWh battery capacity (max 45kWh)
Zero-Emission Vehicle Deduction	DKK 167 500
Zero-Emission Vehicle Discount	60% of total calculated tax

(Motorstyrelsen)

$$ICE\ Vehicle\ Tax = (65{,}800 \times 25\% + (204{,}600 - 65{,}800) \times 80\% + (\text{price} - 204{,}600) \times 150\%) + (\text{Emissions Level} \times \text{CO}_2 \text{ Surcharge}) - 21{,}900 \tag{1}$$

$$BEV\ Vehicle\ Tax = 40\% \times ((65{,}800 \times 25\% + (204{,}600 - 65{,}800) \times 80\% + ((\text{price} - \text{battery deduction}) - 204{,}600) \times 150\%) - 21{,}900 - 167{,}000) \tag{2}$$

To further illustrate the size of the tax relief, Table 7 presents a comparison between a BEV and ICE with the same value of DKK 400 000. I assume that the ICE vehicle emits 130 g CO_2/km, and thus needs to pay an additional DKK 506 per g CO_2/km it emits. Further, I assume that the BEV has a battery with a capacity exceeding 45kWh, and thus receives the full battery deduction. As the calculation shows, the tax difference is immense, and a tax of close to DKK 500 000 for ICE vehicles seems prohibitively high. Historically, vehicle taxes in Denmark have been high, but the tax calculated in Table 7 is not something that everyone in the country pays. Notably, commercial vehicles with yellow plates are exempt from VAT and registration tax (Motorstyrelsen). Danes have historically thus been creative in modifying vehicles to save to money that would have otherwise been spent on registration tax. For instance, owners of off-roaders and sports cars have removed parts of their vehicles' roofs, only to have them remounted as "removable hardtops", in order to be taxed as a pickup (Peter, 2021).

Table 7, Danish Registration Tax, Summary

Tax	BEV	ICE
Value	DKK 400 000	DKK 400 000
Battery Deduction	DKK 1300 x 45kWh = **DKK 58 500**	None
New Taxable Value	DKK 400 000 – 58 500 = **DKK 341 500**	**DKK 300 000**
Base Vehicle Registration Tax	25% x 65 800 + 85% x 138 800 + 150% x 136 900 = **339 780 DKK**	25% x 65 800 + 85% x 138 800 + 150% x 195 400 = **DKK 427 530**
CO_2 Surcharge	None	130g CO_2/km x DKK 506 = **DKK 65 780**
Base Deduction	**DKK 21 900**	**DKK 21 900**
Zero-Emission Vehicle Deduction	**DKK 167 500**	None
Zero-Emission Vehicle Discount	60% x (339 780 – 21 900 – 167 500) = **DKK 90 228**	None
Total Tax	(1-60%) x (339 780 – 21 900 – 167 500) = **DKK 60 152**	= 427 530 + 65 780 – 21 900 = **DKK 471 410**

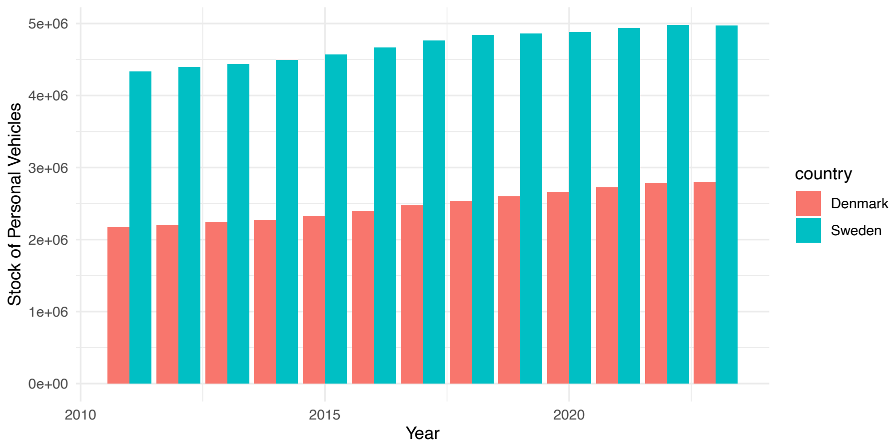
(Motorstyrelsen; Andersen & Martini, nd.)

2.3 Swedish and Danish Vehicle Markets

2.3.1 Overview

As presented in Figure 1, the Swedish Vehicle stock is historically higher than the Danish, although they seem to grow at similar rates. This is largely due population size and the Danish registration tax system. For Sweden, the stock of personal vehicles has increased from about 4 million to 5 million in the period 2011-2023. For Denmark, the vehicle stock has increased from about 2 million to 3 million. Hence relative growth rate of registrations looks to be slightly higher in Denmark, although not significantly.

Figure 2: Vehicle Stocks by Country and Year

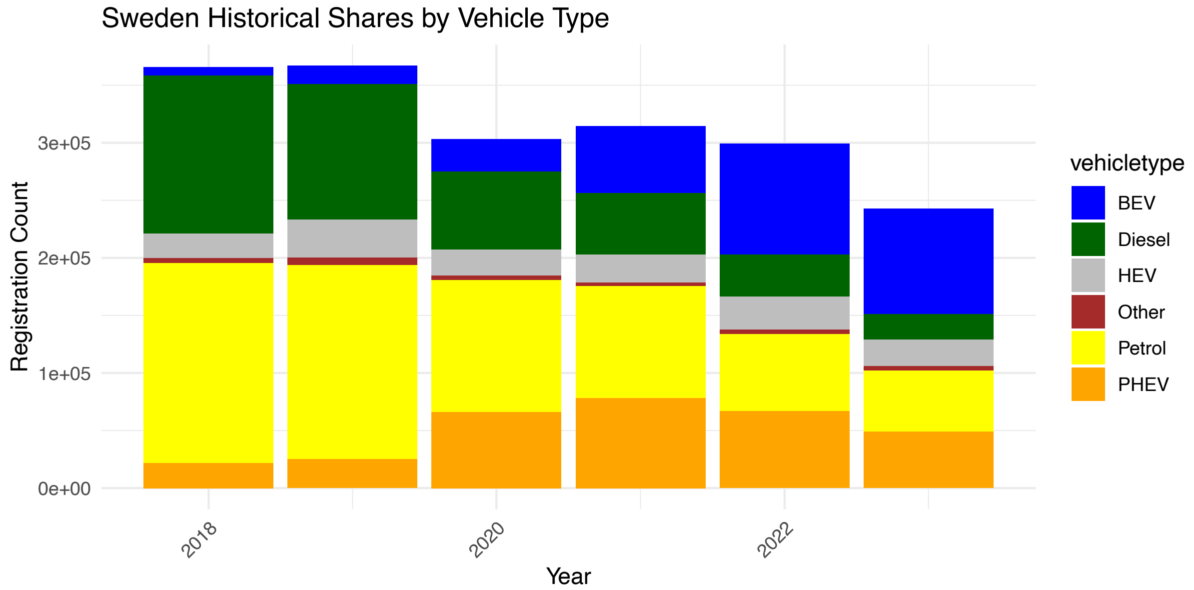


(Statistics Sweden, 2023; Statistics Denmark, 2023)

2.3.2 The Swedish Electric Vehicle Market

The development of the Swedish EV Market has been fast paced compared to other markets, largely due to historical policy incentives and preferences of Swedish consumers (Huse & Lucinda, 2014; Haustein et al., 2021). Looking at Figure 2, representing Swedish yearly registrations by type, we can see a significant increase in both share of PHEVs and BEVs.

Figure 3: Swedish Yearly Registrations by Type



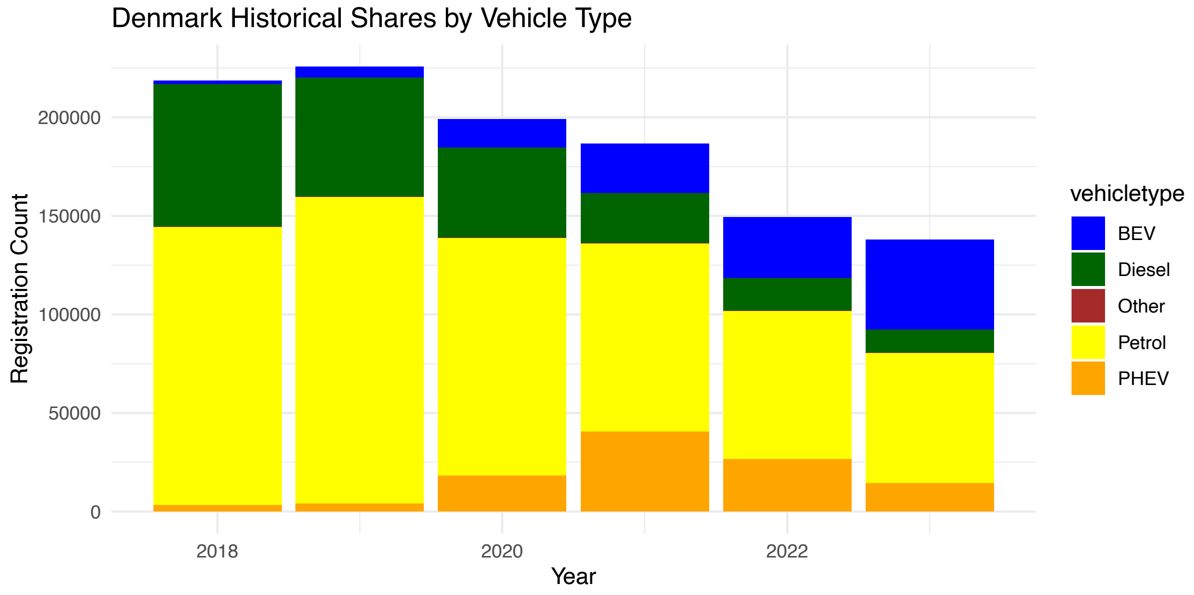
(Statistics Sweden, 2023)

The share of PHEV registrations has decreased gradually since they were excluded from the bonus malus system (they failed to qualify for the bonus). This share has largely been taken by BEVs, which since the bonus qualification change in 2021 has increased market share significantly. This is in line with previous literature, stating that focused bonuses increase the share of the targeted vehicle (Diamond, 2009; Beresteanu & Li, 2011; Huse & Lucinda ,2014; Liu et al., 2021). The share of petrol and diesel registrations have decreased with the increase of BEVs and PHEVs, with diesel ICEVs having the most significant reduction.

