The Bonus-Malus system

- Will it be a cost-effective and fair policy for emission reductions from road traffic in Sweden?

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Abstract

As emissions of greenhouse gases has become one of our times most urgent issues, the policies implemented by governments in effort to reduce them are many and varied. In Sweden, a feebate system for vehicles was implemented in mid 2018. This paper attempts to answer the question whether or not the bonus-side (a subsidy for electric vehicles) of the policy will reduce emissions in a cost-efficient and fair way. The questions in answered by using material available to those who made the decision, and by looking at previous research and data. Mathematical examples of the cost, through the cost of the policy, of reduction is compared to EU ETS to evaluate cost-efficiency. The fairness aspect is reviewed by studying regional data. The conclusions are that the policy is neither cost-efficient nor is it free from interregional equity concerns.

Sammanfattning

Medan utsläppen av växthusgaser har kommit att bli vår tids största utmaningar försöker länder och myndigheter implementera en bred variation av styrmedel för att minska utsläppen. I Sverige, infördes ett s.k. feebate system för personbilar i mitten av 2018 och denna uppsats försöker besvara frågan om Bonusen (subvention av bl.a. elbilar) i styrmedlet kommer att reducera utsläpp på ett kostnadseffektivt vis samtidigt som det inte bidrar till negativa fördelningseffekter. Forskningsfrågan är besvarad genom att använda material som fanns tillgängligt när beslutet att införa styrmedlet fattades, genom att använda tidigare forskning samt statistik. Matematiska exempel över hur kostnaden, genom styrmedlet, för reduktionen blir jämfört med utsläppsrätter för att undersöka kostnadseffektivitet, och fördelningseffekterna är utvärderade genom studier av regional statistik. Slutsatserna är att styrmedlet varken är kostnadseffektivt eller utan negativa fördelningseffekter ur ett interregionalt perspektiv.

Keywords

Feebate, Electric Vehicles, EU ETS, Bonus-Malus, Interregional Equity

Abbreviations

EV	Electric vehicle
GHG	Greenhouse gases
ICEV	Internal combustion engine vehicle
PHEV	Plug-in Hybrid Electric vehicle
EU ETS	EU Emissions Trading System

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1. Introduction

It is well documented that reductions in emission of greenhouse gases (GHGs) are one of the most important, defining and urgent issues of our time (UN, 2019). It is characterized by the fact that greenhouse gases know no borders, the impact of one country is spread world-wide. This has led to international agreements aiming to lower emissions, such as the Paris Agreement (United Nations Climate Change, 2019). As a member of the European Union, Sweden is also encouraged to reduce emission through the EU ETS cap-and-trade system, which target energy production sector among other. The idea is that those who are subject to the system need to purchase permits to cover their emissions or choose to lower their emissions. The price of the permits is therefore considered the marginal cost of reduction and is in this study used as the benchmark for the cost of emitting one ton of carbon dioxide equivalent[1].

On the national level, governments are tasked with trying to move society towards lower emissions while at the same time sustain other goals such as growth and economic welfare systems. The complexities of the climate change make "local" policies more difficult to implement and legitimize[2], as it involves several sectors in society, and the consequences are felt globally. Thus, policy instruments, if not implemented on a larger scale such as globally or at least EU-wide, can be hypothesized to include elements of legitimacy and fairness. However, Canada has implemented a revenue-neutral carbon-tax which gives tax revenue back to households, trying to consider both emission reduction and equity (Nuccitelli, 2018).

In Sweden, around one third of the total emissions comes from transports within the country (Naturvårdsverket, 2018). The average distances driven in Sweden, between 1999 and 2017 (*Graph 1*) shows a quite stable trend until 2008 when it started to decline, whereas emissions per kilometre (*Graph 2*) has decreased quite rapidly. The emissions from road transport as however, compared to the overall emissions of Sweden, which has gradually been reduced over the last 27 years, been quite stable (see *Graph 3*). Combined, this suggests transport as a natural target for the government in the quest to lower emissions and keep up with the international agreements and emission reduction targets.

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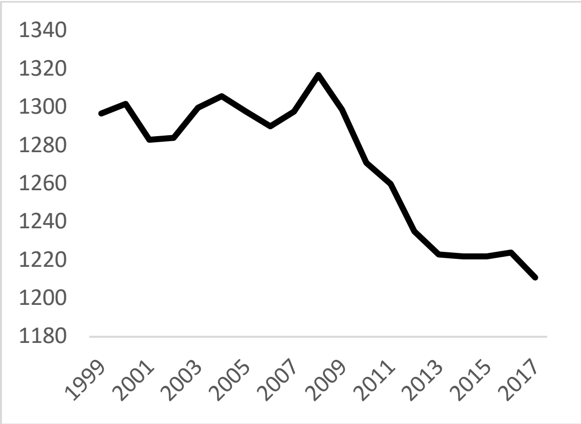
[1] CO_2-eq: carbon dioxide equivalent (a measurement of different GHGs that is equivalent with on ton of carbon dioxide emissions)

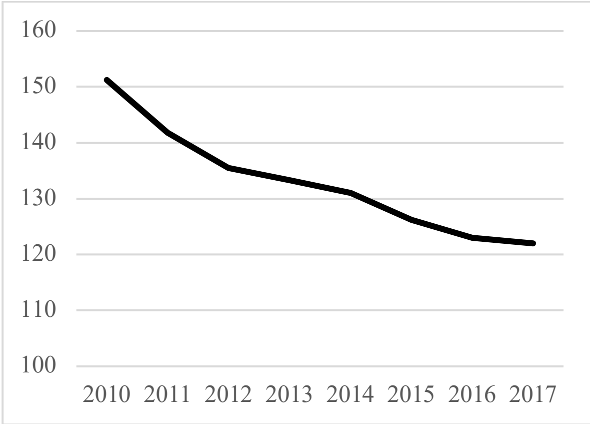
[2] The ongoing protest by the Yellow Vests in France is an example of this. The movement started when the French government tried to implement higher taxes on fossil fuels, which was met by protests. (SVT, January 12th 2019)

***Graph 1 Average yearly distance** (10 km)*



(Data from Trafikanalys, 2019)

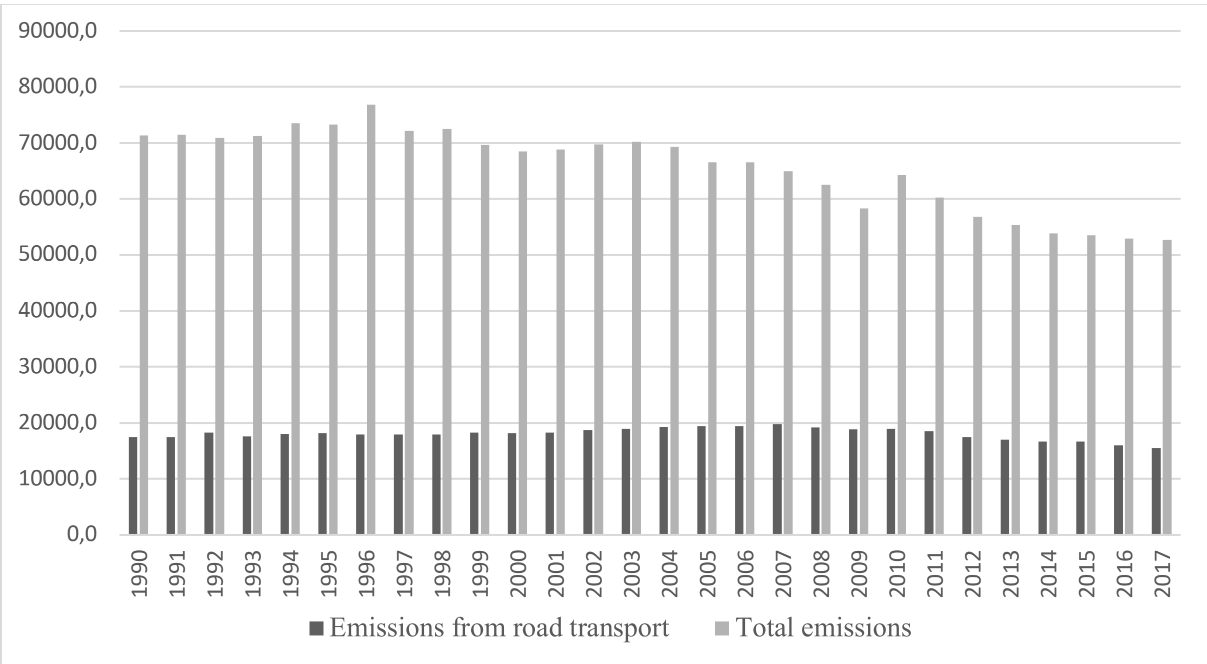
Graph 2 Average emission per kilometer



(Data from Transportstyrelsen, 2019)

Graph 3 Emission of GHGs in Sweden 1990 - 2017

(excluding international transport, measured in thousands of tons)



(Data from SCB, 2019)

To change the behaviour of the citizens governments can use a range of different policy instruments where costs and outcome vary. For example in Sweden, tax on carbon dioxide and a differentiated vehicle license tax to discourage use of high emitting vehicles is two policy tools used over the last decades (Trafikanalys, 2016). On the 1st of July 2018 a new system to encourage low-emission transportation was implemented, targeting new vehicles (in 2017, over 392 000 new vehicles were registered in Sweden (SCB, 2019)). The new policy, the Bonus-

Malus-system (a feebate system), contains of two parts. The first (Bonus) is a subsidy of environmentally friendly vehicles, and the second part (Malus), is an increase in the tax on vehicles with combustion engines, based on the emissions from the exhaust pipe. The idea is to change the relative prices and thus speed up the renewal of the Swedish vehicle fleet. This aims to reduce the fossil fuel use, thus lowering the climate impact from road traffic (Transportstyrelsen, 2019a). The underlying principle is that environmentally harmful activities should shoulder a higher tax, while environmentally friendly alternatives should get a tax relief. This is the fundaments of a so-called "green tax shift".

The harshest way to reduce emissions which harm the environment would be to simply ban the use of it. On the other hand, one could ignore the environmental consequences and continue with business as usual. Most would favour a solution in between. Sweden is a large, but sparsely populated country with a few highly populated urban areas and the dependency of transport by car differs between areas. To ensure that the population in more rural areas have access to the welfare system, proper infrastructure, jobs, education etc is a specific challenge for the government in Sweden. In today's society many citizens depend on their cars for commutes between home and work, or their leisure etc. The consequences of simply banning the combustion engine would likely be severe and would most probably be met by protests[3]. Given the current importance of the combustion engine in many citizens' life, equity concerns and interregional differences are considered in this paper. This notion is further supported by the Cohesion Policy of the EU, which receives 1/3 of the EU budget and work towards lowering interregional equity issues (European Commission, 2019 and SKL, 2019). With this in mind, the effects of policies that try to move society towards sustainability will differ depending on the context in which they are applied. A policy is constructed with a certain aim of what it is supposed to change, and mostly, policies are enforced or implemented equally for all individuals in a country. This last part could be troubling, since the responsiveness or possibility to respond can differ between groups, geographic areas, individuals etc., making the outcome of a policy uncertain and perceived as unfair[4]. On this reasoning, the question of fairness and possible regressive outcome of specific policy arises.

