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The Influence of Government Incentives on Electric Vehicle Adoption: Cross-national Comparison

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Abstract

This paper examines the influence of political incentives which are set by the government and aim at promoting the adoption of electric vehicles (EVs). More specifically, battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are considered. A classification and categorization of different incentives is provided and specified for five countries, namely Norway, Netherlands, Germany, United States and China. Additionally, an empirical study was performed for China and the Netherlands employing the method of time series (TS) analysis. Results reveal that government incentives affect EV market penetration but exact effects differ for both country and type of EV. In China, especially direct rebates increase EV adoption under certain circumstances. In the Netherlands, PHEVs' market share increases more compared to BEVs' market share if both vehicle types receive the comparable incentives.

Keywords: public policy, electric vehicles, political incentives, technology diffusion

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1 Introduction

Currently, 80 % of global energy consumption is based on fossil fuels. The transportation sector with oil products making up 93 % of final energy consumption represents one of the least diversified sectors regarding energy supply in the global economy. In spite of new developments and continuous efforts to increase conventional powertrain's fuel economy, greenhouse gas emissions have increased by 28 % since 2000. Consequently, e–mobility has drawn substantial attention during the last two decades (International Energy Agency, 2016).

Hybrid electric vehicles (HEVs), whose technology is the closest to conventional vehicles (CVs), have both an electric engine and an internal combustion engine (ICE), which is usually smaller than in CVs of similar size. The kinetic energy generated by the braking process is converted into electric energy instead of being wasted as in CVs. As opposed to HEVs, plug-in hybrid electric vehicles (PHEVs) do have a plug to recharge the battery, which is usually larger and offers a higher range than in HEVs. Still, the flexibility of using conventional fuel for longer distances remains. Battery electric vehicles (BEVs) do not have an ICE at all but an electric engine and a relatively large rechargeable electric battery. This paper focuses on PHEVs and BEVs and summarizes them as EVs, which in this case explicitly exclude HEVs.

Even though EV market shares[1] have risen during the last years in most of the important automobile markets (Figure 1), market penetration proceeds more slowly than desired. In the European Union, 24,592 BEVs were newly registered within the first three months of 2017 according to the European Automobile Manufacturers Association (2017b), which is 49 % more than in the same period of the previous year. During this time, only 21,644 PHEVs were registered, which corresponds to an increase of 13 %. In Germany, for example, where a direct incentive scheme is applied since April 2016 providing 3,000 EUR for each newly sold PHEV, sales numbers increased substantially from 2016 to 2017. Especially vehicles in the A and B-Segments more than doubled their growth comparing March 2016 to June 2017 (European Alternative Fuels Observatory, 2017b). This

[1] Market share is defined here as the proportion of EVs newly registered as passenger cars during one year compared to the total number of newly registered passenger cars in the same year.

suggests a certain effectiveness of the provided incentives. Nevertheless, in June 2017, 46 % of the newly registered Porsche Panamera were PHEV versions of the vehicle indicating a huge increase of these vehicle types also in segments which do not get any incentives due to their high list prices. Thus, the question arises whether growing market shares can partly be attributed to incentives or are the consequence of a natural growth.

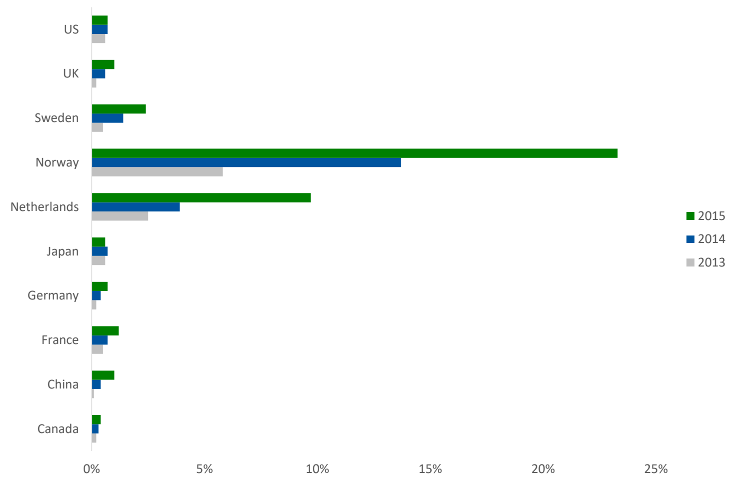

Figure 1: EV market share by country, 2013-2015 (International Energy Agency, 2016)