2.3.3 The Danish Electric Vehicle Market

Looking at the Danish market, BEV and PHEV share has followed a similar trend, although the share of petrol ICEVs is still dominant. Notably, the HEV category is omitted here, due to Danish classification systems, and is included in the petrol and diesel shares respectively (although mostly petrol, as diesel HEVs are uncommon). Denmark seems to be behind sweden in adoption, although the share of BEVs is increasing rapidly. The relatively smaller share of PHEVs can be attributed to the historical policy incentives mainly targeting BEVs, whereas the current incentive structure significantly favors BEVs.

Figure 4: Danish Yearly Registrations by Type



(Statistics Denmark, 2023)

3. Literature Review

3.1 The Effect of EV Incentives

Previous research has found the electrification of the transportation sector to be one of the most promising means to reduce carbon emissions (Wu et al., 2019). The impact of government policies on increased electric vehicle (EV) adoption has thus been a focal point of research, with studies spanning various regions and policy interventions. Diamond's (2009) investigation into state-level incentives for hybrid-electric vehicles in the U.S. was one of the first and establishes a foundational understanding of how financial incentives influence consumer choices. In his research, Diamond found a strong relationship between fuel prices and hybrid adoption and a weaker relationship between policy incentives and hybrid adoption. Of the policy incentives, however, incentives that provided payment upfront were the most efficient. Beresteanu and Li (2011) contribute valuable insights by examining the relationship between fuel prices, government support, and the demand for hybrid vehicles in the United States, finding that fuel prices and government support significantly influence the demand for hybrid vehicles in the United States. Further evidence to the efficiency of subsidy policy incentives comes from Hardman (2019), who finds that policy measures such as direct subsidies, cheaper parking for EVs, allowing EVs to use bus lane, charging infrastructure, customs-exemptions for EVs and tax-relief all have a positive correlation with increased EV adoption. Evidence from China comes from Liu et al. (2021), who found that in the private domain, convenience measures such as charging station construction and non-purchase limitations, contribute to increasing the demand for EVs, while the effect of financial incentives was not as significant as expected.

Sweden, which is a unique market due to its comparatively larger market share of EVs, have historically used several different policy measures to influence adoption. The 'Green Car' Premium (Miljöbilspremien), a subsidy aimed at reducing the purchase price of environmental cars, was found to be effective in promoting electric vehicles, but the cost-benefit of the policy measure in terms of cost per reduced CO_2 deemed comparably poor (Huse & Lucinda, 2014). The 'Super Green Car' premium, which replaced the 'Green Car' premium and was also aimed at decreasing purchase price, was found to decrease emissions with twice the impact of a five-year tax-exemption for 'Green Cars' (Engström et al., 2019).

Although bonus incentives have been found to effectively promote electric vehicles, there is criticism as to their cost effectiveness (Huse & Lucinda, 2014; Beresteanu & Li, 2011). The cost effectiveness was further criticized by in Sweden by the Swedish National Audit Office in relation to the Bonus Malus system that was implemented in 2018 (RIR 2020:1). Hence, some governments have started investigating a removal of bonus incentive systems.

Sheldon et al. (2023) examined the effect of PEV subsidies (Plug-in Electric Vehicles – PHEV and BEV) in the United States and finds that PEV subsidies are becoming less impactful and costlier over time. However, this is due to an increasing share of higher-priced BEVs such as Teslas. Furthermore, their findings suggest that the U.S. PEV market has not yet reached a point where subsidies can be eliminated without consequences on adoption, and that PEV consumers are more price responsive than HEV and ICEV consumers.

Gómez Vilchez & Thiel (2019) look at the European Union and use the system dynamics Powertrain Technology Transition Market Agent Model to investigate the size of timing of purchase incentives through several scenarios. They conclude that although the evolution of EV batteries seems favorable EV purchase subsidies remain an effective policy measure to support the transition over the coming years.

3.2 Consumer Preferences

Consumer preferences play a central role in the adoption of electric vehicles, as evidenced by studies exploring the psychological aspects of consumer decision-making. Previous research has suggested that the main reason behind consumers' reluctance to purchase EV is the high upfront cost, whereas low operating costs favors of adoption (Habich-Sobiegalla et al., 2019, Barth et al., 2016, Rezvani et al., 2015). Thus, purchase incentives given at the time of EV purchase have stronger impact than incentives after purchase. Therefore, increase in financial incentives can increase consumers' intentions to purchase EVs (Singh et al., 2020). Skippon and Garwood's research (2011) in the UK finds that attributes other than vehicle cost, such as range, charging habits, and symbolic meanings like environmental friendliness also affects consumer decisions to purchase an EV. Egbue et al.'s analysis of barriers to EV adoption (2012) provides a nuanced understanding of consumer attitudes and perceptions. They identify key obstacles that policymakers and industry stakeholders need to address, such as battery technology, battery costs, charging infrastructure and consumer acceptance.

Rapson and Muehlegger (2021) suggest that EV advantages and preferences vary between individuals, even when subsidized. They argue that market failures can be location- and time-specific and addressing them with a one-size-fits-all policy is unlikely to create efficient incentives for EV adoption, use, or environmental benefits.

Looking at Sweden and Denmark specifically, Haustein et al. (2021) examine attitudes and behaviors with relation to BEVs in the two countries to estimate project impacts over time. The results showed that car users in Sweden and Denmark have very similar attitude profiles, both remaining stable over time, with the difference being more negative evaluation of and higher uncertainty about political support for BEVs by Danes. Further, they conclude that efforts to increase BEV uptake show an effect but that much more must be done.

4. Theoretical Background

4.1 Diffusion Theory

In the context of electric vehicles (EVs), the Diffusion of Innovations Theory, formulated by E.M. Rogers in 1962, offers an analytical framework to understand the process through technological innovations spread through societies and cultures. The diffusion of innovations theory seeks to explain how and why new ideas and practices are adopted, including why the adoption of new ideas can be spread out over long periods. (Halton, 2023).

Key participants in this adoption are innovators, who are open to risks and new ideas; early adopters, who are keen to try new technologies and establish their utility in society; the early majority, who pave the way for mainstream adoption; the late majority, who follow the early majority; and laggards, representing risk-averse individuals resistant to embracing innovative products (ibid.).

The eventual mainstream integration of new products is steered by factors such as the inclination of innovators and early adopters to assume risks. As innovations become indispensable facets of daily life, even individuals traditionally averse to risk, laggards, are compelled to embrace them. The diffusion of innovations theory is applicable to various parts of innovation adoption, spanning technologies, services, and behavioral shifts. Constructed upon sociological theories of behavioral change, the theory considers factors like the rural-to-urban population ratio, educational levels, and the degree of industrialization across different societies. Societies characterized by diverse attributes exhibit disparate rates of adoption, shaping the rapidity with which members embrace innovations (ibid).

The diffusion process involves five sequential stages: awareness, interest, evaluation, trial, and adoption. Rogers renamed these knowledge, persuasion, decision, implementation, and confirmation in later editions of his book. Potential barriers to adoption may manifest at any juncture in this decision-making process, encompassing concerns regarding usage, perceived value, risks associated with novel technology, and psychological factors such as cultural stigma (ibid.).

The Diffusion of Innovations Theory is useful for understanding the gradual adoption of electric vehicles. Each segment of the population, from innovators to laggards, plays a pivotal role in shaping the trajectory of EV adoption. Furthermore, policy measures and various market attributes can affect the sequential stages, especially through strengthening the factors of positive utility to adoption. The third and fourth stages of diffusion process, evaluation and trial, are mainly influenced by the early and late majority. Thus, policy measures should aim at increasing utility factors important to these consumer groups, such as price and convenience.

4.2 Theoretical Framework

The utilization of BEV adoption variance at the NUTS-3 region level served as a method to address the inherent limitations associated with the use of national-level time-series data. The examination of differences between regions, coupled with variation over time, aids the isolation and differentiation of policy and economic determinants of adoption. Fundamentally, this methodology aims at comparing the market share among jurisdictions over any given time interval, to test how variations in different socioeconomic factors, on average, affect the tendency of consumers to purchase BEVs (Diamond, 2009).