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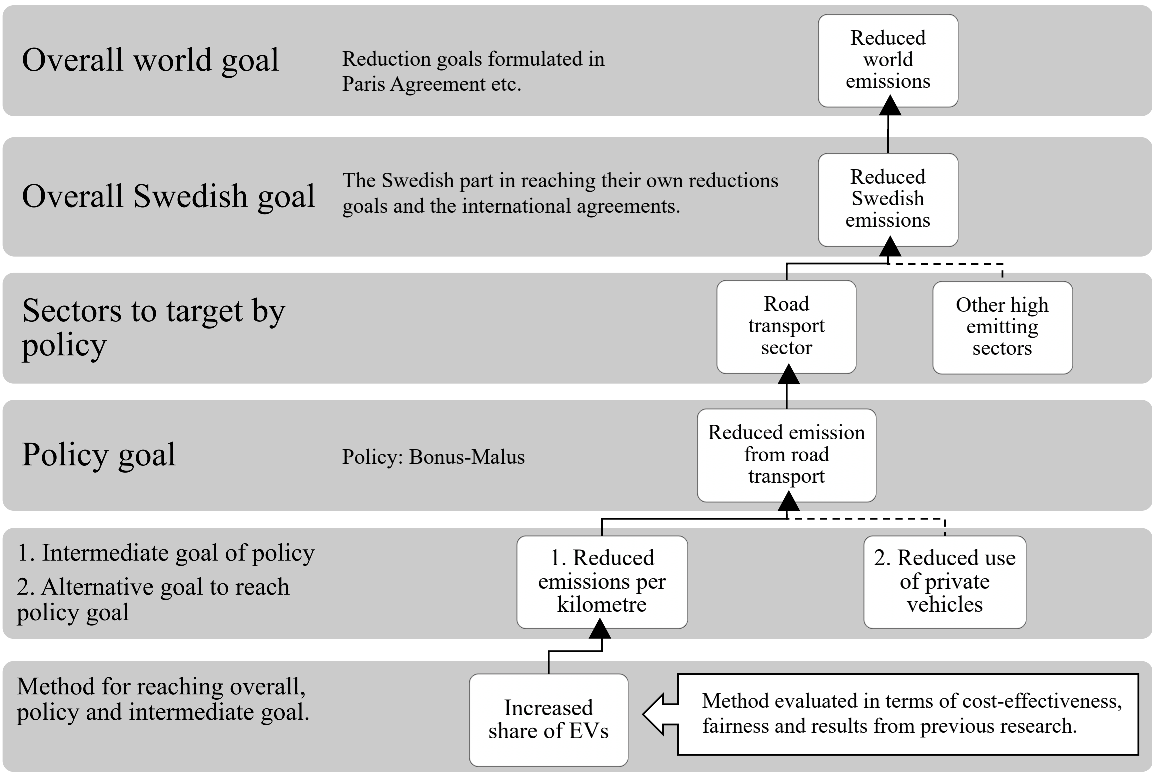
[3] See for example Bensinupproret 2,0, a Facebook-group with 400 thousand members (May 2019) and display anger towards higher prices on fossil fuels in Sweden. (SVT, May 9th 2019)

[4] Economists rarely include fairness in policy evaluations, they may sometimes study how groups are affected, but seldom address equity concerns (Cookson, 2019)

This paper aims to evaluate the new Bonus-Malus-system. Mainly the Bonus side of the policy from a conventional economic standpoint: Is this the most cost-effective way to achieve CO_2-reductions in the transport sector? However, there will also be an assessment of some consideration regarding the consequences of the policy effect on different groups in Sweden, studying regional differences and who are more likely to become subject to the policy.

The starting point of this paper is that the Malus part of the policy is taken as given, therefore excluded from the analysis. The evaluation consists of several criteria regarding efficiency and equity, studied based on a literature study and examples on how the Bonus part of the policy functions in reality. The intension of the policy is that by increasing the share of low emitting vehicles the overall goals can be met. The description of the connections from a world perspective, to a Swedish one and the policy and its supposed emission reducing mechanisms is shown in the schematics below.

Graph 4 Schematics of emission reduction



(Own design and construction)

First, the reductions of GHGs on the international level is one of our times most urgent issues. This in turn consists of the reductions made in all countries in the world, therefore, the second level of the schematics above is the Swedish emissions reductions. Emission comes from all sectors which could be targeted by policies to quicken the reductions. The policy studied in this paper focuses on road transport (responsible for 1/3 of emissions in Sweden), and the privately-owned vehicles in particular. The policy goal is to encourage a renewal of the vehicle fleet, favoring low emitting vehicles, and by extension lowering the emission from this sector (Transportstyrelsen, 2019a). Therefore, the intermediate goal (1.), the mechanism on which the policy focuses, is the in-use emissions, where the aim is to lower the average emissions per kilometer. That is, the emission from the exhaust pipe per kilometer. However, a policy could have had another target (2.), trying to promote shorter distances driven. The last row presents the method of reaching the above-mentioned goals, which is an increased share of EVs[5] (and other low emitting vehicles) in the Swedish vehicle fleet. This method is what will be evaluated in this paper, in relation to the different levels of goals from efficiency and fairness perspectives and on the basis of previous studies.

The schematics tries to visualize the predicted relationships between the different aspects, goals and levels of emission reduction in relation to the policy. On every level, one can ask if it leads to positive effects on the level above, since the schematics show how the connections should work. By doing so, a framework for the evaluation, analysis and conclusions is established.

This paper begins with a formulation of the research question and the context in which the questions is relevant. Thereafter the theoretical background is established and followed by the previous studies used in this paper. The methodology for evaluating cost-effectiveness and equity is presented. Then, the data used is briefly described. The results are presented in four sections and is followed by the analysis, which follows the schematics presented in *Graph 4*. Finally, the thesis ends with conclusions and some suggestions on further work in this field.

[5] Since the policy is strongest (in monetary terms) for electric vehicles (EVs), which emits zero per kilometer, this is the main focus and method for reaching the intermediate goal.

1.1. Research question

Will the Bonus Malus-System be a cost-effective and fair way to achieve reduction in CO_2 emissions?

Theoretically, the concept of cost-effectiveness in economics is straightforward. But how the policy is constructed in relation to the target need to be studied at before further evaluations can be done, since the policy might miss the intended target. However, an evaluation of a subsidy such as the Bonus-Malus is an empirical challenge.

However, equity or fairness, is a much more elusive concept (Le Grand, 1990). Whether a policy in a wider context is fair is in itself a question that requires a more in-depth investigation into the concept of fairness itself. Thus, and very humbly so, the assumption that a fair climate policy is formulated so that geographical location does not determine the consequences for individuals. Thus, in a rather simple attempt, fairness is "operationalized" in terms of geographical impact. Assuming, a fair climate policy is defined as on which does not widen the gap between the urban and rural population.

1.2. Delimitations

First, the policy is to recent to be able to properly evaluate the outcome. This study works with current information and admittedly, the lack of historical data and experiences, makes some of the conclusions "heroic". Data availability limits the scope of the study. One could have established links between who becomes subjects to the two respective parts of the policy and who is left out if there was individual data on socio-economic factors, income, household type etc for those who own an EV and those who doesn't. But there is no such micro data available, and the resources devoted to this research are limited and would not cover a survey. A survey could have given data on which uses the subsidy, who becomes subject to Malus etc.

The benchmark for reduction costs is EU ETS, based on previous studies method of doing so. There could be other policies which on should compare, but as EU ETS is a large and established system, it is considered to be the most relevant comparison available.

The attempt to include interregional equity concerns is somewhat unchartered territory. That part of the thesis limits itself to some minor theoretical suggestions and proposed equity concerns suggested by available date.

2. Context

To meet the challenges of substituting fossil fuels for more environmentally sustainable alternatives there are a broad range of possible solutions and policies. To understand the context of the research question, current Swedish taxes on vehicles, and the new policy is described below. Thereafter, the status of the electric vehicle market, environmental impact and technology is discussed to highlight perspectives enabling an understanding of the prevailing situation.

2.1. Sweden and the policy

In Sweden fossil fuels are subject to VAT, carbon and energy tax. In addition, car owners pay a vehicle license tax (fordonsskatt). There are two distinctive sides of these types of taxes. First, the revenues to the governments fund the infrastructure, welfare services etc, which therefore could be seen as a fee for using the services. The other is the intended changes in the incentives structure. By taxing activities, in this case driving you own vehicle, the policy maker sends out signals that the activity is unwanted and should be reduced. This is done to internalize the negative externalities from the activity. (Pihl, 2014)

From July 1st 2018, the Bonus-Malus-system was implemented. Where Bonus (Latin meaning good) is a subsidy or bonus of maximum 60 000 SEK (≈5850€)[6] and not more than 25% of the price, for vehicles with no in-use emissions of greenhouse gases. The bonus is then gradually lowered by 833 SEK with each gram of emission per kilometre. In the Swedish state budget, 1,24 billion SEK has been set aside for Bonus in 2019 (Transportstyrelsen, 2019). The subsidy or Bonus is payed-out six mounts after purchase, at the earliest. Employees who use an EV (electric vehicle) provided by the employer, on her/his private time, is subject to a taxable benefit value. This benefit value is reduced for vehicles which are subject to Bonus. The Malus part (Latin meaning bad) is a raised vehicle licence tax during the first three years of ownership for vehicles that emit 95g CO_2/km or more. For emissions between 95 and 140g the tax is 82 SEK/g, and above 140g CO_2/km the payment is 107 SEK/g. Additionally, diesel vehicles are subject to an environmental tax and a tax on the fuel. During the first three months of 2019, 81,7% of the money payed out as Bonus has been to legal entities/companies (Transportstyrelsen, 2019a). According to the Swedish government and their projected cost and revenues of the policy is stated in *Table 1* below.

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[6] Exchange rate found at Swedish Central bank, 20190520, 1 € = 10.2567 SEK

Table 1 Policy budget

(billions of SEK)	*2018*	*2019*	*2020*
Revenue Malus	0.45	1.34	2.22
Cost Bonus	-0.02	-1.25	-1.64
Sum	0.43	0.09	0.58

(Source: Projected numbers from regeringen.se/government.se Site visited 20190520)

The projected budget assumes Malus to finance Bonus and create a surplus. The low budget for 2018 is due to the fact that the policy was implemented mid 2018 and that the payouts are delayed.

2.2. Some perspectives on electric vehicles

In Bonus-Malus the emissions from the exhaustion pipe is the determinant parameter. The output of GHGs is measured when the vehicle is driven in a specific cycle. Conventional cars have high emissions, EVs have zero and PHEVs (Plug-in Hybrid Electric vehicle) have something in between. This method excludes the emission from the entire life cycle of the vehicle, the possibility to use biodiesel in ICEVs and the emissions of the production of electricity[7] (EEA, 2018). This could skew the discussion, and decisions and could lead to inefficient solutions. To prevent this, one can look at the life cycle perspective. That is, calculate the emissions from producing raw materials, manufacturing, during use and last, recycling or deposit, to get a more precise evaluation. According to the European Federation for Transport and Environment (2018) a common misconception is that a higher turnover in the vehicle fleet would lower emissions. Their calculations show, on the contrary, that keeping a vehicle 15-20 years is optimal to minimize the emissions over a vehicle's lifecycle. This time becomes shorter (less than 15-20 years) if the in-use emissions has a rapid decrease, as with EVs.

According to IVL (2017), the emissions of GHGs in the production of the batteries used in EVs and PHEVs depend on several technological aspects and the energy mix of the manufacturing country. Which is often quite poor from an environmental standpoint. By

[7] Production of electricity within the EU is subject to EU ETS, meaning that the negative externalities of GHG emissions is internalized in the price of electricity in the member states.

comparing several previous studies with a broad range of estimates they present a measurement of the emissions. The result was that the emissions of GHGs are approximately linear with capacity of the battery and the emissions in manufacturing is between 150 and 200kg CO_2-eq/kWh. An EV with a smaller battery and a range of 200-250 km, has caused emissions of approximately 5 tons of CO_2 before it has left the car dealer, which is equivalent with combusting 2000 litres of diesel. This means that a fuel-efficient diesel vehicle can drive 4-50 000 km, causing the same amount of emissions as the EV has, before the EV has rolled even one meter. This is approximately equal to 3-4 years driving a diesel[8]. Further, if the diesel vehicle uses 40-50% biodiesel, the distance is even longer. Yet, unless the electric vehicle is powered by electricity from coal, there are emissions savings in EVs in comparison with ICEVs when looking at the entire life-cycle (EEA 2018). The savings arise when the EV accumulate distance, and the average emissions per kilometre decrease over the lifetime, unlike the internal combustion engine which continue to emit GHGs while in-use.

An aspect of the life cycle emissions of EVs is the energy mixes of the countries of production and of use. Messagie (2017) compared energy mixes of the European countries and found that in Sweden, each kWh emits 20g CO_2, which was the lowest among the investigated countries (lowest in Europe). However, within the EU the negative externalities regarding greenhouse gases from electricity production is internalized in the price of electricity since it is subject to the EU ETS. Messagie (2017) disregard the EU ETS and calculates that changing from an ICEV (fuelled with diesel) to an EV would on average lower emission by 85%, counted over the entire lifecycle, and when used in Sweden. But even when he studies the effects in Poland, which has the most polluting energy mix (650g CO_2/kWh) his results show that a switch to EVs would lower emissions with 25%. This suggest that a move towards more EVs can be part of the solution towards sustainability, but also that the electricity generation technologies matter to the outcome. Further, if the batteries where produced in a low emitting country such as Sweden, the results would be even more in favour or the EVs.