EVs face a lack of knowledge of potential consumers, a cost disadvantage compared to CVs as well as some technical limitations, for example with regard to their range. Such barriers, which are common during the starting phase of new technologies, prevent a high market penetration of EVs. Rogers (1962) describes the process of innovation diffusion as a spread of a new technology within a social system. The innovation itself is defined as a practically implemented idea, which is subjectively identified as new by potential customers who pass different steps during the decision process – i.e., the first contact with the innovation is followed by an evaluation process and finalized by the actual adoption of the new technology. Manfield (1961) showed that process innovations spread more rapidly within a market if the necessary investments are comparatively low and the expected efficiency enhancement as well as the number of market participants willing to use the new technology is high. This finding can be transferred to the case of electric vehicles, which do not only represent a process but also a product innovation. Currently, the demand for electric vehicles is still relatively low and development costs are spread over small numbers of cars. A high number of EVs in the market generates a potential for economies of scale – especially in the field of battery production. With an increasing acceptance of electric mobility the risk of lost sunk costs is reduced for OEMs who build product-specific production facilities. Even though the outlined theoretical approaches in the literature focus on technology adoption from a supplier perspective, they might easily be transferred to a consumer perspective.

To overcome the above-mentioned barriers of technology diffusion many governments have introduced incentives to promote the adoption of EVs during early development phases. However, the success of political incentives has not yet been sufficiently studied. Empirical literature in this field does not analyze the effect existing incentives have on different vehicle types in different markets. Especially the fact that the same incentives might influence BEVs' market share differently that PHEVs' is not considered in sufficient detail. This paper adds to existing research by addressing three specific questions:

1. What are governments' historical and current incentives for EV adoption?
2. Do incentives positively influence BEVs' and PHEVs' presence on the automobile market in China and the Netherlands?
3. Do different incentives have different effects on the automobile markets in the two countries?

The questions are approached by firstly categorizing and analyzing the most important political incentives concerning EV adoption providing an overview of past and current incentives in selected national EV markets – i.e., Germany, United States, China, Netherlands and Norway – followed by an empirical case study of the Netherlands and China. In 2015, 90 % of EV sales occurred in eight main markets: China, United States, Netherlands, Norway, United Kingdom, Japan, Germany and France (International Energy Agency, 2016). Out of these eight automotive markets, five were chosen due to the following reasons: The automotive industry is Germany's most significant industry in terms of turnover and the federal government has ambitious goals in EV adoption. The United States and China are the biggest automobile markets worldwide with regard to both CVs and EVs. Norway and the Netherlands are characterized by an exceptionally successful performance concerning the introduction of EVs. Between 2012 and 2013 the Netherlands experienced the highest increase in EV market share worldwide (Mock and Yang, 2014). This paper focuses on China and the Netherlands in an empirical case study as incentives in Germany are very limited, Norway already introduced most incentives during the last decade and the United States is characterized by significant regional variation.

A time series (TS) analysis of BEVs' and PHEVs' monthly market shares from 2010 to 2016 is conducted, respectively. Controlling for other potential socioeconomic factors that may influence the market share, such as gasoline and electricity prices, the number of models in the market and the Consumer Confidence Index (CCI), our analysis allows an assessment of the relative importance of government incentives.

This paper is structured as follows: Section 2 classifies the main political incentives concerning EV adoption and provides a structured overview of current and past incentives in selected important EV markets. Section 3 reviews relevant literature on HEVs and EVs. Section 4 provides the case studies of China and the Netherlands. It summarizes data, model and methodology employed and presents the regression results of the TS analysis for each country and vehicle type. Section 5 concludes this paper and gives suggestions for further research.

2 Incentives for EV Adoption

In Norway, first incentives were provided during the 1990s indicating the government's vision and persistence in promoting e-mobility. This is one potential reason why, in terms of EV market share, Norway keeps leading throughout the world – the market share after the first half in 2016 was 15.7 % for BEVs and 13.4 % for PHEVs (European Alternative Fuels Observatory, 2016). In addition to a diverse set of non-financial incentives, a considerable tax break is offered by the government. Doyle and Adomaitis (2013) calculate that financial incentives summed up to yearly savings of USD 8,200 per EV in 2013. This amount includes tax breaks of USD 1,400 per year, annual savings in road tolls of approximately USD 1,400, free parking worth USD 5,000 and other avoided charges of estimated USD 400. As water transportation plays an important role in Norway's daily life, free access to road ferries is another attractive incentive for EVs. One successful non-financial incentive, the access for EVs to bus-only lanes, has already generated controversy because buses struggle to keep on schedule with high numbers of EVs on their lanes, especially during rush hours. However, critics argue that Norway's huge financial incentives for EVs are not feasible in the long term and are possible only due to the country's vast revenues from oil and gas.