To model individual consumer behavior for vehicle purchasing, I adapt a model first provided by Berry et al. (1995) and later built upon by Diamond (2009) and Beresteanu & Li (2011). Consumers are assumed to be utility maximizing and can be assumed to choose between BEVs and other vehicles (OVs). At any given time, the indirect utility of consumer *i* for vehicle *j* can be expressed as

$$U_{ij} = f(p_j, x_j, \varphi_i; \theta_j) + \varepsilon_{ij} \tag{3}$$

where, p is the price of vehicle *j*; x is the observed product characteristics of vehicle *j* (such as size, power, and features); φ is a vector of the preferences and socioeconomic characteristics of consumer *i* (such as geographical characteristics, environmental awareness and previous experiences) and θ is a parameter of the policy measures aimed at increasing the BEV share. Furthermore, ε captures random taste shocks and unobserved features of vehicle demand.

Consumer *i* will purchase vehicle *j* (BEVs) if and only if

$$U_{ij} = f(p_j, x_j, \varphi_i; \theta_j) + \varepsilon_{ij} \geq U_{ij} = f(p_r, x_r, \varphi_i; \theta_r) + \varepsilon_{ir} \text{ for } r = 0, 1, 2, \ldots, \mathrm{J}; r \neq j \tag{4}$$

where r represents other alternatives, and r=0 corresponds to the outside alternative of not purchasing a vehicle. In terms of my decision modeling, a consumer will hence only choose a BEV if and only if

$$U_{i,BEV} \geq U_{i,OV}. \tag{5}$$

Equation (5) implies that a consumer's utility from purchasing a BEV must be higher than or equal to the utility gained from purchasing another type of vehicle. For a given population, the aggregate demand A_j is given by

$$A_j = \{i : U_{ij} \geq U_{ir}\}, \quad \text{for } r = 0, \text{BEV}, \text{OV}; r \neq j. \tag{6}$$

Where A_j is the sum of consumers having utility resulting in the purchase choice *j; r* represents the vehicle alternatives and $r = 0$ is the alternative of not purchasing a vehicle. The market share, s_j, of a given model is now a function of

$$s_j = f(p_j, x_j, \bar{\varphi}_i; \theta_j) + \varepsilon_{ij} \tag{7}$$

In (7), although market share is a function of price, policy instruments and attributes of vehicle *j*, the preferences and socio-economic characteristics are now the overall population average $\bar{\varphi}_i$. Furthermore, populations are assumed to be NUTS-3 regions and demanded vehicles are assumed to be BEVS. Additionally, vehicle attributes x_j and price p_j are omitted from the model as they are assumed to remain constant within regions. I further assume that region-varying determinants of BEV market share remain constant over a month but can vary between months. Hence, the monthly time subscript t is introduced to determinants that can vary within a region between months. Now, the market share of BEVs in region (län) *l*, at time *t*, can now be defined as

$$BEVshare_{l,t} = f(\bar{\varphi}_{l,t}; \theta_{l,BEV,t}) + \varepsilon_{l,BEV,t} \tag{8}$$

It can be concluded from the theoretical framework that various factors can affect the variation in BEV adoption across time and region, and to empirically assess how the change in EV incentive policy and other factors affect the BEV share, the theoretical equation (8) will be the basis of my econometric model.

As per equation (8), policy measures are expected to affect the share of BEVs in the vehicle market. Furthermore, as the purpose of this thesis is to assess how the removal of the climate bonus affected the BEV share in the Swedish vehicle market, we must understand how the change in policy affected consumers' utility.

Previous research and empirical evidence from various regions, including Sweden, have consistently shown that financial incentives, such as subsidies and bonuses, effectively influence consumer decisions in favor of electric vehicles (Diamond, 2009; Beresteanu & Li, 2011; Huse & Lucinda, 2014). The climate bonus incentive, being a direct financial incentive, has played a crucial role in encouraging consumers to choose BEVs (RIR 2020:1). Consumer preferences for electric vehicles are often influenced by financial considerations, such as upfront costs (Habich-Sobiegalla et al., 2019, Barth et al., 2016, Rezvani et al., 2015). The climate bonus likely contributed to making BEVs more financially attractive to consumers by reducing their effective purchase price. The removal of this incentive could result in a higher perceived cost of BEVs, potentially deterring some consumers from choosing electric vehicles.

Sweden, with its comparatively larger market share of electric vehicles, presents a unique context where policy measures have historically played a significant role in influencing adoption. The previous success of policies like the 'Green Car' Premium and the observed impact of the 'Super Green Car' premium replacement provides a historical basis for expecting notable changes in BEV adoption patterns with the removal of the climate bonus.

Thus, in order to examine the effect of removing the climate bonus on the BEV market share in Sweden, the following hypothesis will be tested:

- **H1:** The removal of the climate bonus incentive will decrease in the market share of Battery Electric Vehicles.

5. Data & Methodology

5.1 Variable Description

In order to examine the hypothesis, I gathered and examined monthly time series panel data from 32 NUTS-3 regions in Sweden and Denmark, spanning the period May 2021 to October 2023. Among these, the 21 Swedish Län (NUTS-3 classified) were affected by the removal of the climate bonus in November 2022, after which the policy has remained effectively the same until October 2023. The electric vehicles (EVs) considered in this study are only BEVs, as the subsidy of up to 70,000 SEK was not applicable for any hybrid vehicles. Hence, both PHEVs and HEVs were excluded from the effect, and rather treated in the same way as ICEVs. Below follows a summary of the and description of the variables and sources used for the regression analysis.

Table 8: Description of Variables and Data Sources

Variable	Description	Source
bev_share	The share newly registered passenger BEVs (%)	Statistics Sweden (2023), Mobility Sweden (2023), Statistics Denmark (2023)
sweden	Dummy variable equaling 1 if the NUTS-3 region is located in Sweden, 0 if otherwise	Statistics Sweden (2021)
nobo	Time dummy equaling 1 if the time period is after the removal of the climate bonus	Transportstyrelsen (2022)
pop_dens	Measure of population density of the NUTS-3 region in people per km2	Statistics Sweden (2023), Statistics Denmark (2023)
chargepoint_density	Number of charge points per km2 in NUTS-3 region	Power Circle (2023) Uppladdning.nu (2023)
kpi	Consumer price index measure with price level for 2015=100	Statistics Sweden (2023), Statistics Denmark (2023)
petrol_price_eur	National monthly maximum price of petrol in EUR	Circle K Sweden (2023), Cirkle K Denmark (2023)
diesel_price_eur	National monthly maximum price of diesel in EUR	Circle K Sweden (2023), Cirkle K Denmark (2023)
el_price	Monthly average electricity price for energy area in EUR/mWh	Nordpool (2023)
euro_exchange	Measure of value of local currency in terms of EUR	OFX (2023)

Registration data is compiled from Statistics Sweden and Mobility Sweden as well as Statistics Denmark. Controls such as consumer price index, population size and land area are gathered from Statistics Sweden and Statistics Denmark for the countries respectively. Charge point data for Sweden is collected from PowerCircle, and for Denmark from Uppladdning.nu. Fuel price data is collected from Circle K Sweden and Circle K Denmark respectively. Data on electricity pricing is collected from Nord Pool and exchange rate data is collected from OFX.

The use of BEV registration share instead of count provides a normalized measure that accounts for the growth or decline in the overall vehicle market. This is important when studying the adoption of EVs over time, as it reflects the proportion of electric vehicles relative to the total number of registered vehicles. Registration share allows for a more direct comparison across different regions, cities, or time periods. Policymakers and industry stakeholders are often interested in understanding the market share of specific technologies rather than just the absolute numbers. Hence, when comparing Sweden and Denmark, the use of shares is reasonable, aiding in controlling for eventual exchange rate fluctuations, varying pandemic effects and other macro or policy trends.

Control variables are selected based on findings from previous studies, in which they have been found to influence EV adoption, as well as intuition stemming from the theory section. The different variables incorporated into the model all have potential effects towards the utility function of purchasing EVs: measures of relative costs, such as the consumer price index variable, affects budget constrictions, where relative cost increases of other goods decrease the possibility for consumers to purchase a vehicle. Although this may have been taken care of with the use of BEV shares, the relative expensive nature of electric vehicles could entail a shift from purchasing a BEV to purchasing a cheaper vehicle, or none at all. Furthermore, prices of fuels also affect the utility of purchasing an ICEV, as the relative total cost of ownership (TCO) increases/decreases with higher/lower fuel prices. The same argument applies for electricity price on BEVs, although the price of electricity also affects other parts of a consumer's life, such as home ownership. Exchange rates are used to control for the various strengths of the Swedish and Danish currency. The treatment, *nobo,* occurs in December of 2022, even though the policy was implemented mid-November, to account for some time lag from the use of registrations as dependent variable.

5.1 Descriptive Statistics

Table 8 and 9 present descriptive statistics of the variables used for the regression.