Given the reasoning above, questions arise regarding availability and possibility to move away from ICEVs towards EVs. Even when new technologies have been invented and has been introduced to the broad market, the prices are usually higher than for the older technologies, and the new product could be considered riskier (as technology is still not tested on a large scale) to the potential consumer. One reason why an electric vehicle is more

[8] Calculations: 40 000km / 12 000 km = 3.33 and 50 000km / 12 000 = 4.16 (12 000km is Swedish yearly average)

expensive than a conventional one is due to the high cost of the batteries (Newbery and Strbac, 2015). Thus, to speed up the transition towards a climate friendly transport sector a subsidy can be used. When subsidized, the price consumers meet is lower, and the climate friendly vehicle has a better chance to compete with the ICEVs.

The early adopters of the new technology have some special features. By identifying them, policies and regulations can be streamlined to encourage the group of early adopters to go from idea to action thus lowering the cost of the policies (Plötz et al. 2014). The idea is that it takes less recourses when those close to adoption is targeted. Electric vehicles are such a technology that is characterized by high initial cost and uncertainty (lifetime of batteries, environmental impact, range, price on the used-cars market, energy mix available etc.) This exemplifies one trade-off between efficiency and fairness, if early adopters already can be considered as “privileged”, many might be left out or the policy.

3. Theory

3.1. Environmental economics and policy instruments

When economic activity, such as driving your own vehicle, causes pollution which is not included in the price of the activity, we talk about negative effects/externalities. That is, the private cost of the activity is lower than the social cost. To minimize the misuse of the limited resources, governments use policy instruments to internalize, price the external effects, and thus change the behaviour of individuals and firms. Ideally, a tax on the economic activity should make the price of the activity equal to the social cost. (Pihl, 2014)

A subsidy in the case of pollution could be a transfer for each unit of pollution reduction. It could also be a subsidy to encourage innovations, investments and infrastructural changes that facilitate lower emissions. An alternative to the subsidy would be a fee for each unit of emissions. The main different is the effect for the government budget and what the policy signals out to society. (Pihl, 2014)

Another instrument used to deal with emissions are cap-and-trade systems. In such schemes, allowances exist for the amount of pollution that is considered acceptable, and those included in the scheme must hold the amount allowances that reflect their emissions in each time period. The allowances can be handed out or actioned out and are thereafter tradeable. Which results in a situation where those with the highest marginal abatements cost (cost per reduced unit) buys allowances from those with low abatement cost. This type of schemes internalizes the negative externalities caused by pollution, and the polluter gets a financial burden that he has incentives to lower. (Pihl, 2014)

A policy is set up to reach a certain goal (can be more or less precise) and whether the policy is dependable in reaching it is an objective that should be studied. Achieving the goal is simple if the abatement cost of reductions is known, however, often these costs are not known and therefore the rate or level of a policy is difficult to match the target. This means that the outcome of the policy is uncertain, it could land above or below the target, decreasing the dependability of the policy. (Perman et al 1999)

To evaluate a policy there are several aspects to account for. One would be if the policy is effective (reaches the target), another is if it is reaching the target in a cost-effective way. For a policy instrument to be efficient from an economic perspective, the net benefits of the policy must be equal to the maximum net benefits of the society (Field and Field, 2017). In the area of emissions this is achieved when marginal abatement cost is equal to the marginal damage cost. This however requires information on these two costs, which needs to be empirically estimated. For this reason, looking at cost-effectiveness can be a more direct way to evaluate a policy. From that standpoint, one would evaluate the maximum improvement of the damaged environment that can be achieved given a fix amount of resources. In this simplified example, the most cost-effective policy meets some target, i.e. a certain reduction of emissions, at lowest cost. This makes policies comparable in cost, which is the method of choice in this paper.

3.2. Subsidies and equity concerns

As this paper argues, a subsidy can come to have impact on interregional equity, the mechanisms contributing to inequality and the role of subsidies are described in this section. To receive a subsidy, one must buy a vehicle that is covered by the policy. The decisions to make such purchases are theorized in consumption theory. Individuals or households make consumption decisions based on several different aspects. In the most simplified version consumer theory economics look at the budget constraint and the prices of goods (Perman et al 1999). Often there is an assumption that the goods are homogenous, and that there is perfect competition. However, more reasonable assumptions might be to look at goods as differentiated and that consumers also care about other aspects than price. Quality, attributes, in-use costs, environmental concerns, user-friendliness, brands etc can matter when making a purchasing decision. When a subsidy is introduced on a good, the price that the consumer meet becomes lower and the reason for the introduction of such a policy is to change relative prices, behaviours or incentives for consumers. By subsidizing, the hope is to increase the activity which has a positive externality, in this case, the hope is to lower a negative one.

A subsidy is a transfer from the government to individuals who are eligible for that specific transfer. In contrast to taxes, a subsidy would be considered regressive with income if those with higher income receives larger sums or if the subsidy is a larger share of income. Subsidies are funded by fees or taxes, and the redistribution of those recourses is a fundamental aspect of economics, which is to economize our limited resources (Pihl, 2014).

With every policy that is imposed on a market or country, there are costs and benefits. These can be distributed in different ways. The criteria presented by Field and Field (2017) regarding fairness/equity points out this aspect, the distribution of the monetary and nonmonetary cost and benefits of the policy and onto whom the effects fall.

Briefly considering Rawls's Theory of Justice, and his Differences principle, saying that "Social and economic inequalities are to be arranged so that they are both a) to the greatest benefit of the least advantaged, consistent with the just savings principle, and b) attached to offices and positions open to all under conditions of fair equality of opportunity" (Rawls, 1971), the aspect of equity is deepened and defined. Equity regarding a policy is defined as the distribution of the cost and benefits among members of society, and that might lead to the perception of the policy to be reasonable or unreasonable (Ecola and Light, 2009). By extension, there could be individuals or groups who are neither in the "cost" or "benefit" group of the policy but left out of the policy altogether.

To evaluate who gains and who loses is one important aspect when choosing a policy. This can have ethical and moral implications, but as the yellow vests in France showed, it may also affect the possible success of implementing the policy. A policy that do not achieve fairness may be difficult to politically implement. That a policy should not create or enhance inequality between groups of people is often an important condition when deciding on a new policy. Inequalities can be defined as differences in incomes, social status, interregional equity etc. It could be a question of differences between groups, for example the question on whether the implementation of a new scheme is regressive with income. (Field and Field, 2017)

4. Previous research

Since Bonus-Malus has not, May 2019, been implemented for a whole year, the outcome cannot fully be evaluated, but the conditions that prevailed before it was decided can. Also, the results of similar policies in countries that are comparable to Sweden, and previous subsidies in Sweden, indicates how the policy might work. Therefore, the previous studies and data used in this paper are for the most part published before the policy was introduced, which mirrors the knowledge that was accessible for those who made the decision, when they were making it. The material used in this paper is presented in the *table 2*.

Table 2 Previous studies

Reference	*Main focus*	*Investigated time period, country*	*Method*	*Results*
Holtsmark and Skonhoft, 2014	Subsidies of EVs, rebound effect, cost	2014, Norway	Surveys	The subsidies have not been cost-efficient, and should not be adopted by other countries.
Huse and Lucinda, 2013	Green car rebate	2013, Sweden	Structural model of Swedish car market	Expensive compared to EU ETS
Langbroek et al. 2016	WTP and incentives for EV adoption	2016, Stockholm, Sweden	Transtheoretical model of change and Protection Motivation Theory	Policies focusing on marginal cost would be more efficient than subsidies
Plötz et al. 2014	Early adopters of EVs	2013, Germany	Surveys and some statistical analysis	Early adopters are men, in suburbs of smaller/average cities. Low MC is important.
Trafikanalys (traffic analysis) 2016	Evaluation of policies	2016, Sweden		Vehicles who were targeted by policies are exported after only a few years
Inkinen, 2018	Emission reductions, short-run effects	2018, Sweden	Simulation analysis	Moderate response of the system, 1.3% reduction from new vehicles.
National Institute of Economic Research, 2018	Energy efficiency, Bonus-Malus	2018, Sweden	Mathematical calculations	Relative price shift, long-term effects.

Norway is a country that has taken vigorous action trying to increase the share of electric vehicles in their vehicle fleet. With tax cuts and exceptions for EVs in regard to tolls, charging, parking and congestion the promote electric vehicles. Holtsmark and Skonhoft (2014) evaluated these policies asking the question 'whether it should be adopted by other countries?'. They used survey data on driving habits and car ownership to evaluate what the EV policies achieved. They argue that the commonly used argument, that this kind of subsidy would increase incentives to spend more on R&D doesn't hold in this case. There already exists strong incentives for investments, since battery technology is used in many other products. Further, they found that the ownership structure of the Norwegians changes with the policy, many households kept their conventional car for long distance driving and bought an EV for city driving as the fixed cost shrunk and the marginal cost of driving it was low. This last part also encouraged a change in driving habits and created rebound-effects. For example, biking and the use of public transport was substituted with driving the EV, made possible by free charging in the largest cities, free parking and the permission to use bus lanes to circumvent congestion. The authors used a mathematical example to put the cost of the policy in perspective to emissions reducing alternatives, see *Table 3*.

Table 3 Holtsmark and Skonhoft	*Values*	*Unit*
Average distance	7500	km
Emissions	110	g/km
Yearly emissions	0,6	ton/year
Cost relief for EV owner	8100*	USD
Number of EVs	20 000	
Nr of EU ETS	50	million
Cost per ton with policy	13 500	USD/ton
Cost of EU ETS	5	USD/ton
Compared to EU ETS	2700	Times as expensive

**Including all tax reliefs, exceptions from tolls and parking fees, lost revenue from VAT on fuel, calculated over 10 years, discounted.*

(Source: Holtsmark and Skonhoft (2014) and table constructed by author)

With the policy, each reduced ton of emissions of CO_2 cost 13 500 USD for the government in terms of forgone taxes etc., which is 2700 times higher than the price of emissions permits (using the price of EU ETS permits in 2014, which was 5 USD). Since energy production within the EU (and Norway) is subject to the cap-and-trade system, the emissions reductions from the switch from ICEV and EV is the emission that would have happened if the ICEV drove the distance (Norwegian average). If the money spent on this policy would have been used to buy emissions permits (EU ETS) the permits would cover all emission in Norway and the country would have been considered "carbon neutral". This reasoning is based on the idea that Norway would had bought, but not used the permits, thus raising prices by lowering the supply available for those required to buy them. The supply of energy in a country plays a crucial role on the climate effect of EVs. The final remarks made by B. Holtsmark and A. Skonhoft (2014) is that not only should Norway stop this subsidy immediately; other countries should not adopt it. They recommend taxes and restrictions on car use as efficient means to reduce emissions from private transport.

The National Institute of Economic Research, NIER (Konjunkturinstitutet 2018) made an estimate of the total cost of the Bonus, by including the taxes one would have payed if an ICEV was used. The analysis was made from energy efficiency perspective, since an electric vehicle is more efficient per added kWh than a combustion engine. As electricity is taxed lower than fossil fuels, an EV avoids the taxes on fuel and the increased vehicle tax (Malus). The reasoning and result by NIER (2018) can be seen as an extension to the Norwegian example (Holtsmark and Skonhoft, 2014) as it covers a broader range of cost associated with the Bonus. The conclusion of the NIER (2018) analysis is that long-term, the energy tax will not be enough to internalize the external cost of the road traffic, to the same extent as the taxes on fossil fuels has when the tax systems is formulated based on fossil fuel dependency.

A previous policy that was implemented in Sweden, the Supermiljöbilspremie (a green car rebate, GCR) was a rebate similar to the Bonus part of the current policy, of a maximum of 40 000 SEK. As with the Bonus, most rebates were payed out to companies for their vehicle purchase. And the method used by Holtsmark and Skonhoft (2014) is similar to the one used by Huse and Lucinda (2013) when they evaluated the policy, their result was that the GCR was five times as expensive as the price of EU ETS at the time of their study. Also, the scheme included vehicles running on flexi-fuel, meaning that they could choose to only run on petrol, erasing the potential reduction of CO_2 and diminishing the purpose of the policy.