In the Netherlands, recent incentives have drastically fostered EV adoption resulting in an EV market share of 2.4 % after the first half of 2016 (European Alternative Fuels Observatory, 2017a). Company car tax collection for privately used business cars was repeatedly modified during the last years. A certain amount corresponding to a fixed percentage value of the car's list price is added to the employee's taxable income. As this percentage depends on the car's CO2 emissions, there is a tax benefit for fuel efficient cars. Until the end of 2013, company cars emitting less than 50 g/km of CO2 were exempted from this tax charge (for at least 60 months depending on the registration date). Since January 2014, BEVs face a reduced company car tax rate of 4 %, and PHEVs emitting less than 50 g/km pay 7 % while CVs face rates of 14–25 %. In order to explicitly encourage the adoption of BEVs, they are exempted from company car tax again in 2016 and 2017. For this period, tax rates were increased to 15 % for emissions less than 50 g/km and to 21–25 % for CVs. The motor vehicle purchase tax (BPM), a one-time tax, is levied according to vehicle emissions and its classification becomes stricter each year causing a more explicit preference for EVs. Before 2013, the exemption criterion were emissions above 90 g/km, and it decreased to 88 g/km and 85 g/km in 2013 and 2014, respectively. Since January 2015 only zero-emission vehicles are exempted while PHEVs benefit from a reduced BPM. Motor vehicle road-use tax (MRB), an annually-paid tax, was not levied for both EVs in 2014 and 2015 while the exemption has only continued for BEVs since January 2016. In addition to these financial incentives, the Netherlands offered free parking space partly equipped with charging infrastructure in some regions such as Amsterdam and Rotterdam from 2009 to March 2012. Since April 2012, the city of Amsterdam offers free parking while charging (parking in Amsterdam costs up to 55 EUR per day). Finally, the national government offers a direct rebate for purchasing electric taxis and delivery vans of 3,000 EUR since January 2011 and some cities such as Amsterdam, Maastricht and Tilburg offer additional subsidies of 3,000–5,000 EUR on top. Additional local government incentives include the circumvention of waiting lists for parking permits of EVs in Amsterdam since April 2012 and one year of free parking downtown for EV owners in Rotterdam. Rotterdam offers a subsidy of up to 1,450 EUR for installing home chargers using green energy, and Amsterdam offers the free installation of a public EV charging station for residents if requested. In April 2016, the Labor party in the Netherlands officially proposed that the Netherlands will ban domestic sales of petrol or diesel vehicles after 2025, which is, however, not legally binding yet. With this policy coming into effect, the Netherlands would be the first country in the world to ambitiously turn all new cars into BEVs.

Germany set the goal of having 1 million EVs on the road by 2020. Nevertheless, the EV market adoption has turned out to be slow and reluctant. EV sales in Germany summed up to 23,464 electric cars in 2015, accounting for only 0.7 % of the total passenger vehicles market. Until the end of 2015, 50,535 EVs were registered in Germany, which is far away from the national goal. Consequently, Germany recently introduced direct purchase rebates in May 2016 after continuous discussion between politicians and top executives of German automakers. The German government and automakers will jointly finance the subsidies for BEVs (4,000 EUR per car) and PHEVs (3,000 EUR per car) for list prices up to 60,000 EUR. The subsidy will either end in 2019 or when the total budget of 1.2 billion EUR will have been spent. Sales numbers and market shares of EVs before the introduction of the subsidy reveal that tax exemption and reduction as the only incentives were too weak to significantly increase EVs' market share in Germany. In December 2012, it was released that EVs benefit from certain years' exemption of the motor vehicle tax, which usually amounts to 540 EUR per year if the car weights 1,500 kg. A 5-year exemption applies to cars registered before 18th May 2011 and a 10-year exemption applies to cars registered between 18th May 2011 and 31st December 2020. After years of free tax, a 50 % reduction is granted if the electric range exceeds 30 km – from 2018 this requirement will be extended to 40 km –, and PHEVs' emissions are below 50 g/km. A special rebate exists for electric company cars. As a significant amount of the price difference between CVs and EVs is attributed to the battery price, a reduction of the purchase price by a fixed amount of 300 EUR (in 2017) per kWh of battery capacity (max. 8000 EUR) is granted (Vereinigte Lohnsteuerhilfe e.V., 2015). For average BEVs with a capacity of 22 kWh, this sums up to a rebate of 6600 EUR. Consequently, the company car tax to be paid decreases as well. The federal government also introduced non-financial incentives, which allow municipalities to offer bus lane utilization, parking privileges and exemptions of driving bans in city centers since 12th June 2015. Since January 2013, ministries strive to have a share of EVs of at least 10 % in the government fleet – a goal which is far from being reached.