Table 9: Descriptive Statistics: Sweden

Variable	Mean	Standard Deviation	Max	Minimum	Observations
bev_share	0.3	0.09	0.62	0.09	630
pop_dens	51.83	77.77	378.24	2.51	630
chargepoint_density	0.09	0.17	1.35	0	630
kpi	109.91	7.02	119.95	100	630
petrol_price_eur	1.87	0.18	2.28	1.59	630
diesel_price_eur	2.14	0.3	2.68	1.6	630
el_price	74.29	52.76	289.28	5.93	630
euro_exchange	0.09	0	0.1	0.08	630

Table 10: Descriptive Statistics: Denmark

Variable	Mean	Standard Deviation	Max	Minimum	Observations
bev_share	0.24	0.1	0.54	0.04	330
pop_dens	670.98	1266.41	4499.77	59.68	330
chargepoint_density	0.61	0.77	2.7	0.04	330
kpi	107.45	4.61	112.96	100	330
petrol_price_eur	1.94	0.22	2.47	1.56	330
diesel_price_eur	1.8	0.28	2.31	1.33	330
el_price	142.38	88.11	456.75	54.31	330
euro_exchange	0.13	0	0.13	0.13	330

In Sweden, the mean share of newly registered passenger Battery Electric Vehicles (bev_share) is 0.3, indicating a substantial presence of electric vehicles in the market and a higher rate of diffusion. In Denmark, the mean bev_share is slightly lower at 0.25, indicating slightly less widespread adoption compared to Sweden. The standard deviations are similar, being 0.08 and 0.1 for Sweden and Denmark respectively. The population density (pop_dens) of Sweden, with a mean of 53.35 people / km^2, ranges from a minimum of 2.52 to a maximum of 378.24, due to Sweden's larger land area and population clusters in cities. For Denmark, population density is far higher with a mean of 656.85 people per km^2, showcasing significant variability, ranging from 59.68 to 4499.77. The charge point density is notably higher in Denmark, with a mean of 0.61 compared to Sweden's

0.09, reflecting the smaller country size and relative charging infrastructure investment compared to Sweden.

Despite differences in adoption rates, both countries share similarities in terms of the consumer prices (kpi), with mean values around 107-110, indicating that prices have developed at similar rates, although Sweden on average has had a higher price evolution relative to 2015. The petrol prices in Denmark are notably higher, whereas Sweden has a higher diesel price. The mean electricity price (el_price) is substantially higher in Denmark at EUR 142.38, with a standard deviation of 88.11 suggesting significant variability. The Danish currency is also more valuable than the Swedish currency.

5.1 Difference-in-Difference Design

Since I use a panel data set looking at NUTS-3 regions, I estimate an average effect of $\bar{\theta}_{l,BEV,t}$, as derived in the theory section. This is the average treatment effect of removing the climate bonus and can be found from comparing to the counterfactual scenario. Hence, I estimate $\bar{\theta}_{l,BEV,t}$ with a difference-in-difference method. Equation (9) shows a standard difference-in-difference design inherited from Liu et al. (2021).

$$Y_{it} = \beta_0 + \beta_1 du_{it} + \beta_2 dt_{it} + \beta_3 du_{it} dt_{it} + \beta_4 X_{it} + \varepsilon_{it} \tag{9}$$

Let *i* stand for a NUTS-3 region and *t* for a month. Y_{it} denotes BEV market share. The variable du_{it} is a dummy variable indicating the treatment group (1 for the Sweden – 0 for Denmark). Similarly, dt_{it} is a dummy variable indicating the period during which the subsidy policy is in effect, that is, when the climate bonus has been removed. The coefficient of the interaction term, $du_{it}dt_{it}$, indicates the effect of the subsidy policy. X_{it} represents a vector of control variables. From this, I derive the main specification

$$bev\_reg\_share_{lt} = \alpha + \delta sweden_{lt} + \gamma nobo_{lt} + \delta sweden_{lt} \times nobo_{lt} + \phi X_{lt} + \varepsilon_{lt} \tag{10}$$

where $bev\_reg\_share_{it}$ denotes the share of BEV registrations for month *t* and region *l*; $sweden_{it}$ is a dummy indicating if the region is part of the treatment group (Sweden, $\delta = 1$) or otherwise (Demark $\delta = 0$); $nobo_{it}$ is a dummy variable indicating the treatment period (post the removal of the climate bonus) and X_{it} is a vector of controls.

5.6 Assumptions

To use the difference-in-difference method, we must satisfy the parallel trends assumption, that is, we must find common trends for Sweden and Denmark to achieve ceteris paribus. Historically, EV adoption rates have differed somewhat for the two countries, largely due to different policies shaping the vehicle market. Sweden has had a larger and more consistent support for both BEVs and PHEVs over time, which has facilitated accelerated diffusion. As per May 2021, however, the relative support for BEVs has been largely similar. The Swedish climate bonus reduced the upfront price a consumer needed to pay to purchase a BEV by up to 70 000 SEK, and thus for an assumed purchase price of 520 000 SEK (Tesla Model 3 price), this equates to a price reduction of 13,5%. To find the Danish bonus equivalent, I take registration tax cut for a similar priced vehicle (DKK 342 000, assumed 1 DKK = 1.52 SEK, OFX, 2023) and compare with an ICE of the same price. Using (2), Registration tax for the BEV will be

$$BEV\ Vehicle\ Tax = 40\% \times ((65\,800 \times 25\% + (204\,600 - 65\,800) \times 80\% + ((342\,000 - 58\,500) - 204\,600) \times 150\%) - 21\,900 - 167\,000) = DKK\ 22\,776.$$

For a similar priced ICEV with an emissions level of 120 g CO_2/km, the registration tax will be

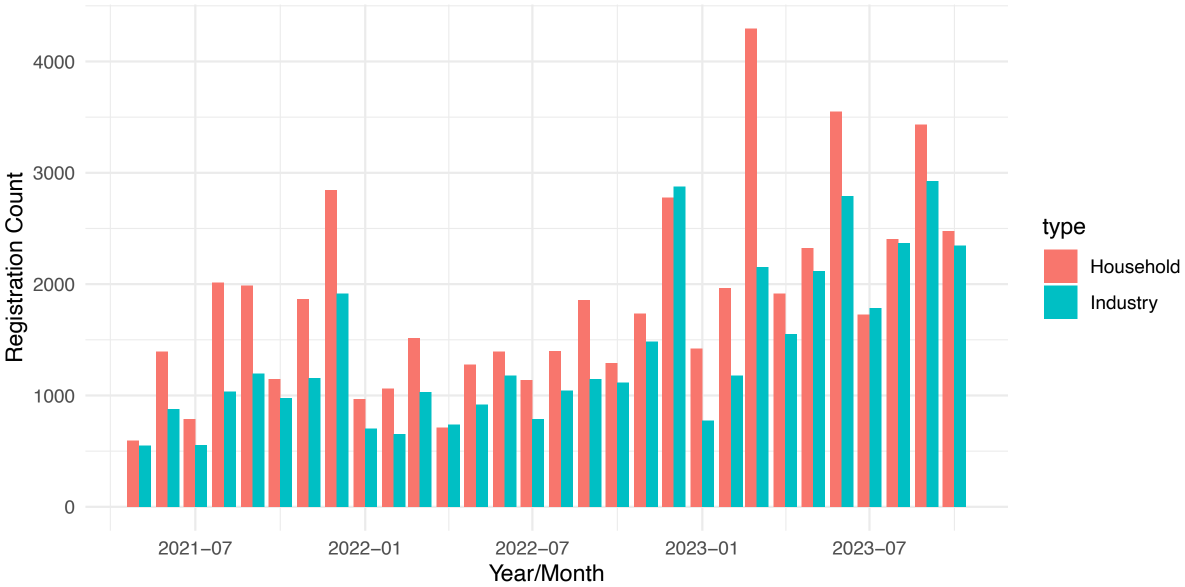
$$ICE\ Vehicle\ Tax = (65\,800 \times 25\% + (204\,600 - 65\,800) \times 80\% + (342\,000 - 204\,600) \times 150\%) + (120\ \times\ 253) - 21\,900 = \text{DKK}\ 342\,050\ .$$

The comparative discount of the purchase price will thus be

$$\frac{(342\,000+22\,776)}{(342\,000+342\,050)} = 47\%.$$

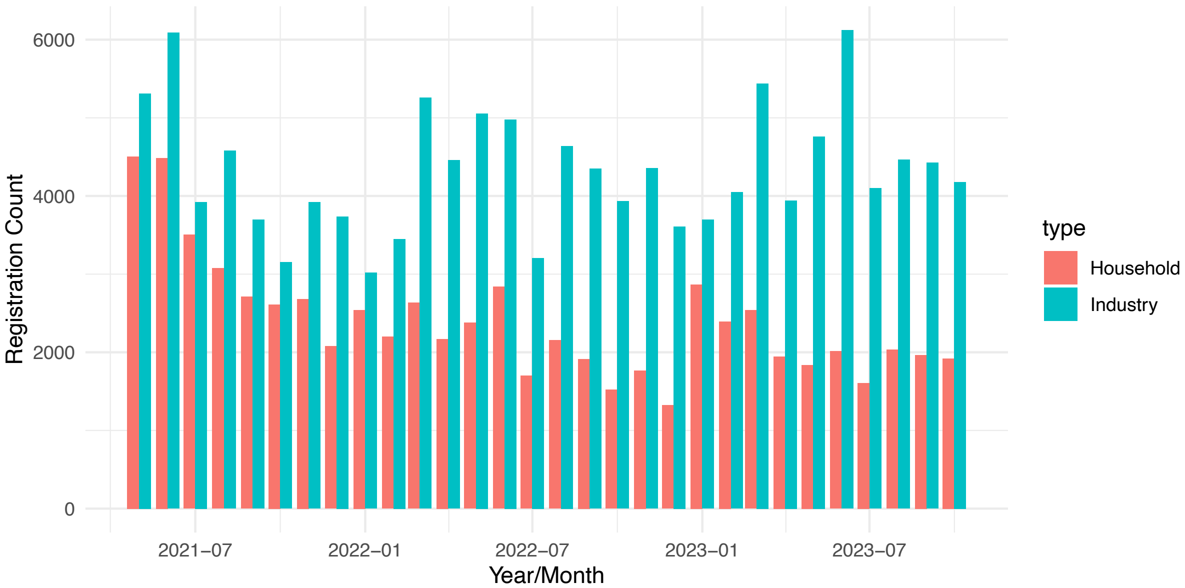
While the difference in the discount rate seems concerning, we must also factor in relative market size and especially market failures. As per the background section, many Danes use a loophole in the registration tax rules when registering a new vehicle. Namely, they register as a work vehicle (registering in the industry classification, rather than household) as these registrations are tax exempt. I can thus formulate a sub-hypothesis that Danes to a larger extent register high emission vehicles in the industry classification to remove registration tax. But in order to understand how large scale this phenomenon is, we must examine data on registration types. Looking at Figure (1), we can see that there is no clear discernable favoring of registration type, with shares being roughly equal between industry and household registrations. However, when looking at Figure (2) and (3), we can see a clear favoring of industry registration. Furthermore, we can see that the difference is the largest for diesel vehicles. This supports the hypothesis that Danish people to a larger extent will register high emission vehicles to reduce tax liability.