Inkinen (2018) carried out a simulation study to investigate the effect in terms of lowered emissions of the feebate (Bonus-Malus) system in Sweden. The focus is on the short-term effects when looking at the change in composition of the vehicle fleet, average mileage and CO_2 emissions. The author estimates the short-run changes in emissions due to the new scheme, as a 1.3%[9] reduction in emissions from new vehicles when adjusted for rebound effects

[9] All values rounded down to one decimal point.

(increased mileage because of low in-use cost of driving an low-emitting vehicle). Another result is the noticed effects on the market shares of both EVs and PHEVs, they increased by 35.7% and 17.8% respectively in comparison to their previous market shares. However, the small reduction in emissions is compared in the paper with an alternative policy, an increase in fuel taxes. Given the estimations, an increase in the tax on fossil fuels by 3% would generate the same (slightly higher) reduction of emissions, without the cost of the rebate/subsidy. The author concludes that the Bonus-Malus system should not be expected to generate large environmental benefits and that the reductions are negligible in comparison to the cost of the policy.

Langbroek et al (2016) provide some insights on the behaviour and incentives of people in Stockholm, Sweden, in regard to EVs. Using a stated choice experiment in the form of a two-stage survey they collected data on the behaviour, willingness to pay (WTP) and also attitudes towards EVs. The aim was to evaluate the effectiveness of possible policies by looking at WTP, stage-of-change and what contributes to a higher probability of EV-adoption. Their main results were that policies in general have a positive impact on the sales of EVs, but that subsidies (which changes the fixed cost) are an expensive and less efficient instrument compared to those who change the marginal cost of using the EV. They looked at free parking, access to bus lanes inside the city centre, free changing, among others possible policy changes. These policies achieved a high willingness to pay in the survey and would not be a direct cost for the government or municipality but results in lower revenues. Also, they found that people in a higher stage-of-change, meaning that they are closer to making a purchase, are less sensitive to price, and require fewer extra incentives to purchase an EV. That means, according to the study, that if policymakers focused on moving people to a higher stage-of-change by raising awareness, the cost for the government to increase the incentives to purchase an EV would be lower. Also, it could be more efficient to create policies that focuses on those who already have a high probability to buy an EV, rather than trying to persuade those who never considered it.

In Germany, Plötz, Schneider, Globisch, and Dütschke,(2014) asked which consumer group was most likely to become early adopters of EVs after the fact Germany set a goal to become the leading market for EVs. The higher initial cost of EVs and the adaptation needed to use it has been stated reasons why the conventional cars are still in a vast majority. By finding the group of “early adopters”, solutions to encourage a broader use of EVs could be identified. First, they identified the characteristics of those who would think that purchasing an EV was economically and environmentally sound. Second, they studied the characteristics of the consumers who already had one or had strong intension of buying one, in relation to those who did not show interest. The parameters were socio-economic factors and attitudinal ones. Combined, these two parts, a likely group of early adopters was identified. Men with families who work full-time, are environmental aware, interested in new technologies and who has a commute to work (he lives in a suburb, in a house where they can charge the EV in their garage). The short but frequent kilometres driven makes the EV economically attractive. Plötz et al (2014) result's is confirmed by Vassileva and Campillo (2017). They identified the early adopter in Sweden as men with families, with average to high income, highly educated living in suburban or sparsely populated areas commuting to urban areas. Low in-use cost and the environmental aspect was the primary reasons for choosing an electric vehicle. Also, the average distance driven fits well with the range of the EVs, they are charging at home during the night (charging on off-peak hours both for convenience and cost efficiency reasons). The income aspect of early adopters is again verified in a study by Mersky et al. (2016) who identified EV owners in Norway and found income to be the best predictor for adoption.

The authority responsible for analysis and evaluation of the transport sector in Sweden, Trafikanalys, published their analysis of the fossil fuel dependency and the associated policies in 2016. They found that most of the vehicles that are classified as "environmentally friendly" where bought by legal entities and used by employees of the companies. 94% of the recipients of the Supermiljöbilspremie (subsidy previous to Bonus) where legal entities, the vehicles where only used for a few years and then exported to other countries (Trafikanalys, 2017). This means that the intended effect of the economic instruments that are in place to increase the turnover rate and increase the share of low emission vehicles in Sweden is weakened when the vehicle never enters the used car market in Sweden. Also, this is contrary to the intention that governmental agencies and corporations would take the initial high costs and then sell the vehicles on the used cars market, making low emission vehicles affordable to the public. One possible reason for this behaviour, according to the analysis, is that the companies who get the vehicles back after the leasing period is over, sells them to the highest payer, regardless of geography. Another reason might be the uncertainty regarding the expected life time of the batteries in EVs, which makes pricing on the used market difficult. The export of these vehicles leads to a lower net increase of low emission vehicles in Sweden. This report also suggests that the consumers view the type of vehicles that are subject to the policy instruments as less practical to use, something that they have focused on in Norway, where the economic instruments has been supplemented with other policies that simplifies ownership of these vehicles (Trafikanalys, 2016).

Trafikanalys & Stelacon (2016), evaluates different policies and outcomes in several countries. One important issue discussed is whether or not the policy is long-term and if that is well known to the public. A history of short-term policies might be one explanation of the low share of EVs in Sweden. Further, economic instruments targeting consumers have had very different outcomes in the different countries. Their conclusion is that to increase the share of low emission vehicles policymakers must look at the situation as a whole, not only on one aspect of owning an EV for example. At least the following should be considered: infrastructural changes that makes ownership simple, incentives for ownership, policies to increase the comfort of ownership and ensure that the policies are long-term to reduce uncertainty (Trafikanalys and Stelacon, 2016).

5. Methodology

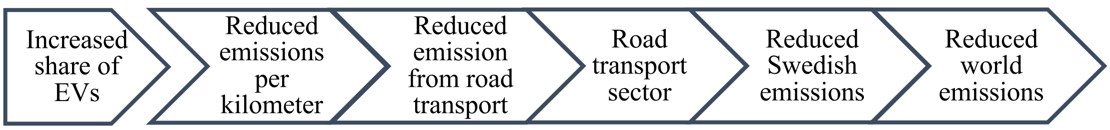
To find a suitable one or to evaluate existing environmental policies Field and Field (2017), provide criteria for evaluation. These are used in this paper for evaluating the Bonus-Malus policy in Sweden. The first two criteria, which are the main focus of this papers research question, are cost-effectiveness and equity. The way this paper analyses them is presented below. Field and Field (2017) also considers enforceability, flexibility, incentives for technological innovations and moral considerations as criteria, although they are not subject for evaluation in this paper. The two chosen criteria are seen at the bottom of the schematics in *Graph 4* and in a simplified version in *Graph 5*, where they are put in to context with the process of emission reduction.

5.1. Efficiency and cost-effectiveness

The Bonus-Malus policy is in place to increase the share of environmentally friendly vehicles and reduce the impact on the climate from the transport sector, i.e. reduce emissions. First, one must look at the construction of the policy, looking at what is included in the policy and if the previous research supports the construction. In light of that, one can look at the cost of the reductions the policy achieves.

In *Graph 4*, the stages of the process of the policy and the overall goal of emission reduction are visualized. Methodically the stages are reviewed and follows the process (*Graph 5)*, through the chain which could lower emissions.

Graph 5



Simplified version of Graph 4

For *Increased share of EVs*, one must look at whether or not the policy is successful and cost-effective in doing so, since this is the method for reaching the goals of a less fossil fuelled dependant fleet. This is evaluated in several ways. One is to look at the dependability (Perman et al, 1999), leading to questions on whether or not the construction of the policy is targeted in the right way. This is evaluated by looking at an example of a vehicle available in several versions and the impact of Bonus-Malus on their price and the construction of the policy itself. The previous studies supply insights on whether these kinds of policies have been efficient. As

Field and Field (2017) concluded, even if a policy is successful in meeting its targets, it might not be cost-effective in doing so. For this reason, the estimated reductions from implementing the Bonus-Malus-system is compared to the established cost of greenhouse gas reductions within the EU ETS cap-and-trade system, a benchmark used both by Huse and Lucinda (2013) and Holtsmark and Skonhoft (2014). By using average driven distances in Sweden per year, the method presented by Holtsmark and Skonhoft (2014) along with calculation methods from the NIER is used to compare the cost of the policy with an alternative use of them. This calculation indicates how much each metric ton of greenhouse gas reduction cost when using the Bonus-subsidy. It can be defined as the avoided emissions from using a zero-emitting EV for the average distance driven. The calculated cost will then be compared with the price of the EU ETS.

The policy aims to *Reduced emissions per kilometre* through the increase in EVs. This stage is somewhat problematic, since emission from the exhaust pipe is not the only emissions caused by the vehicle over its lifecycle but is the only parameter in the policy. To evaluate this stage the previous studies and results of similar policies are used along with a compilation of the structure of the policy.

The third stage in the schematics (*Graph 5* above) is *Reduced emission from road transport*, which follow most of the reasoning of the previous stage but add the aspect of distance. Again, the previous studies along with studying the implementation setup of the policy can help evaluating this. Through a reduction of emission from road transport the two steps above are consequently included in the results and analysis. Regarding emission reductions world-wide, this will be discussed and analytically conceptualized using the life cycle perspective of electric vehicles. The life cycle perspective which is an aspect that should not be ignored when introducing national policies, because of the global nature of emissions, adds some analytical complexity to the overall evaluation.

The overall goals, on a Swedish and an international level are analysed on the basis of the previous stages in the process above (*Graph 5*), the success in meting them and the background of the previous studies will determine the success of the overall goals.

5.2. Fairness / Equity

From *Graph 5* the equity aspects come in at the first stage, the policy in implemented to increase the share of EVs though a subsidy that can have equity issues, and thus, the aspect of this comes in where the policy does. This is also where policies such as the Canadian carbon-tax differ, as it has considered equity in the policy itself.

The equity and fairness definition presented by Field and Field (2017) and Ecola and Light (2009) is the base for the evaluation of the Bonus-side of the policy. The least advantaged should reap the largest benefits and concerns of the redistribution of cost and benefits can contribute to perceived inequality.

To determine which aspects of interregional equity to use the previous studies section of this paper was used as a framework. The aim is to see if there are any differences in the possibility to be subject to Bonus, which would suggest that the policy increases inequality, across Sweden. At the time of writing, historic data of this policy did not exist. Thus, the data is from 2017, showing the situation that prevailed before the policy was implemented. And all data, except the one for *access*, is calculated as per inhabitant since the population size of the municipalities are so diverse and a per inhabitant calculations make them comparable.

Newbery and Strbac (2015) points out that the cost of producing the batteries for an EV, makes the EV more expensive than an ICEV. Also, both Plötz et al. (2014) and Vassileva and Campillo (2017) found that the most probable early adopters of the EV are those with average to high income and are highly educated. In Norway, regional income was the best predicator for EV adoption (Mersky et al, 2016). In light of that, *income* inequality and distribution and level of *education* (those between 16 and 74 with post high-school education) over regions is a parameter to include when evaluating the presence of interregional equity concerns.

In the study by Langbroek et al (2016) the willingness to pay was higher for the in-use aspects of EVs. Trafikanalys and Stelacon (2016) states that to increase the number of EVs policymakers should consider policies that increase the comfort of ownership. This becomes a question of accessibility. For example, the presence of *public charging stations* can influence consumers' purchasing decision. As of now, 2019, there is no data for the number of public charging stations in Sweden. However, there are websites on which EV owners can report stations they have found, which then is summarized on the website for others to use. By collecting data from the site Uppladdning.nu[10] the approximated numbers of stations/outlets per municipality can be used as a variable to evaluate fairness, as it describes the access, thus, the possibility of comfortable ownership and use of an EV.

[10] Loose translated as "charging now". https://uppladdning.nu Last accessed 20190330

The distance between residence and work, schools, welfare services etc has a potentially large impact on the equity aspect (Ecola and Light, 2009). These data may highlight the transport needs in light of population density and access to essential infrastructure. For some sparsely populated areas, having longer distances to travel, driven distances could be an indicator of need for transport and thus a situation that might lead to interregional equity problems. This is done by looking at the average *yearly distance* driven in each municipality.

To widen the analysis on need for transport, data on number of *vehicles per person* is also included. A high number would suggest that the need for owning and using a private vehicle is large and/or that the household can afford the extra vehicle. On the other hand, a low average for a municipality would suggest that this specific policy would not affect them as much. Also, data of the ages of the registered vehicles contribute to the analysis by identifying the location of the most polluting vehicles. Data on *new vehicles* is also of interest, as it could to some extent show it there is a habit of purchasing new vehicles (instead of used vehicles) in that municipality.

Lastly, the Bonus-Malus policy is not the first of its kind in Sweden. The precursor, Supermiljöbilspremien was a subsidy similar to the Bonus-side of the new policy, targeted at other emission limit values. Data showing how the *previous subsidy* was distributed (payed out) over the country gives an indication on the inclination to move from fossil fuelled vehicles to an electric or hybrid vehicle.

The variables above can be summarized a model describing the likelihood of EV purchase. Due to the availability of data and the scope of this paper, the model is presented, then qualitatively assessed on the basis of existing observations and previous studies.

Equation 1

$$Likelihood/possibility\ of\ EV\ purchase_i = f\begin{pmatrix} income, education, \\ new\ vehicles, access, previous\ subsidy \end{pmatrix}$$

Additionally, distances driven and vehicle ownership, variables that would suggest a need to own your own vehicle, are not included in the model. This is because it describes need, not possibility to purchase. They are however very important in analysing concerns on interregional equity, as it can be construed as determinants of inequality.

A policy can enhance, reduce or be neutral with respect to inequality. The Bonus-subsidy promotes the purchase of a new electric vehicle. If the model above is equal for all i, the policy is neutral, but differences would point to regional differences, enhancing or reducing inequality.

In Sweden, there are 290 municipalities. It would not be possible to illustrate the individual results in a comprehensive manner. For that reason, the classification of municipalities by SKL (Swedish Association of Local Authorities and Regions) is used to simplify the analysis. Their classification is based on size of urban areas, proximity to urban areas and commuting inclination and pattern, which fits this papers objective well. There are nine groups (i = 1,..,9); Large cities, Commuting close to large city, Larger city, Commuting to larger city, Smaller city, Commuting to smaller city, Low commuting to larger city, Rural with tourism and Rural. (SKL, 2017)

Throughout the analysis, the average per group of municipalities are the entity displayed, thus, the comparison is between the above listed nine groups and the Swedish average to review the model and discuss the plausible outcome. The following table describes how the results are interpreted based on the previous studies. A group of municipalities that is positioned at either end of the spectrum will suggest interregional equity concerns.

Table 4 Variable effects

Variables	*Above average*	*Below average*
Income, High education, New vehicles, Access and Previous subsidy	More likely to adopt EVs	Less likely to adopt EVs
Vehicles per person, Yearly distance	Larger need of vehicles	Smaller need of vehicles

5.3. Data Collection

Below follows section on how data, in the form of examples, articles, books and statistics where collected to conduct the results. The method of gathering the previous studies can be found I Appendix 3.

5.3.1. Example of vehicles and policy implications

To be able to show the implications of the policy, the paper needed a valid example. In communications with Motormännen (the largest organization for vehicle owners in Sweden), a comparison of a vehicle which comes with different types of engines was suggested and the specific vehicle was Volkswagen Golf. By using the independent site for comparing vehicles, Facit.com, the values needed was retrieved. Information on emissions per kilometre, price and range from facit.com and calculations on how the vehicles was treated in Bonus-Malus on the website of the authority of transport, is summarized in *Table 6*. (Facit, 2019 and Transportstyrelsen, 2019)

5.3.2. Data for Sweden

For the fairness aspect data on the situation in Sweden was collected (per municipality). Data on income, education, vehicles per inhabitant and new registrations was collected from Statistics Sweden (SCB) for the year 2017. To find data on the yearly driven distances and vehicles ages on municipality level, the dataset was provided by placing a special order to Trafikanalys (Transport Analysis). Transportstyrelsen (Authority for Transport) supplied the data of how the previous subsidy has been payed out, on the municipality level, upon request. The data has been recoded, to show municipality names, since data is provided on municipality codes. Data on access to charging stations does not exist, but there are website on which EV-users add information on existing stations for everyone to see. The website Uppladdning.nu and their list was collected and divided to municipality level by hand. Notice, the collection was done in March 2019, and is continually updated, not static.

The data was then divided according to the classification made by SKL (2017).

6. Results

6.1. The construction of the policy

A policy is constructed to reach a certain target, but what it might gain by including more factors it might lose in applicability, convenience and it could be to resource intensive to implement and follow up on. Leaving factors or perspective out of the policy might lead to skewness in the results or in the incentives that are signalled out to the public, decreasing the dependability of the policy. Elements which could be taking into account in the policy are gathered from the previous research and background and presented below (*Table 5*).

Table 5 Policy construction

Element	*Omitted/ Included*	*Effect*
Life cycle (LV) perspective	Omitted	Vehicles that have low emissions can be unnecessary substituted for an EV, causing emissions in manufacturing. PHEVs are somewhat mistreated, since it can have lower life cycle emissions than an EV.
Emissions from use	≈ Included	Main focus but follows a simplified view on electricity production.
World emissions	Omitted	When not considering LV emissions, the policy omits the emissions in the country of manufacturing.
Facilitate use of EV	Omitted	Previous research suggests that lowering marginal cost of use has more effect and higher willingness to pay than policies focusing on fixed cost.
Incentives for emission-lowering consumption	Included	Yes, in the policy signals to those looking for a new vehicle but ignoring the used cars market.
Incentives for decreased car use	Omitted	Research suggest a rebound effect, with increased use of car as a form of transportation.
New fuel types in ICEV	Omitted	Only include the emissions when driving on conventional fuels, omitting the presence of HVO for example.
Concerns on equity	Omitted	The policy, in its structure, is equal for all consumers, disregard regional differences.

6.2. Example of policy implications: Volkswagen golf

By looking at a vehicle model that is popular in Sweden and that is available with several different technologies (EV, PHEV, ICEV) the perspective of the consumer can be clarified when applying the Bonus-Malus on the respective versions. The Volkswagen Golf was the second most popular vehicle in 2018, and third in 2017 (BilSweden, 2019), making it a good example. The choice is between engine type (and price) in the same vehicle, all other attributes equal. From the assumption that a consumer is interested to purchase a vehicle in the size of a Volkswagen Golf, but has not decided on which version, *Table 6* shows the options and the implications of the Bonus-Malus system, given that the vehicles is purchased by a individual, not a company/legal entity.

Table 6 Volkswagen Golf and the policy implications

Type	*Fuel*	*Model (bonus/malus) price**	*Price after Policy*	*Emission per kilometre**	*Additional information*
Battery electric vehicle (EV)	Electricity	E-Golf (60 000 SEK Bonus) 403 900 SEK**	343 900 SEK	Depends on the energy mix, in Sweden, close to zero***.	Battery: 35,8kWh, Range: 300km
Plug-in hybrid electric vehicle (PHEV)	Electricity and Petrol	GTE Golf (28 346 SEK Bonus) 386 900 SEK	358 554 SEK	38g/km	Battery: 8,8kWh Range: 50km
Internal combustion engine vehicle (ICEV)	Diesel	TDI 115 3-d (0 Bonus, subject to Malus, 902 SEK extra per year during the first 3 years.) 228 900 SEK	Same, but additional marginal costs 228 900 SEK	106g/km	

* *From the impartial site for comparing vehicle models, facit.com. All version of the vehicle is without additional features that the consumer can add.*
** *1 € ≈ 10.2567 SEK*
*** *20g CO_2/kWh (Messagie, 2017), but this is internalized in the price of electricity, since the production is subject to EU ETS.*

The prices after Bonus has rearranged the order, the EV in then cheaper than the PHEV, but still, the ICEV costs roughly 2/3 of the other two. Thus, the policy has not, in this case, changed the relative prices in favor of the electric vehicles.

6.3. Subsidy contra emission permits – a mathematical example

The budget for Bonus each year is around 1.24 billion SEK (121 million euro)[11] and so far, 81.8% of the pay-outs has been to legal entities (Trafikverket, 2019a). The emissions from road traffic increased in 2018, and the emissions from privately driven vehicles was the same on average as in 2017, even though there is an increase in both EVs and PHEVs the number of new ICEVs increase more (Trafikverket 2019b).

Following the model presented by Holtsmark and Skonhoft (2014) the calculation for the average driver in Sweden is conducted below to test the cost-effectiveness of the policy. The comparison made by Holtsmark and Skonhoft, with the EU ETS permits is also made by Huse and Lucinda (2013) when looking at the previous Swedish green car rebate. The idea is that the price of the permits should reflect the cost of emissions, since the theory of cap-and-trade assumes that the price of the permit is the marginal cost of reduction. This follows the method by Field and Field (2017), where cost-effectiveness can be evaluated by looking at efficient ways to use a bundle of given resources, in this case, the budget of Bonus.

For the average Swede, the distance driven in a year is 12 110 km. The ICEV version of Volkswagen Golf emit 106g/km, a low assumption, compared to the second calculations, based on the average in Sweden (122g CO_2/km) (Transportstyrelsen 2019b). Driving the average yearly distance with the small ICEV emits 1.28 tons of CO_2 yearly, which is the avoided emissions when using an EV. Assumptions are that the driver continue with his/her pattern of driving and a lifespan of 10 years for the vehicle. The cost of the reduction is the Bonus and is 4 674 SEK/ton, if one assumes the zero emission with an EV and that the full Bonus (60 000 SEK). Which is almost 24 times more expensive than the cost of EU ETSs for the same reduction. If the average vehicle in Sweden is used instead, the calculations result in savings of 14.8 ton/year and to use the budget for the subsidy instead of EU ETS is 20.6 times more expensive, a lower estimate since the number tons of GHGs reduced are more with the higher initial emissions. The calculations are summarized in *Table 7*.

Further, the budget would, given the price of permits in February 2019 (197 SEK), purchase 6 300 000 permits of one ton of CO_2-eq each. If we assume that the entire budget is payed to consumers who buy the EV version the Volkswagen Golf, receiving the maximum bonus, the budget would suffice 20 700 EVs. However, if the government would buy the EU ETS for the entire budget, those allowances would cover the yearly emissions made by 4 900

[11] Exchange rate found at Swedish Central bank, 20190520, 1 € = 10.2567 SEK

000 vehicles (emitting 106g/km) driven by the average driver and fuelled by diesel, for the average vehicle the result is 4 600 000. This result can in turn be compared with the total number of vehicles in Sweden, which was 4 870 000 in 2018 (Trafikanalys, 2019), resulting in a situation where the use of a private car in Sweden would be considered carbon neutral. The idea behind this comparison introduces by Holtsmark and Skonhoft (2014) is that if the allowances are taken away from the market of allowances and simply not used (emissions form vehicles are not included in EU ETS), the allowances available is reduced within the Euro area. Theoretically, the purchase of emission allowances of this quantity would drive the price up and thus forcing companies who are required to have allowances to choose between buying more expensive allowance or to lower their emissions, creating an indirect effect on emission reduction.