Figure 5: Danish BEV Registrations by Type



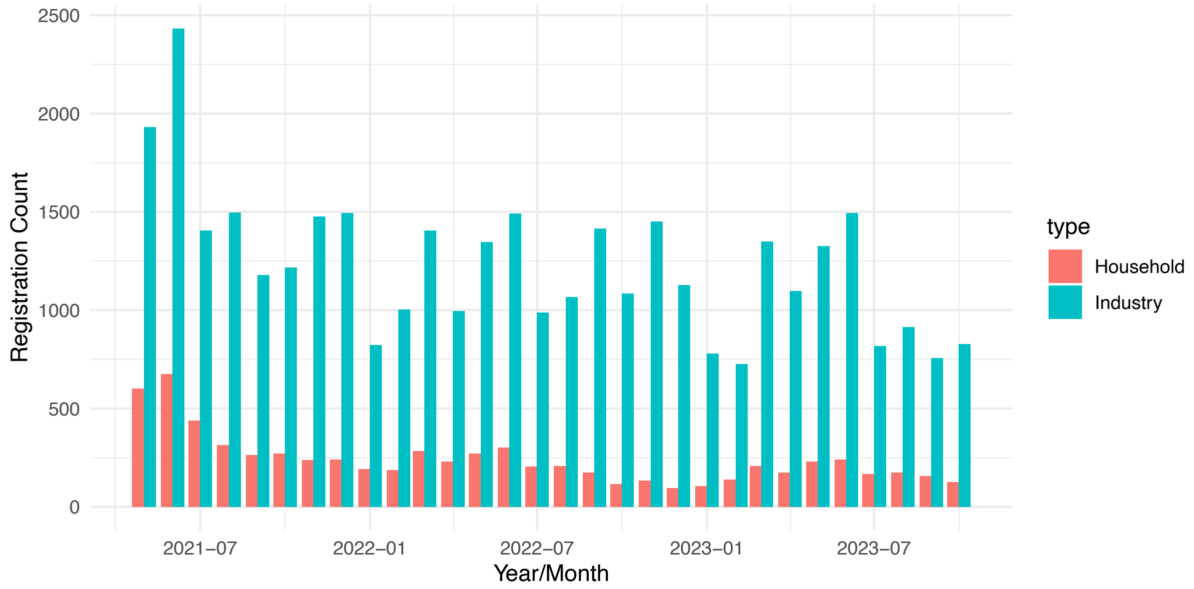
(Statistics Denmark, 2023)

Figure 6: Danish Petrol Registrations by Type



(Statistics Denmark, 2023)

Figure 7: Danish Diesel Registrations by Type



(Statistics Denmark, 2023)

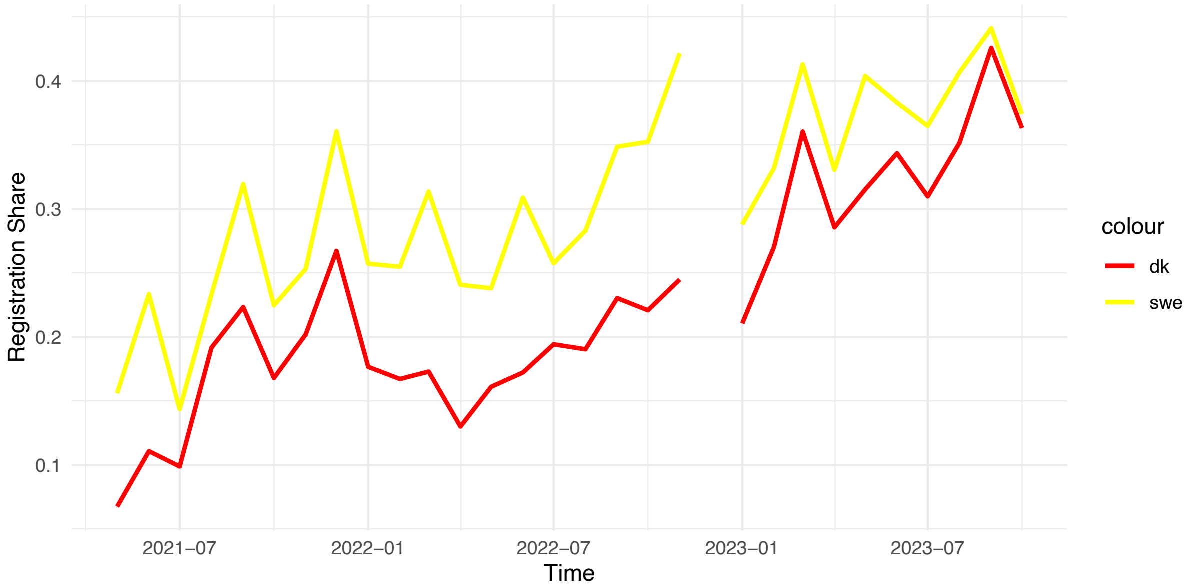
The effective discount rate thus reduces dramatically in Denmark and helps support the policy similarity argument for parallel trends.

There are several other similarities between Sweden and Denmark that help support the parallel trends assumption; Both are neighboring countries in the Nordics and share similarities that contribute to their high living standards. Demographics, including life expectancy, average age, and birth- and death rate are largely the same. Furthermore, quality of life measures are practically the same, apart from cost of living in which Denmark ranks worse, and the economies are similar apart from slightly higher cost of living and salaries in Denmark (Worlddata.info).

Consumer preferences are similar between the countries, which was evidenced by Haustein et al. (2021), who showed that preferences and attitude towards BEVs were largely identical. The countries are also similar in environment and geography as neighboring countries, as well as economy and openness through EU membership.

Although there has been stronger historical policy support from Sweden for EV adoption, the measures set for the given time frame have been largely similar, and hence a parallel trend is expected. We can further strengthen this by viewing a time series illustration of the two trends, as shown in Figure 4.

Figure 8: BEV Shares of New Registrations, Monthly



(Statistics Sweden, 2023; Statistics Denmark, 2023)

Visually inspecting the trends, they seem to follow a very similar path, further indicating parallel trends, with some variation in magnitude of peaks.

However, when F-testing the pre-trends to test for commonness, the results show significant difference in the pre-trends, which is a large problem for internal validity of the results, as the parallel trends assumption cannot be verified. The implications of this is further discussed in section 7.4.

6. Results

6.1 Testing the effect of the Climate Bonus Removal

I use the difference-in-difference method on panel data with time and region fixed effects, controlling for time-invariant differences between regions, as well as seasonality in deliveries. A Hausman test is conducted to show if the model is to be estimated with region fixed effects, where the null hypothesis is that the models are not significantly different. To reject the null hypothesis in the Hausman test, the p-value should be <0.01. In the case of regression (1) and (2), I am unable to reject the null, but for regression (3), the null is rejected, and region fixed effects are preferred. Hence, I discard random effects in favor of fixed effects. Furthermore, month fixed effects are used in (3), to control for seasonality in the delivery of vehicles. For instance, companies may push to deliver more vehicles in the end of the year to meet delivery targets. Table 10 presents the results of the different regressions of the 32 regions over the period May 2021 – October 2023.

Table 11: Results from Fixed Effects Panel Regression

Indep. Variable	(1)	(2)	(3)
nobo	0.155*** (0.008)	0.140*** (0.013)	0.075*** (0.013)
sweden:nobo	-0.067*** (0.010)	-0.142*** (0.016)	-0.122*** (0.013)
chargepoint_density		0.010 (0.013)	0.005 (0.011)
pop_dens		-0.0006. (0.0003)	-0.0007* (0.0003)
kpi		0.005*** (0.001)	0.011*** (0.001)
petrol_price_eur		-0.133*** (0.025)	0.087*** (0.025)
diesel_price_eur		0.093*** (0.021)	-0.053* (0.022)
el_price		0.0003*** (0.00004)	-0.0002*** (0.00004)
euro_exchange		-2.651 (1.907)	-0.487 (1.605)
Year FE			X
Region FE	X	X	X
Observations	960	960	960
R^2	0.375	0.550	0.734

Column (1) is a basic panel difference-in-difference panel regression only looking at the effect of the active variables *nobo*, *sweden* and the interaction *nobo:sweden* on *bev_share*. The dummy variable *sweden* is cancelled out by region fixed effects. From the initial results in (1) we find support for the hypothesis that the removal of the climate bonus (*sweden:nobo*) yields a negative and significant effect (at the 1% level) on the share of BEV registrations in Sweden. The interpretation of the estimate is that the removal of the climate bonus has decreased the share of BEVs, on average, by 0.067 %-points, which is a relatively small effect. The R^2 of this model is quite low, which is intuitive with respect to the utility function set in the theory section, as price and policy measure are not the only utility factors determining total utility of purchasing a vehicle. However, this measure is not critical to our analysis of the effect of the climate bonus, as it may be significant while not explaining larger parts of the variation in the data.