To further complicate the situation, the subsidy is not the entire cost from the government perspective, since taxes on fossil fuel is forgone when using an EV. The calculations made by The National Institute of Economic Research (Konjunkturinstitutet) are based on assumptions that are not grounded in Swedish statistics, therefore the results was recalculated. By using a discount rate of 4% over 10 years, including forgone energy and carbon dioxide tax the total cost is calculated for the Swedish average vehicle. In their example they use a petrol driven vehicle consuming 0.48 litre/km and the situation is that someone is considering buying a new EV or a new ICEV (petrol). When accounting for the cost of the subsidy, forgone taxes and Malus, it sums up to 128 881 SEK per EV. The new estimate would buy 13 100 000 permits, and that would be almost 42 times cheaper than the policy. (all calculations can be found in in Appendix 1)

Table 7 Policy and EU ETS	*Volkswagen golf*	*Swedish average vehicle*	*Swedish average including foregone taxes*	*Unit*
Emissions per kilometer	106	122	122	g/km
Yearly emissions	1.284	1.477	1.477	ton/year
Nr of subsidized EVs	20667	20667		
Nr of EU ETS with budget	6 294 416	6 294 416	13 101 134	
Nr of ICEVs covered by EU ETS	4 903 492	4 260 411	8 870 097	
EV used for 10 years	12.8366	14.7742	14.7742	Tons avoided
Cost per ton with policy	4674	4061	8453	SEK/ton
Compared to EU ETS	23.73	20.6	42.9	

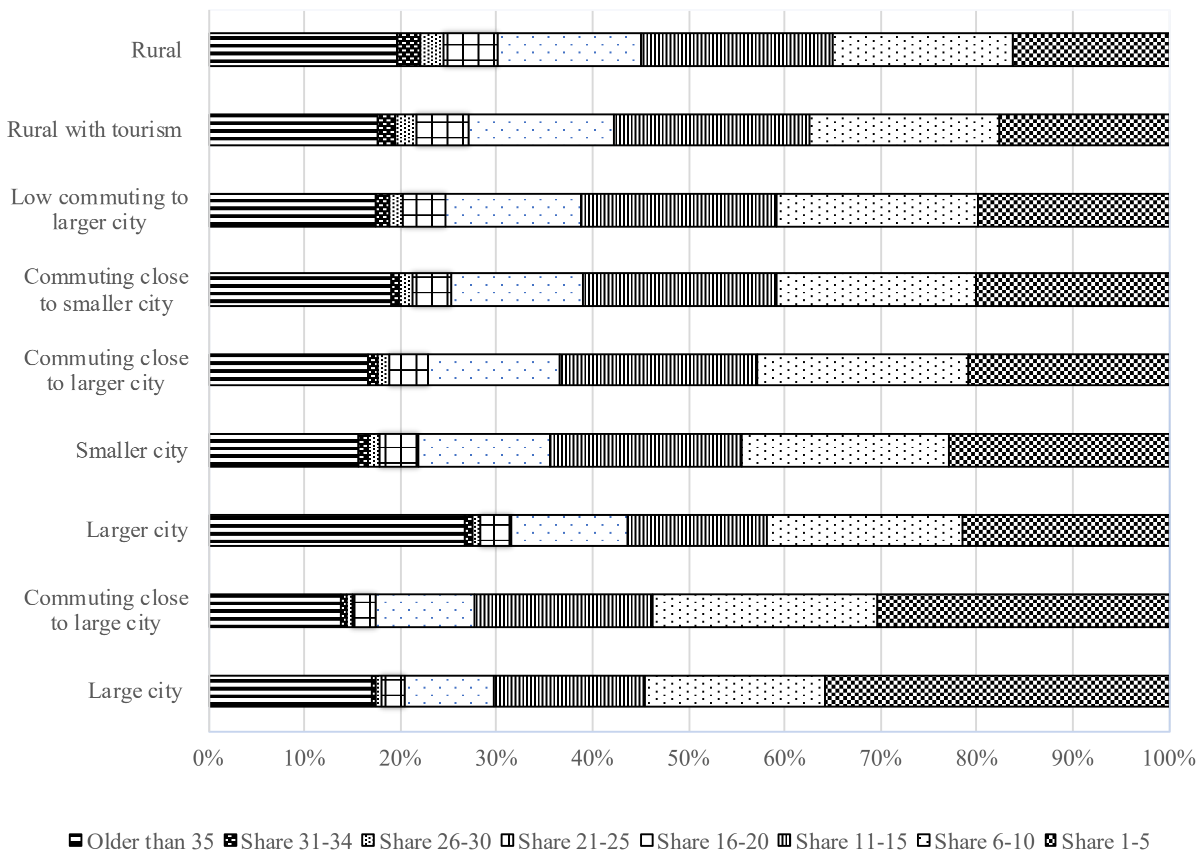
Budget: 1.24 billion SEK, Cost of EU ETS: 197 SEK/ton, Average distance: 12 110 km/year

(Data from Trafikanalys (2019), Facit.com (2019), European Energy Exchange (2019))

6.4. Interregional differences

To know where or on what to focus a policy, the initial situation should be reviewed. In the following *Table (8),* the entire fleet per municipality group has been divided into age-cohorts (based on data from 2017) and the number of vehicles registered in each group can be found in the symbol description below *Table 9*. Showing the ages of the vehicles and thus indicating turnover, in each group. In the most extreme comparison, the three municipalities considered to have Large cities, has a fleet where 55% is younger than 10 years, whereas in Rural, the youngest 55% is over 15 years. Following the guideline of the European Federation for Transport and Environment (2018), when there is technological change as EVs should be considered to be, turnover should be below 15 years. Large cities and those municipalities with tendency to commute to them, should not be the main target of a policy, as their fleet is younger.

Table 8 Age of the vehicle fleet



(Data from Trafikanalys (2019) table by author)

As this policy consists of a transfer from the government to those who are eligible trough their purchase, the possibility to be eligible is investigated. The variables looked at are grounded in the previous studies and theories. They are income, education, vehicles per inhabitant, new vehicles per inhabitant, yearly driven distances, access to public charging stations and the distribution of the previous subsidy. Given the time frame and scope of the paper it was not possible to visualize all 290 municipalities. Therefore *Table 9* shows the statistics of each municipality type, a classification made by the Swedish Association of Local Authorities and Regions (SKL). A group of municipalities are put in relation to +/- a half, one and more than one standard deviation from the mean in the table. The characteristics of the municipality groups are that way visualized. The exact values can be found in Appendix 2. In Appendix 4 a table of zero-values and their distribution over the municipality groups for the variable's Previous subsidy and Public charging stations is presented.

Table 9 Data on municipality groups

Variable	**< -1 st.dev.**	**1 →1/2 St.dev.**	**-1/2 st.dev. → Mean**	**Swedish mean (st.dev)**	**Mean → +1/2 st.dev.**	**1/2 → 1 St.dev.**	**> 1 st.dev.**
INCOME average	< 273,83	Rur, R. t 273,83 - 294,22	Low, Sma, C. s, Lr 294,22 - mean	314,61 (40,7792)	C. Lr, L mean - 334,99	334,99 - 355,39	C. L 355,39 <
HIGHER EDUCATION average share	< 0,1372	0,1372 - 0,1691	Rur, R. t, Low, C. s, C. Lr 0,1691 - mean	0,201 (0,0638)	Sma mean - 0,2329	Lr, C. L 0,2329 - 0,2648	L 0,2648 <
VEHICLES per inhabitant	L, Lr, C. L < 0,555	0,555 - 0,596	Sma 0,596 - mean	0,637 (0,0819)	Low, C. s, C. Lr mean - 0,678	0,678 - 0,719	Rur, R. t 0,719 <
NEW VIEHCLES per inhabitant	< 0,0127	0,0127 - 0,020	Rur, R. t, Low, C. s, C. Lr 0,020 - mean	0,028 (0,0153)	Sma mean - 0,0357	Lr, C. L 0,0357 - 0,0433	L 0,0433 <
YEARLY DISTANCE per inhabitant	Lr, L, C. L < 658,8	658,8 - 711,7	Sma 711,7 - mean	764,6 (105,8)	Low, C. s, C. Lr mean - 817,5	Rur 817,5 - 870,4	R. t 870,4 <
PUBLIC CHARGING STATIONS average in municipality		Rur, C. Lr, C. s 0 - 3,8	Low, R. t, C. L, Sma 3,8 - mean	18,59 (29,59)	Lr mean - 33,38	33,38 - 48,17	L 48,17 <
PREVIOUS SUBSIDY per inhabitant			Rur, R. t, Low, Sma, C. s, C. Lr 0 - mean	11,44 (32,06)	C. L mean - 27,47	Lr 27,47 - 43,5	L 43,5 <

Exact values for all variables and municipality groups can be found in Appendix 2.

Tabel 10 Symbol description

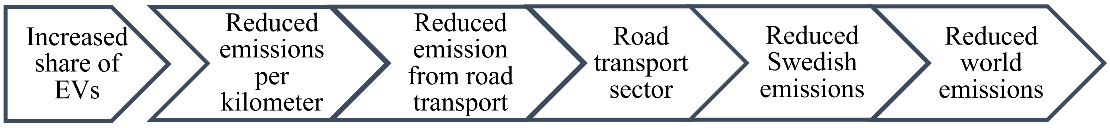
Rur	**Rural (346 465)**	C. s	**Commuting close to smaller city (400 367)**	Lr	**Larger city (1 277 711)**
R. t	Rural with tourism (107 136)	Low	Low commuting close to larger city (355 950)	C. L	Commuting close to large city (949 706)
Sm	Smaller city (812 170)	C. Lr	Commuting close to larger city (580 284)	L	Large city (784 571)

Municipality group (vehicles in those municipalities) (classification by SKL, 2017)

7. Analysis

7.1. Efficiency and cost-effectiveness

The analysis of efficiency and cost-effectiveness follow the stages presented in *Graph 4* (and simplified below), using the same titles, thus following the arrows and the chain of effects.



7.1.1. Increase in number of EVs in Sweden

The Bonus-Malus-policy is constructed to create incentives for emission lowering consumption, by subsidizing new vehicles *(table 5)*. However, the used cars market is excluded, which included 1 180 000 vehicles in 2017 (Teknikens värld, 2018). Therefore, the effect of the policy is limited to those who are looking to buy a new vehicle. Following the recommendations by European Federation for Transport and Environment (2018) on optimal turnover, urban areas have lower share of vehicles that are older than the optimal turnover, with the exemption of Larger cities *(table 8)*. In rural areas, almost half the fleet is above 20 years, and should from the environmental perspective be encouraged to have a higher turnover rate.

In *Table 6* the result of the policy on a real example shows that the intention, of changing relative prices, does not completely change in favour of an EV. It is still 50% more expensive than the ICEV alternative, but the in-use cost is lower. However, including the total cost of ownership, the consumer could choose the EV, because of the low cost of use *(see table 7)*. Noticeable is the relative price change, created by the subsidy, on the PHEV compared to the EV. The hybrid becomes more expensive than the electric.

In the light of previous studies, subsidies of this kind do increase the number of EVs. The most recent study, a simulation of the Bonus-malus, found increased market shares (Inkinen, 2018). Langbroek et al (2016) and Plötz et al. (2014) support this, since the subsidy should move those close to adoption to purchase. However, Langbroek et al (2016) came to the conclusion that people not only value policies focusing on in-use cost higher, that type of policies is more efficient than policies targeting fixed cost.

Even if a policy can be seen as efficient in reaching the intended goal (payments to EV-owners, has been done in 2018 and 2019), the means needed to do so might be excessive. The cost-effectiveness of a policy matters. The replication of the mathematical model by Holtsmark and Skonhoft (2014) for Sweden is a comparison between the cost of emission reduction trough the subsidy and trough the emission permit system on the European cap-and-trade market. The results from Norway are of another magnitude, but still, for Sweden, the subsidy cost 20.6 – 23.7 times more than permits for the same reduction. Using the method of The NIER along with the model used for Norway, the results are that the policy is 43 times as expensive as permits for the same amount of reduction. In light of Huse and Lucindas (2013) results on the GCR, which was 5 times as expensive as EU ETS the continues reductions of permits (resulting in raise in permit prices) and the higher subsidies, has made these kinds of policies more expensive compared to the benchmark. Inkinen (2018) verifies this, by stating that the policy would have negligible effects on emissions compared to the cost. The results are that a lot more emissions could be avoided if the money spent for Bonus was spent on other CO_2-reducing policy/activity.

7.1.2. Reduced emission per kilometer

The determinant of the Bonus is emissions from the exhaust pipe, favoring those with zero emissions highest. This creates incentives for adoption of low-emission vehicles. The zero-emission assumption is done, even though the production of electricity causes emission, because the cost of the emissions is internalized in the price of electricity through the EU ETS.

The Swedish average emission per kilometre was 122g CO_2/km in 2017, and the direction that the average is going will depend on the responsiveness of the Bonus-Malus. Simplifying, for anyone who change from an emitting vehicle to an EV the average is lowered. The idea is that the policy will increase turnover and successively lower the average emission per kilometer. Looking at *Graph 3*, the emissions has gone down by 1/5 between 2010 and 2017, suggesting a momentum downwards.

7.1.3. Reduced emissions from road transport

First, the policy does not encourage other means of transport or reduced driving, only changes in the incentives structures when buying a new vehicle. This is a quite small share of the entire fleet, in 2017 there was 392 000 new vehicles registered, compared to the total number on vehicles (4 870 000). New vehicles were therefore 8% of the entire fleet in 2017, and the budget for bonus would suffice for ca 21 000 EVs yearly.

Second, the lower tax on electricity compared to fossil fuels and the zero-emission assumption signals that it is ok to drive as much as one would want with their EV. This could lead to similar results in Sweden as in Norway, where there was a rebound effect. When the marginal cost is lowered the use increase, people substitutes public transport in favor of an EV, contributing to congestion. Also, the increased demand for electricity when the number of EVs increase could endanger the zero-emission assumption. It will depend on how Sweden manage to handle an increased demand; from which sources the electricity will come from and *if the EU ETS is considered to be efficient*.

On the other hand, if one considers the ceteris paribus scenario, where vehicles per inhabitant and yearly driven distances unchanged, each new EV on the Swedish roads will have a positive impact on emission reductions from road traffic. However, both Holtsmark and Skonhoft (2014) and Inkinen (2018) comes to the conclusion that taxes would be a more efficient way to achieve the same results. Inkinen find that an increase of the tax on fossil fuels by 3% would have the same modest results on emission reduction form road transport as the Bonus-Malus, without the cost for the government and the possibility to use the revenue to i.e. even out regional differences.

7.1.4. Overall Swedish goal and overall world goal

Since greenhouse gas emissions know no borders, a global perspective gives the analysis more depth. As Sweden is linked to the world, and the EU in particular, the EU ETS and the indirect effects that a large purchase of permits made by Sweden would have are substantial effect.

The construction of the Bonus-Malus system is fairly straightforward, the emission from the exhaust pipe per kilometre is the only parameter included. What it might gain in simplicity must be weighed against what the policy omits. One omitted aspect is the lack of life-cycle perspective, sending out misleading signals to society. A vehicle can receive the entire bonus, regardless of emissions in the manufacturing stage. This is a quite narrow way of looking at emissions, since it focuses solely on emissions that are included in the Swedish records. But, even when looking at the entire life cycle, an EV in Sweden, given our energy mix, emits 85% less than the benchmark conventional vehicle (Messagie, 2017). On the other hand, this estimate depends on what the owner is changing from. Messagie use a diesel, emitting 120g CO_2/km as a reference, which is only 2g lower than the Swedish average and therefor a good comparison for Sweden. Including the calculations by IVL (2017) the reasoning leads to a question that would be an interesting future study: how old and how polluting should the old vehicle be, for it to be reasonable to purchase an EV that has already contributed with high emissions in production even before one drives it? The emissions from production of the old vehicle have already occurred, whereas the production of the EV is determined by the demand for it.

This leads to the discussion on the ambitions and arguments for the Bonus-Malus system in Sweden, which is that it would quicken the renewal of the vehicle fleet towards a higher share of environmentally friendly vehicles. This is problematic from several perspectives when looking at the previous studies. First, according to the European Federation for Transport and Environment (2018), to use the existing vehicle for 15-20 years is to minimize lifecycle emissions, this is a perspective that is missed in the present system. If the Bonus Malus was combined with a policy that tried to increase turnover, specifically for the older vehicles, the policy could follow the guidelines on turnover better. However, it is also possible that if the old car was sold on the used cars market, the new owner of the old car in turn scraped his/hers even older and more polluting vehicle, creating incentives for a shift in vehicle ages. But only the new vehicles are included in the policy. The shift would be an indirect effect. One alternative policy would be a Bonus-Malus which include the used cars market.

Today consumers are given incentives to buy an EV, regardless of the type of vehicle they own today. Also, the result of the policy is that the PHEV becomes more expensive than the EV in the Volkswagen Golf example. For a consumer who drives short distances, less than 50km/day (or per charge), which is below the Swedish average mileage, and want to purchase an electric vehicle would with Bonus-Malus choose the EV in the Volkswagen Golf example, since it becomes cheaper than the PHEV when including Bonus. The battery in the PHEV is ¼ of the battery in the EV, which according to IVL (2017) means that the emission in producing the batteries in the PHEV is also ¼ of the emission of the EV. And the emissions from driving the PHEV is based on a test cycle where the result is based on a mix between driving on petrol and with electricity. If the individual in this example only drive <50km between charges, if would have the same emission per kilometre as the EV, assumed to zero. This is an example where a policy has, in its construction, led to misleading price signals. The policy encourage a purchase that contribute to unnecessary emissions, in this case, emissions from production. Hence, the policy has a downside in regard to the signals that are sent out to the consumers in the case of the Volkswagen Golf. On the other hand, the result could be similar to the ones found by Huse and Lucinda (2013), where PHEV owners drove on petrol/diesel more than what was assumed.

7.1.5. Other aspects

The fact that the policy is for the most part payed out to legal entities gives an important insight. The turnover for leasing deals are short and there are lessons to be learned from the previous subsidy; EVs where to a large extent exported after the leasing-period was over. The incentives created by the lower taxation for employees who use their work-vehicle privately, increase turnover and use of the policy. But the fruit of the Swedish subsidy end up outside the country when people sell to the highest bidder, which might be people in countries which does not subsidize EVs. This type of leakage would not occur if policies was focused on in-use costs and access rather than fixed costs. Neither would we have the same issues if policies was implemented on a higher level, such as the EU. These results made by Huse and Lucinda (2013) seem to correspond to the ones found here, policies in this form is for the most part used by legal entities and have a tendency to be exported.

From a government perspective, as Malus is supposed to finance Bonus, in the Volkswagen Golf example, each Bonus for their EV requires Malus payments from 22 conventional vehicles. So, if Malus is successful (decreasing demand for ICEVs), the Bonus loose its funding and requires funds from somewhere else.

7.2. Interregional equity

The paper by Plötz et al. 2014 is an example of when cost-effectiveness comes into conflict with concerns of fairness. They suggest that cost can be minimized by focusing a policy on a group that is less sensitive to price and leave out those who are further from adopting an EV. If this is done by a monetary transfer, the policy could be regressive with income and therefore enhance inequality. This conflicts with Rawls principles and the definition by Ecola and Light (2009), saying that the advantaged individual should get an improved situation from a policy change. However, there was 57 municipalities where no one in the municipality took part in the previous subsidy in 2017, most of them are rural or those with small cities. The trade-off is the initial concept which resulted in this papers research question. Also, to complicate the matter, it seems that no paper has studied equity concerns in regard to these types of subsidies before. This is therefore a humble attempt to initiate methodological studies in this field.

In relation to the export-tendency of EVs and consumption patterns, some questions of fairness are revealed. Richer municipalities, with a population with higher income and education, buy new vehicles to a larger extent and have a greater possibility to change their means of transport to more sustainable alternatives. This is verified as they used the previous subsidy to a higher degree and the result from Norway where income was the best predictor for EV adoption (Mersky et al. 2016). However, they already have a younger fleet which suggest a higher turnover but drives less than the rural areas. The policy does not explicitly target the early adopters in the manner suggested by Plötz et al (2014), but the reality suggests that it is the way the policy works, benefiting them with better circumstances. This goes against the cohesion policy principles of the EU, trying to lower the differences between regions. Again, there is a trade-off between cost-effectiveness and fairness. There are more vehicles registered in urban areas, and they are younger than those in more rural areas. But even if that large share of old vehicles represents a small volume, when looking at fairness it is the perceived inequality in those areas that must be considered.

One could argue that the subsidy is in place to make it possible for those with lower income to afford an electric vehicle. However, as was seen in the example of the Volkswagen golf, not only does the EV still cost 50% more than the ICEV when including the subsidy, only those who can afford a new vehicle to begin with (and wait the six months before pay-out) can reap the benefits of the subsidy. It seems that many are neither in the cost, nor the benefit side of this policy. As both in France and Sweden, have started to protest the higher cost of fossil fuel etc, one could wonder if perhaps, climate policies should take some other form, benefitting more people. Creating policies which are revenue-neutral, taxes on emissions which gives back to the citizens to reduce interregional equity issues and reduce opposition could be an alternative. The benefits of Bonus are limited to a few, perhaps a Bonus-Malus which includes the used-vehicle fleet would win more acceptability in Sweden as it would make participation less sensitive to geography and income.

Looking at *Equation 1*, and *Table 9*, the two types of rural municipalities have high values in the need-indicating variables (Vehicles per person and Yearly distance) but low for the variable that would suggest people to be more prone toward adoption. They are also those who have the lowest access (10 municipalities have zero public charging stations). The opposite is true for Large cities, Larger cities and Commuting to large city. In the middle of the data are the groups Smaller cities, Low commuting to larger city, Commuting to small city and Commuting to larger city.

In an urban vs rural discussion, *Table 9* and the reasoning above portrays the issue. The policy seems to benefit those with the lowest need, in terms of vehicle ownership and driven distances, and the highest possibility for early adoption, the most. Whereas those with higher need but lower purchasing power and access are left out, not intentionally by the policy, but the presence of regional equity issues along with this type of policy results in this skewness. Only in a situation where there are no differences in income, commuting distances to work and welfare services etc can a policy like this one be fair. However, this one, is not.

8. Conclusions

The Bonus-malus, as implemented in Sweden, does not seem to meet the conditions to become a cost-efficient, and further, as this study suggests, a fair policy for emission reduction. Previous studies, from other countries and from Sweden, confirms this dismal result. The conclusions drawn here could have been made before the policy was implemented, as all data and most research was published by that time.

In addition, the simplicity of the policy misses the lifecycle perspective, and the importance of the used cars market, on which most people make their vehicle purchase, limits its possible beneficial effects. In addition, most Swedes are excluded from this policy altogether, and those who are interested in EVs does not value subsidies as high as other policies. Further, the policy does not provide possibilities for the whole of Sweden to contribute to work to lower emissions.

Focusing on in-use costs and taxes would be more effective and cost-efficient for reduction and would not create the leakage when subsidized EVs are exported. Mainly, a policy which is 43 times as expensive as the going rate of emissions cannot be considered cost-effective, something that had been suggested by several other studies before this one. Incentives for fast turnover towards low emitting vehicles can increase the share of EVs and lead to lower per kilometre emissions (on average), but the gains from the subsidy is only for those who can afford the initial purchase or has a job entitling them to a vehicle provided from their work. The possibility to take part in this initiative is not, using the standards outlined in this thesis, fair, and shows interregional equity concerns in an urban versus rural perspective.

9. Future studies

The aim of this paper, to understand the implications of the policy and the effectiveness would be verified and broadened by a more in-depth analysis using data on household level. To understand the purchasing decision, attitudes and the determinative factors of EV adoption would widen the understanding on the responsiveness to the policy and also generate data for an extension of the interregional equity aspect.

As this paper was developed, the subsidy of electric bikes was debated in the media, where some claimed that prices had gone up due to the subsidy. This phenomenon should be studied, both for electric bikes, but also for the Bonus-Malus-System.

Perhaps, in light of the Canadian carbon-tax, fairness will receive more attention from decisionmakers and a study of alternative policies that includes the used cars market and thus, includes a larger share of the Swedish population, would be of interest. Both to lower emissions more effectively but also from the aspect of equity.

Generally, the field of electric vehicles is in constant change and the technological advancements are fast. This calls for updates of the research on both the estimated reductions of GHGs, cost of recent policies and the temperature of public opinion regarding these kinds of policies.

10. References

10.1. Written sources

Bil Sweden, *New registrations of cars in Sweden*, 2017 and 2018, http://www.bilsweden.se/statistik/nyregistreringar (Retrieved 2019-02-25)

Cookson, Richard, 2016, *Methods for Incorporating Equity into Economic Evaluation of Social Investments*, The National Academies of Science, Engineering, medicine. 7th April 2016.http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_171854.pdf [2019-04-09]

Ecola Liisa, Light Thomas, 2009, *Equity and congestion pricing*, RAND http://www.rand.org/content/dam/rand/pubs/technical_reports/2009/RAND_TR680.pdf [2019-03-20]

European Commission, 2019, *Cohesion policy: Frequently asked questions*, https://ec.europa.eu/regional_policy/en/faq/#1, [2019-04-30]

European Environment Agency, *Electric vehicles from life cycle and circular economy perspectives*, 13 (2018)

European Federation for Transport and Environment, *CO_2 emission from cars: the facts*, 2018

Field Berry and Field K. Martha. 2017, *Environmental economics: An introduction*, 7th edition, New York, McGraw Hill.