In column (2), additional regressors are included to capture exogenous variation and further sharpen the *sweden:nobo* estimate. When we include the other determinants of BEV share of registrations, the average treatment effect of *sweden:nobo* increases to -0.142. This means that the removal of the climate bonus has thus far yielded a 0.142 %-point reduction in BEV share compared to the counterfactual. This is a larger effect, albeit still small. The model estimates charge point density to be a barely insignificant determinant, which means that I cannot argue that it is significantly different from zero. Population density is a barely significant predictor of *bev_share*, of which the model estimates the effect of an increase per person and km^2 to be -0.0006. This means that for every additional person per square kilometer, the share of BEV registrations reduces with 0.0006 %-points. This effect makes more sense when considering cities, where it is common that the monthly change can be in numbers of thousands. The increase in consumer price index (CPI) yields a positive and significant effect on the share of BEVs of 0.005, which means that a relative CPI increase of 1 (2015=100), yields an increase in BEV share of 0.005 %-points. The estimated coefficient for *petrol_price_eur* indicates that the increase in prices of petrol with one EUR, leads to a decrease of BEV share with 0.133 %-points. The adverse effect is estimated for diesel price increases, where the increase of the price of diesel of one EUR leads to an increase in BEV share by 0.093 %-points. The two fuel price estimates are both significant, and are also important to be interpreted carefully, as the increase in fuel price by one EUR is highly unlikely, as it would entail almost a doubling of price. Furthermore, the difference in effect between the petrol and diesel estimates is noteworthy, and should be further analyzed.

The estimate for electricity price's effect on BEV share is significant and indicates that the increase in price of electricity by one EUR per mWh yields a 0.0003 %-point decrease in BEV share. The value of respective currency seems to be unrelated to BEV share. Furthermore, the adoption of additional predictors of BEV share yields a higher R^2 of 0.55, which means that more of the variation in the data can be explained. The adjusted R^2 of 0.53 indicates that the increase in the explainability is not primarily due to addition of new predictors, but that their ability to predict BEV share is significant.

In (3), I include month fixed effects to account for seasonality, and thus receive new estimates. The effect of removing the climate bonus is decreased to -0.122, albeit still significant, meaning that the climate bonus removal resulted in a decrease in BEV share of -0.122 %-points on average. The effect of charge points is still insignificant, whereas the effect of population density is slightly strengthened in significance and magnitude. The estimate for the *kpi* coefficient becomes more significant and increases to 0.011. The petrol and diesel price estimates are noteworthy, firstly as they have different effects, and secondly as they are both inverted when comparing to (2). The petrol price now as a positive and significant effect on BEV share of 0.087, meaning that for each EUR increase in petrol prices, the BEV share increases by 0.087 %-points. The diesel price, on the other hand, is now found to have a negative and significant effect of 0.053, which means that the increase of diesel price by one EUR will lead to a decrease in BEV share of 0.053 %-points. The electricity price estimated effect is also inverted when adding month fixed effects, where the increase in electricity price per mWh of 1 EUR is now estimated to decrease BEV share of 0.0002. This effect is significant. The currency value remains insignificant when adding time fixed effects. Lastly, the R^2 further increases to 0.734, adds to the explainability of the results.

7. Discussion

7.1 Climate Bonus Removal Impact on EV Adoption

The examination of the dataset aligns with the hypothesis (H1) proposed in the theoretical framework. That is, the data supports the hypothesis that the removal of the climate bonus negatively impacted the share of BEVs in Sweden. The negative effect of -0.122 percentage points on BEV share corresponds with the expected impact of removing financial incentives, particularly the climate bonus. This observation reinforces the theoretical foundation, providing empirical support to the notion that the climate bonus is a significant factor in BEV adoption dynamics. Furthermore, the results are also in line with previous research, such as Diamond (2009), Beresteanu & Li (2011), Huse & Lucinda (2014), Hardman (2019), Engström et al. (2019), and Liu et al. (2021). Furthermore, the results also support other utility factors as determinants of BEV share, although some the other factors remain endogenous. The population density measure indicates that living in areas with higher population density decreases utility of purchasing a BEV. One intuitive explanation of this could be that living in areas with higher population densities, such as cities, reduces the need for vehicles, and that consumers thus rather prefer cheaper vehicles. The *kpi* estimate, which represents cost of living, indicates that an increase in living expenses increases the share of BEVs. This seems contradictive, as the prices of BEVs are generally higher. However, running costs of electric vehicles are much lower compared to ICEVs, and the introduction of cheaper BEV models could support this effect.

The price of fuel should correlate negatively with BEV share, as per the utility function set in the theory section, as increased fuel costs are a direct increase in cost for ICEVs, and hence decreases utility. This is supported by the estimated coefficient for petrol price, where an increase in petrol prices is significantly related to an increase in BEV share. However, the diesel price coefficient contradicts this hypothesis, as an increase in diesel price is significantly negatively related to BEV share. One potential reason for this is that PHEVs are included in the share of other vehicles contrasting the BEV share, and that an increase in diesel price would increase PHEV share more than BEV share. This could be a potential explanation, as nearly all PHEVs are petrol ICE, which would explain why this effect is not seen for increases in petrol prices.

Electricity price is negatively and significantly related to BEV share, which also supports the utility theory. As electricity price determines running cost of a BEV, the increase of such would increase the cost of owning a BEV, and hence reduce its utility.

As per diffusion theory, it seems that Sweden has come further due to historical policy measures, but that Denmark has achieved a higher rate through maintaining BEV incentives after 2022. Furthermore, the theory suggests differential rates of adoption in different areas, which we can support due using the population density estimate. As both Sweden and Denmark seem to be somewhere in the decision / implementation stage, the early and late majority are crucial to achieve large scale adoption. Hence, the theory and data suggest that policy measures should be aimed at this group of people. The early and late majority have different utility weights compared to early adopters, where product attributes and novelty are less valuable, and thus policy measures should be targeting utility factors that weigh heavier for the early and late majority, such as price and convenience measures. A bonus system should thus be effective in increasing the market share of BEVs, which is consistent with related literature (Diamond, 2009; Beresteanu & Li, 2011; Huse & Lucinda, 2014; Liu et al., 2021 etc.) and the results of this study.

7.2 Implications of the Climate Bonus Removal

The effect removal of the climate bonus on BEV share is strengthened by the relevant theory, literature, and results, but the implications for CO_2 emission reduction as well as the long-term diffusion effects, remain important factors to consider. The cost effectiveness of direct subsidy measures has been critiqued by previous literature (Beresteanu & Li, 2011; Huse & Lucinda, 2014) and reports (RIR 2020:1). An electric vehicle in Sweden, can save close to 200 g CO_2 per kilometer (Transport and Environment, 2022). An average vehicle in Sweden drove 11 260 km in 2022 (Trafik Analys, 2023). The reduction in BEV share of 0.122 %-points thus entails a reduction of 117 BEVs (the data used from Statistics Sweden for 2022 shows BEV registrations to be 96 136). This equates to $200\ g\ \times\ 117\ BEVs\ \times\ 11\ 260\ km/vehicle\ = 263\ 484\ 000\ g \approx 263\ tons$ per year. Which is not a lot. However, as this study is very close in time to the policy removal, long term effects may be underestimated. As per Figure 4, we can see that the share of BEVs were close to identical for Sweden and Denmark for the first time ever, and that the relative trend now seems to be more positive for Denmark. As for the long-term, this could entail a shift in the countries' relative position in EV adoption, as the rate of diffusion increases in Denmark relative to Sweden. Hence, given that the Danish market acts as a counterfactual scenario, the carbon reduction per year is likely grossly understated. Furthermore, as EV battery manufacturing improves carbon efficiency, the generated emissions from BEVs will also decrease further compared to ICEVs.

The cost efficiency of the removal, in times where interest rates general costs of living are high, could be argued to be reasonable in the short term, as compared with the relative cost of maintaining the bonus (RIR 2020:1). However, the cost efficiency can from the previous argumentation in the long-term reduce, and I propose the analysis of this effect for further research.

Lastly, the removal of the climate bonus serves as a signaling measure from the government, extending beyond its immediate economic impact to carry broader implications for the electric vehicle (EV) landscape. The policy decision communicates a new direction to industry stakeholders, influencing manufacturers, investors, and innovators within the EV sector. The government's stance on supporting electric vehicle adoption is not only a regulatory change but a powerful signal that shapes industry perceptions and decisions. It can stimulate or hinder investments, innovation, and strategic planning within the sector. With Sweden's historical role as a leader in EV adoption, this change may affect other countries attitudes towards EVs and incentives, further going against the climate change mitigation.

Furthermore, the signaling effect also applies to consumers, impacting their confidence and attitudes toward electric vehicles. Clear and consistent government support signals confidence in the technology, fostering consumer trust and encouraging adoption. Conversely, policy changes, such as the removal of incentives, may create uncertainty or skepticism among potential EV buyers.

While short-term cost considerations may drive policy changes, the long-term environmental impact becomes a critical consideration. The removal of the bonus may have immediate economic justifications, but its consequences on carbon reduction and environmental sustainability should be thoroughly evaluated. Policymakers must carefully navigate the interplay between short-term economic concerns and long-term environmental sustainability goals to ensure a balanced and effective transition to sustainable transportation.

7.4 Limitations and Other Factors Affecting EV Adoption

The main limitation of this study is that the parallel trends assumption, which is the identifying assumption of the difference-in-difference method, failed to hold in the pre-trend. This invalidates the results from an econometric standpoint and should be further assessed in future research. This calls into question the use of Denmark as a basis for the parallel trends' assumption. As there are multiple factors pointing towards similar or common trends between the BEV share of Sweden and Denmark, such as commonness in cultures and demographics as well as simply visually inspecting the curves, one potential solution to this problem would be to change the time interval between observations from months to for instance quarters, half-years, or years. This would smoothen the trends and remove some volatility that can be caused by, for instance, supplier seasonality difference, time lag or other differing variation. However, this may also hide some characteristics of the data that is important to analyze, such as end-of-year supply increases and precise effects of policy implementation. Furthermore, one can use propensity score matching or other synthetic controls to manufacture parallel trends. While this method is sound econometrically, I chose to retain the base comparison with Denmark to ensure comparability for policy makers and other stakeholders. EV- and climate mitigation policies are under much scrutiny for efficiency and effectiveness, and the most common way to scrutinize and evaluate policies are through comparisons with other countries. Hence, the comparison with Denmark is still very relevant and important, even though the identifying assumption did not hold.

Due to the failure of the parallel trends assumption, the test results are to be looked at critically, although they can still say something about the effects at play. The relatively low R2 indicates that the utility function concentrating on price and policy measures may not fully explain the variation in BEV share. Unconsidered utility factors may play a significant role in determining the total utility of purchasing a vehicle. Certain determinants of BEV share, such as population density and cost of living, may be endogenous, influencing results. The inclusion of additional predictors in subsequent models partially addresses this limitation. Furthermore, the contradictory effects of petrol and diesel prices in different models raise questions about the relationship between fuel costs and BEV share. The unusual inversion of effects warrants careful interpretation and further analysis.

Long-term effects of the climate bonus removal may be underestimated, given the study's proximity to the policy change. The relative trend shift observed between Sweden and Denmark suggests potential long-term implications that need further exploration. The insignificant impact of currency value on BEV share may oversimplify the complex interplay between currency fluctuations and consumer behavior, requiring a more nuanced analysis. While month fixed effects are introduced to account for seasonality in Column (3), the analysis may not fully capture the intricate temporal dynamics influencing BEV share.

Furthermore, other factors may have affected the results of my study, such as the malus (reduktionsplikt). The effect of its incoming reduction (Energimyndigheten, 2023) should be examined as well, seeing that fuel prices are a significant determinant of BEV adoption. The reduction of the malus would further the governments new apparent stance on electric vehicles and would increase the effect seen in this study. Furthermore, although vehicle registrations is a good measure of BEV adoption, one should also consider later stages of the life cycle, in which Sweden does currently not have significant incentives, which is shown by many used vehicles going to markets like Norway and the Netherlands (Alenius, 2023).

Exploring the long-term cost efficiency of the climate bonus removal is crucial, considering fluctuating interest rates and general costs of living. This investigation will provide an understanding of the evolving economic consequences of the policy change. Analyzing of how the removal of the bonus affects Sweden's global reputation and its ability to attract international investments and collaborations is also interesting and could be a topic for future research, as it would shed light on the broader implications of the policy beyond national borders.

Conducting a qualitative study on consumer perceptions and attitudes towards electric vehicles post-incentive removal would offer valuable insights into the signaling effect. Understanding how policy changes influence consumer behavior is important for predicting and shaping the adoption of electric vehicles. Building on diffusion theory, future research should focus on tailoring policy measures to the early and late majority. A thorough evaluation of the removal's environmental impact, considering factors such as CO_2 reduction and advancements in EV battery manufacturing, is necessary. This research will contribute to a comprehensive understanding of the consequences of the policy change on environmental sustainability. Further exploration of the influence of population density on BEV share should consider urban-rural dynamics and specific factors influencing consumer choices in different spatial contexts.

The changing dynamics in the conventional fuel market, as indicated by the effects of petrol and diesel prices, warrant deeper exploration. Understanding consumer responses and their implications for EV adoption in response to fuel market changes will contribute valuable insights to the evolving discourse. Analyzing the effects of policy changes on global perceptions and investments in the electric vehicle sector is crucial. This research will provide insights into the broader economic and strategic implications of national policy changes, contributing to a more comprehensive understanding of the global landscape.

Addressing these topics will enhance the depth and applicability of this study's findings, as well as contribute to the evolving discourse on electric vehicle adoption dynamics and policy effectiveness.

8. Conclusion

This thesis has provided a comprehensive analysis of the impact of the removal of the climate bonus subsidy on electric vehicle (EV) adoption in Sweden. The study employed a Difference-in-Differences framework, comparing the share of newly registered passenger cars of battery electric vehicles (BEVs) with shares of internal combustion engine vehicles (ICEVs) and hybrids. The findings reveal a statistically significant decrease in the share of newly registered passenger BEVs following the subsidy removal, indicating a negative impact on BEV demand. This result aligns with previous studies that have found the impact of similar subsidy programs on the proliferation of environmentally friendly cars to be relatively small, yet significant. However, due to the failure of the parallel trends assumption, the internal validity should be viewed critically. Nonetheless, results are still important to policy makers and stakeholders for comparability and direction for future policy measures to achieve effectiveness when targeting the mobility industry and climate change.

This research contributes to the existing literature on vehicle incentives and their effects on EV adoption. By focusing on the specific removal of a substantial subsidy, the thesis aids in filling a gap in understanding how such policy changes affect the market. The study's methodological approach and its focus on the Swedish context provide valuable insights into the dynamics of EV adoption in response to policy shifts.

The findings of this study have important implications for policymakers and stakeholders in the automotive industry. The observed decrease in BEV registrations post-subsidy removal suggests that financial incentives play a crucial role in promoting EV adoption. This insight is vital for governments and regulatory bodies considering similar policy changes. It underscores the need for a balanced approach that considers the economic aspects of EV adoption alongside environmental goals.

Future research should explore the long-term effects of subsidy removal on EV adoption, considering factors such as changes in consumer preferences, technological advancements, and market dynamics. Additionally, comparative studies across different countries with varying policy landscapes would provide a broader understanding of the global impact of such policy changes on sustainable transportation.

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Förordning (2022:801) om ändring i förordningen (2017:1334) om klimatbonusbilar

Appendices

Appendix A: Robustness Checks

1. Breusch-Godfrey Test & Pesaran CD Test

```
	Breusch-Godfrey test for serial correlation of order up to 1

data:  paneldidyfe
LM test = 270.89, df = 1, p-value < 2.2e-16


	Pesaran CD test for cross-sectional dependence in panels

data:  bev_share ~ sweden + nobo + (sweden * nobo) + chargepoint_density +
pop_dens + kpi + petrol_price_eur + diesel_price_eur + el_price +
euro_exchange + factor(month)
z = 19.306, p-value < 2.2e-16
alternative hypothesis: cross-sectional dependence
```

Robustness checks of the results indicate generally poor performance. This is expected, and the performance of robustness checks is negligible in this specific case, due to the failure of the parallel trends assumption, which invalidates results anyway. However, as discussed in the work, comparability and direction purposes maintain the importance of the work, and the results may act as indications and motivations for future studies.

2. Correlation Matrix

	chargepoint_density	pop_dens	el_price	euro_exchange	petrol_price_eur	diesel_price_eur	sweden	bev_share	nobo	kpi
chargepoint_density	1	0.58	0.15	0.45	0.12	-0.19	-0.47	-0.01	0.18	0.06
pop_dens	0.58	1	0.16	0.36	0.06	-0.18	-0.37	-0.12	0	-0.07
el_price	0.15	0.16	1	0.45	0.35	0.12	-0.43	-0.06	-0.25	-0.08
euro_exchange	0.45	0.36	0.45	1	0.17	-0.5	-0.98	-0.34	-0.14	-0.35
petrol_price_eur	0.12	0.06	0.35	0.17	1	0.68	-0.17	0.06	-0.17	0.18
diesel_price_eur	-0.19	-0.18	0.12	-0.5	0.68	1	0.48	0.34	-0.07	0.43
sweden	-0.47	-0.37	-0.43	-0.98	-0.17	0.48	1	0.26	0	0.18
bev_share	-0.01	-0.12	-0.06	-0.34	0.06	0.34	0.26	1	0.54	0.62
nobo	0.18	0	-0.25	-0.14	-0.17	-0.07	0	0.54	1	0.78
kpi	0.06	-0.07	-0.08	-0.35	0.18	0.43	0.18	0.62	0.78	1