Holmström, Christian, 2019, *Konsumtionskatter på diesel*, Ekonomifakta, https://www.ekonomifakta.se/fakta/energi/styrmedel/konsumtionsskatter-pa-diesel/ January 16th [2019-02-26]

Holtsmark, Bjart, Skonhoft Anders. 2104, *The Norwegian support and subsidy policy of electric cars: Should it be adopted by other countries?* Environmental Science and Policy, 42 (2014) 160-168.

Huse, Christian and Lucinda, Claudio. 2013, *The market impact and the cost of environmental policy: evidence from the Swedish Green Car Rebate*, The Economic Journal, 124 (2013) 393-419.

Inkinen, Ville, 2018, *Short-run Effects of Feebate Schemes of Car Markets and CO_2 emissions,* University of Gothenburg, Department of Economics.

IVL, Swedish Environmental Research Institute, 2017, *The life cycle energy consumption and greenhouse gas emissions from lithium-ion batteries*.

Konjunkturinstitutet, *Miljö, ekonomi och politik*, 2018:26.

Langbroek Joram H.M., Franklin, Joel P., Susilo, Yusak O., 2016, *The effect of policy incentives on electric vehicle adoption,* Energy Policy, 94, (July 2016) 94-103.

Le Grand, Julian, 1990, *Equity Versus Efficiency: The Elusive Trade-Off*, The University of Chicago Press, 100, no 3 (1990) 554-568.

Mersky, Avi Chaim., Sprei, Frances., Samaras, Constantine., Qian, Zhen. 2016, *Effectiveness of incentives on electric vehicle adoption in Norway*, Transport research Part D, 46 (2016) 56-68)

Messagie, Maarten, *Life cycle analysis of the climate impact of electric vehicles*, 2017, Vrije Universiteit Brussel. Draft.

Naturvårdsverket, 2019, *Agenda 2030 och globala hållbarhetsmålen*, https://www.naturvardsverket.se/Miljoarbete-i-samhallet/Agenda-2030-och-globala-hallbarhetsmalen/ [2019-04-17]

Naturvårdsverket, *Utsläpp av växthusgaser från inrikes transporter*, 2018, https://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser-utslapp-fran-inrikes-transporter/, [2019-01-30]

Newbery, David., Strbac, Goran., 2015. *What is needed for battery electric vehicles to become socially cost competitive?* Economics of Transportation 5 (2016) 1-11.

Nuccitelli, Dana. 2018, *Canada passes carbon tax that will give most Canadians more money*, The Guardian, 26th October. https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/oct/26/canada-passed-a-carbon-tax-that-will-give-most-canadians-more-money [2019-05-21]

Perman, Roger., Ma, Yue., McGilvray, James., Common, Michael. 1999, *Natural Resource and Environmental Economics*. 2 ed. Pearson Education Limited.

Pihl, Håkan, 2014, *Miljöekonomi för en hållbar utveckling*, 5th edition, Lund: Studentlitteratur AB

Plötz, Patrick., Schneider Uta., Globisch, Joachim., Dütschke, Elisabeth, 2014, *Who till buy electric vehicles? Identifying early adopters in Germany*, Transportation Research Part A, 67 (2014) 96-109.

Rawls, John, *En teori om rättvisa* (1971), sv. övers. 1996, Bokförlaget Daidalos AB, Uddevalla

Riksbanken, *Valutakurser till Deklarationen*, https://www.riksbank.se/sv/statistik/sok-rantor--valutakurser/valutakurser-till-deklarationen/ [2019-05-20]

Skatteverket, *Nya skattesatserna för bensin och diesel från 1 juli 2018*, https://www.skatteverket.se/foretagochorganisationer/skatter/punktskatter/nyheterinompunktskatter/2018/nyheterinompunktskatter/nyaskattesatsernaforbensinochdieselfranden1juli2018.5.41f1c61d16193087d7fd1f3.html, [2019-04-29]

Sveriges Kommuner och Landsting (SKL), *Kommungruppsindelning 2017*, (2016), http://webbutik.skl.se/sv/artiklar/kommungruppsindelning-2017.html [2019-03-04]

Sveriges Kommuner och Landsting (SKL), 2019, *Sammanhållningspolitik*, EU, https://skl.se/samhallsplaneringinfrastruktur/regionalutveckling/sammanhallningspolitikeu.2076.html [2019-04-30]

SVT, 2019a, *What the Yellow vest wants*, https://www.svt.se/nyheter/utrikes/vad-vill-de-gula-vastarna-har-far-du-svarenm, [2019-04-04]

SVT, 2019b, *De driver bensinprotesterna på Facebook som samlar hundratusen svenskar*, https://www.svt.se/nyheter/inrikes/de-driver-bensinprotesten-pa-facebook-som-samlar-hundratusen-svenskar [2019-05-13]

Swedish Government, 2017, *Bonus-Malus and bränslebytet*, https://www.regeringen.se/artiklar/2017/09/bonus-malus-och-branslebytet/ [2019-03-20]

Teknikens värld, 2018, *Begagnade bilar slog rekord 2017,* https://teknikensvarld.se/begagnade-bilar-slog-rekord-2017-581684/, [2019-05-15]

Trafikanalys and Stelacon, 2016, *Styrmedel för ökad andel miljöbilar – internationella exempel.*

Trafikanalys, 2016, *Personbilsparkens fossil oberoende – utveckling och styrmedel*, Rapport: 2016:11

Trafikanalys, 2017, *Export av begagnade miljöbilar och fossiloberondet,* Rapport 2017:6

Trafikanalys, 2019, *Fordon i län och kommuner 2018*, https://www.trafa.se/vagtrafik/fordon/, [2019-03-04]

Transportstyrelsen, 2017, *Koldioxidutsläpp personbilar, 2010–2016*.

Transportstyrelsen, 2019a, *Bonus malus-system för personbilar, lätta lastbilar och lätta bussar*, https://www.transportstyrelsen.se/bonusmalus#166185, [2019-01-30]

Transportstyrelsen, 2019b, *Ökad lastbilstrafik orsakade utsläppsökning*, 2019-02-27, https://www.transportstyrelsen.se/sv/Nyhetsarkiv/okad-lastbilstrafik-orsakade-utslappsokning/ [2019-03-05]

United Nations (UN), 2019, *Climate Change*, https://www.un.org/en/sections/issues-depth/climate-change/index.html [2019-04-09]

United Nations Climate Change, 2019, *The Paris agreement*, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement [2019-04-17]

Vassileva Iana., Campillo Javier, 2016, *Adoption barriers for electric vehicles: Experiences from early adopters in Sweden.* Energy 120 (2017) 632 – 641

10.2. Data sources

European Energy Exchange, 2019, *Emission Allowances Prices*, https://www.eex.com/en#/en [2019-02-25]

Facit.com/ Modern Car Group, 2019, http://www.facit.com/se/

RUS (Regional Utveckling och Samverkan i miljömålssytemet), *Körsträckor och bränsleförbrukning*, http://extra.lansstyrelsen.se/rus/Sv/statistik-och-data/korstrackor-och-bransleforbrukning/Pages/default.aspx [2019-02-25]

SPBI (Svenska Petroleum och Biodrivmedels Institutet), 2018, *Statistik*, https://spbi.se/statistik/ [2019-02-25]

Trafikanalys, 2019, *Körsträckor 2017*, Special order, [2019-03-05]

Trafikanalys, 2019, *Bilflottans ålder 2017*, Special order, [2019-03-11]

Transportstyrelsen, 2019, *Payouts of Supermiljöbilspremien 2017-2018*. Sent by email to author on March 22nd 2019.

Appendix 1

		Calculations	Value	Comment/source
A	Average distance driven		12 110 km/year	SCB
B	Volkwagen golf ICEF emission		106	Facit.com
C	Swedish average emission /km		122	Transportstyrelsen 2019b
D	Emission per year (Golf)	(A) * (B)	1,284 ton /year	
E	Emission per year (Swedish average)	(A) * (C)	1,477 ton / year	
F	EU ETS price		197 SEK /ton	European Energy Exchange (2019)
G	Bonus Budget		1 240 000 000	
H	Permits for the budget	(G) / (F)	6 294 416	
I	Subsidy		60 000 SEK	
J	Cost per reduced ton with Bonus (golf)	(I)/ (D*10)	4674 SEK / ton	During 10 years
K	Cost per reduced ton with Bonus (average)	(I)/(E*10)	4061 SEK/ ton	
L	Compared to EU ETS (golf)	(J)/(F)	23,73 times as expensive	
M	Compared to EU ETS (average)	(K)/(F)	20,6 times as expensive	
N	Energy tax (per kWh)		0,331 SEK/kWh	Skatteverket, 2018
O	Energy tax (per liter of petrol)		3,87 SEK/liter	Skatteverket, 2018
P	Carbon dioxide tax (per liter of petrol)		2,57 SEK/liter	Skatteverket, 2018
Q	Consumption electricity per year (with EV)	1,7 * (A)	2058,7	1,7 is the electricity needed for 10 km driving (KI, 2018)
R	Energy tax per year	(N)*(Q)	681,4	
S	Cost of electricity	(Q) * 1	2058,7	1 SEK /kWh (KI, 2018)
T	Consumption of petrol	0,48 * (A)	581,28 liter /year	0,48 liter/10 km (KI, 2018)
U	Cost of petrol per year	16 * (T)	9300,48	16 SEK/liter (KI, 2018)
V	Carbon dioxide tax per year	(P) * (T)	1493,9	
W	Energy tax per year	(O) * (T)	2249,6	
X	Difference of yearly cost	(U) – (S)	7241,8	
Y	(X) Discounted over 10 years	$\frac{7241{,}78}{(1+0{,}04)^1}+\cdots+\frac{7241{,}78}{(1+0{,}04)^{10}}$	58 737,32	Discount rate: 4% (KI, 2018)
Z	Avoided Malus, discounted over 10 years	See method above	6144	
AA	Full benefit for EV buyer	(Y) + (Z) + (I)	124 881	
AB	Cost per reduced ton	(AA) /(E)	8 452,7 SEK/ton	
AC	Compared to EU ETS (average)	(AB) / (F)	42,9 times as expensive	

Appendix 2

Municipality type	**Income**	**Higher education**	**New registrations**	**Viehle ownership**	**Yarly distance**	**Public charging stations**	**Previous subsidy**
Rural	292,4	17,5%	0,0220	0,7066	827	2,65000	4,7
Rural with tourism	293,8	17,9%	0,0204	0,7220	876	5,73300	3,8
Low commuting to larger city	300,1	17,8%	0,0234	0,6614	804	4,38700	5,3
Smaller city	314,4	20,5%	0,0354	0,6307	732	12,00000	10,8
Commuting close to smaller city	298,7	18,1%	0,0231	0,6743	808	3,46154	6,2
Commuting close to larger city	310,6	18,8%	0,0239	0,6459	794	3,23214	3,7
Large city	327,2	30,4%	0,0529	0,4246	501	99,33333	60,5
Commuting close to large city	378,1	24,8%	0,0360	0,5285	649	7,6512	27,2
Larger city	312,0	26,3%	0,0400	0,5465	640	28,90476	34,1
Swedish average	**314,6**	**20,1%**	**0,0277**	**0,6365**	**765**	**18,59477**	**11,4**
Standard deviation	40,8	0,064	0,0153	0,0820	106	31,3743757	32,1

Appendix 3

To find literature on the subject of electric vehicles and subsidies, *Google Scholar* and the university database has been used. As this is a quite small field, the network of papers and references back and forwards was established by searching for papers including combinations of the following words: EV, electric vehicles, fee-bate, Bonus-Malus, Sweden, subsidies, fairness, equity. To establish the background and Swedish membership in the EU, reports made for or by the union has been used.

Appendix 4

Table of zero-values

	Nr of municipalities with zero	*Rural*	*Rural with tourism*	*Low commuting to larger city*	*Commuting close to smaller city*	*Commuting close to larger city*	*Smaller city*	*Larger city*	*Commuting close to large city*	*Large city*
Previous subsidy (2017)	57	16	8	5	9	15	2	0	2	0
Public charging stations	32	10	1	3	10	6	0	0	2	0

The table describes how many municipalities that have zero-values for payouts of the previous subsidy (in 2017) and number of charging stations in columns 1 and 2. The rest of the columns describes how these zero-values was distributed over the municipality types.