3. Main Model

Below follows the output from the main specification in R.

```
Oneway (individual) effect Within Model

Call:
plm(formula = bev_share ~ sweden + nobo + (sweden * nobo) + chargepoint_density +
    pop_dens + kpi + petrol_price_eur + diesel_price_eur + el_price +
    euro_exchange + factor(month), data = panel_data, model = "within")

Balanced Panel: n = 32, T = 30, N = 960

Residuals:
      Min.    1st Qu.     Median    3rd Qu.       Max.
-0.1831635 -0.0296118 -0.0014473  0.0295674  0.2023903

Coefficients:
                      Estimate  Std. Error t-value  Pr(>|t|)
nobo                 7.4917e-02  1.2506e-02  5.9906 3.011e-09 ***
chargepoint_density  5.0296e-03  1.0607e-02  0.4742 0.6354856
pop_dens            -6.5400e-04  2.5870e-04 -2.5280 0.0116405 *
kpi                  1.0595e-02  1.3320e-03  7.9543 5.343e-15 ***
petrol_price_eur     8.6557e-02  2.5361e-02  3.4129 0.0006711 ***
diesel_price_eur    -5.3357e-02  2.2452e-02 -2.3765 0.0176866 *
el_price            -1.6081e-04  4.3574e-05 -3.6905 0.0002371 ***
euro_exchange       -4.8661e-01  1.6046e+00 -0.3033 0.7617635
factor(month)2      -2.4619e-03  8.6691e-03 -0.2840 0.7764910
factor(month)3       5.3515e-02  8.6602e-03  6.1794 9.702e-10 ***
factor(month)4      -2.0444e-02  9.1366e-03 -2.2376 0.0254876 *
factor(month)5      -2.8847e-02  9.5415e-03 -3.0233 0.0025704 **
factor(month)6      -2.6774e-03  8.8592e-03 -0.3022 0.7625527
factor(month)7      -3.0129e-02  9.0530e-03 -3.3281 0.0009096 ***
factor(month)8       1.9796e-02  8.5155e-03  2.3248 0.0203048 *
factor(month)9       6.4424e-02  8.6124e-03  7.4803 1.749e-13 ***
factor(month)10      1.3482e-02  8.7706e-03  1.5372 0.1245959
factor(month)11      5.3761e-02  9.8478e-03  5.4592 6.174e-08 ***
factor(month)12      1.6688e-01  9.5103e-03 17.5471 < 2.2e-16 ***
sweden:nobo         -1.2190e-01  1.3374e-02 -9.1150 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    7.9034
Residual Sum of Squares: 2.1049
R-Squared:      0.73368
Adj. R-Squared: 0.71872
F-statistic: 125.069 on 20 and 908 DF, p-value: < 2.22e-16
```

4. Alternative Models

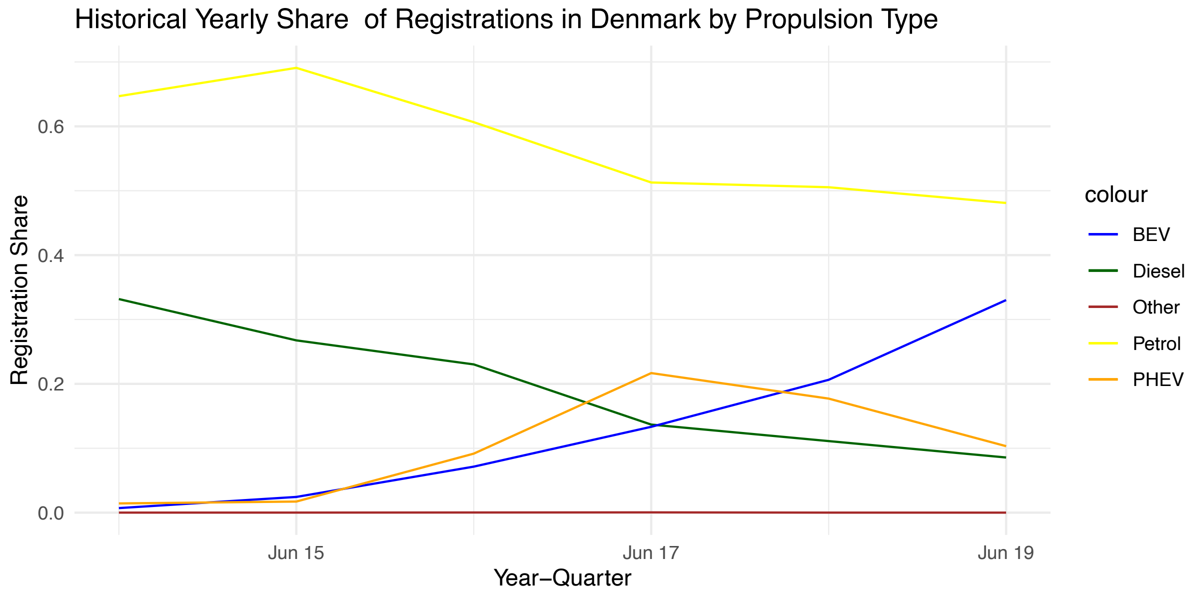
As the dependent variable is in a continuous interval between 0 and 1, it is also interesting to use models specified for this purpose, although previous researchers that this work is based on have used standard regressions. Hence, below follows a Beta Regression model, which is well-suited to modelling variables in a continuous interval, typically between 0 and 1. This type of regression is particularly useful when the dependent variable is probabilities, rates, proportions, or fractions, which my dependent variable is (proportion, that is).

a) Beta Regression Output:

```
Call:
betareg(formula = bev_share ~ sweden + nobo + (sweden * nobo) +
    chargepoint_density + pop_dens + kpi + petrol_price_eur + diesel_price_eur +
    el_price + euro_exchange, data = panel_data)

Standardized weighted residuals 2:
    Min      1Q  Median      3Q     Max
-3.8628 -0.6960  0.0204  0.6467  3.2931

Coefficients (mean model with logit link):
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)         -5.101e+00  1.944e+00  -2.625 0.008678 **
sweden               3.659e-01  3.883e-01   0.942 0.346081
nobo                 6.915e-01  6.647e-02  10.404  < 2e-16 ***
chargepoint_density -3.449e-02  2.854e-02  -1.209 0.226844
pop_dens            -1.321e-05  1.854e-05  -0.712 0.476383
kpi                  3.490e-02  7.348e-03   4.749 2.04e-06 ***
petrol_price_eur    -5.320e-01  1.374e-01  -3.873 0.000108 ***
diesel_price_eur     4.304e-01  1.143e-01   3.767 0.000165 ***
el_price             1.022e-03  2.177e-04   4.695 2.67e-06 ***
euro_exchange        4.286e-01  1.035e+01   0.041 0.966961
sweden:nobo         -6.970e-01  8.457e-02  -8.242  < 2e-16 ***

Phi coefficients (precision model with identity link):
      Estimate Std. Error z value Pr(>|z|)
(phi)   41.470      1.876   22.11   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)
Log-likelihood:  1236 on 12 Df
Pseudo R-squared: 0.5401
Number of iterations: 25 (BFGS) + 2 (Fisher scoring)
```

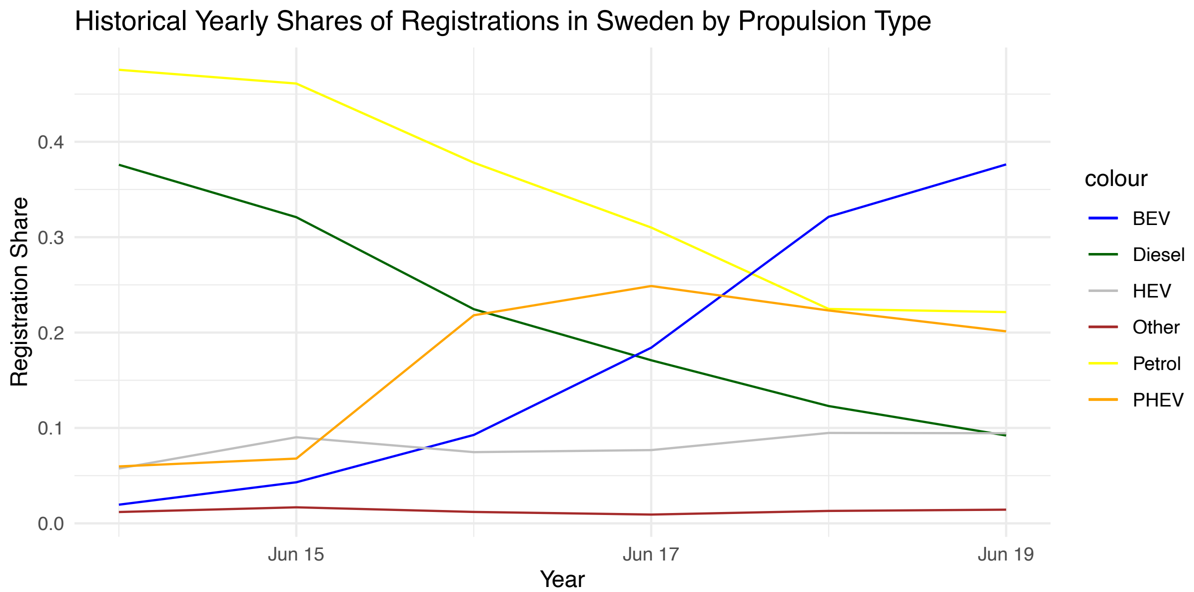
Appendix B: Historical Graphs

1. Historical Yearly Share of Registrations by Propulsion Type, Denmark



(Statistics Denmark, 2023)

2. Historical Yearly Share of Registrations by Propulsion Type, Sweden



(Statistics Sweden, 2023)