The United States are characterized by a high diversity across the single states regarding EV market shares. Figure 2 (National Conference of State Legislatures, 2015) shows local governments' incentives on EV adoption, such as tax incentives, direct subsidies, free parking and access to high occupancy vehicle (HOV) lanes. The federal government applied direct rebates with phase out strategies, i.e., if one model's sales volume exceeds a certain amount, it is no longer qualified for subsidies. Currently, tax credits, which can only be used to offset taxes at a later time, are in effect. Additionally, the United States department of energy announces R&D investments of USD 1.5 billion offered to manufactures to foster the efficiency of batteries and their components and to support domestic production, and USD 500 million for the domestic production of other components needed for EVs, e.g. electric engines, to sustainably foster the development of next generation electric

[1]B. T. Signaal (2016); Figenbaum and Kolbenstvedt (2013); Holtsmark and Skonhoft (2014); EVNorway (2016)

[2]City of Rotterdam (2015); European Alternative Fuels Observatory (2017a); Government of the Netherlands (2016a); Government of the Netherlands (2016b); N. L. Agency (2013); City of Amsterdam (2016); Raivereniging (2017); The Hague (nd)

[3]BMF (nd); BMWI (2016a); BMWI (2016b); (European Alternative Fuels Observatory, 2017a)

[4]International Council on Clean Transportation (2014); National Conference of State Legislatures (2015); U. S. Department of Energy (nd)

[5]Cai (2013); International Council on Clean Transportation (2014); Municipal Government Office (2016); State Administration of Taxation (nd); State Administration of Taxation (2012)

Table 1: Incentives for EVs with timeline in Norway, Netherlands, Germany, United States and China

Category		Norway[1]	Netherlands[2]	Germany[3]	United States[4]	China[5]
One-time tax	Exempted	Import tax since 1996, VAT[a)] on purchase until 2018 or until 50,000 EVs on the streets, Purchase tax before 12/2018	BPM[b)] until 12/2014, only BEV since 01/2015		In 8 States: esp. excise tax, state use and sales tax, title tax, motor fuel tax	VPT[c)] 09/2014 – 12/2017
	Reduced		BPM for PHEV			
Annual tax	Exempted	Road tax since 1997	MRB[d)] 01/2014 – 01/2016, only BEV since 01/2016	Motor vehicle tax (for 5 or 10 years) 05/2011 - 12/2020		VVT[e)] since 2012
	Reduced	Registration tax since 1996, Company car tax since 2000	MRB for PHEV, Company car tax	Motor vehicle tax after years of exemption, Company car tax	Vehicle license tax (1 state)	
Tax credits					In 13 states for EVs and EVSE[f)]	
Direct rebates			BEV taxis and delivery vans since 2011 (3000 EUR)	BEV (4000 EUR) PHEV (3000 EUR) since 2016	In 12 states	One-time bonus
Fees	Exempted	City toll since 1997				
	Reduced				Registration fee (3 states), Toll rates (2 states)	
Free access to bus lanes/HOV lanes		Nationwide since 2005		Local initiatives	In 12 states	
Free parking		Since 1999	Parking lots exclusively for EVs	Local initiatives	In 2 states	
Charging facilities		Promotion program nationwide since 2009, increasingly free charging	Local priorities (e.g. subsidies for charging points), fast-charging stations		Subsidies for chargers in 13 states, 25% of public charging stations free, Special charging rates (9 states)	
Other		Free access to road ferries since 2009, own identifying license plates: EL, increased mileage allowance rate for EVs (from employers), Funding of research projects		Funding of research (showcases, etc.) since 04/2012	Emission tax exemption in 20 states, incentives for R&D, insurance discount in 1 state, 3 states offer grants and other funding, Special (annual) registration fee to pay for EVs (8 states)	Plates privilege in some cities

[a)] VAT=Value-Added Tax, [b)] BPM=Private Motor Vehicle and Motorcycle Tax, [c)] VPT=Vehicle Purchase Tax, [d)] MRB=Motor Vehicle Tax, [e)] VVT=Vehicle and Vessel Tax, [f)] EVSE=Electric Vehicle Supply Equipment vehicles (U. S. Department of Energy, nd). The leading state in terms of e-mobility is California. There is a well-developed credit trading system favoring zero emission vehicles (ZEV) (comprising PHEVs, BEVs and fuel cell electric vehicles (FCEVs) in the next stage as of 2018), which consists of both sales mandates for large volume manufactures and market trading schemes among all companies. The government of California provides tax credits for customers in addition to the federal government's subsidy as well as subsidies for charging infrastructure and HOV lane access for BEVs and PHEVs. Special parking lots in cities or discounted parking fees are offered in California as well.

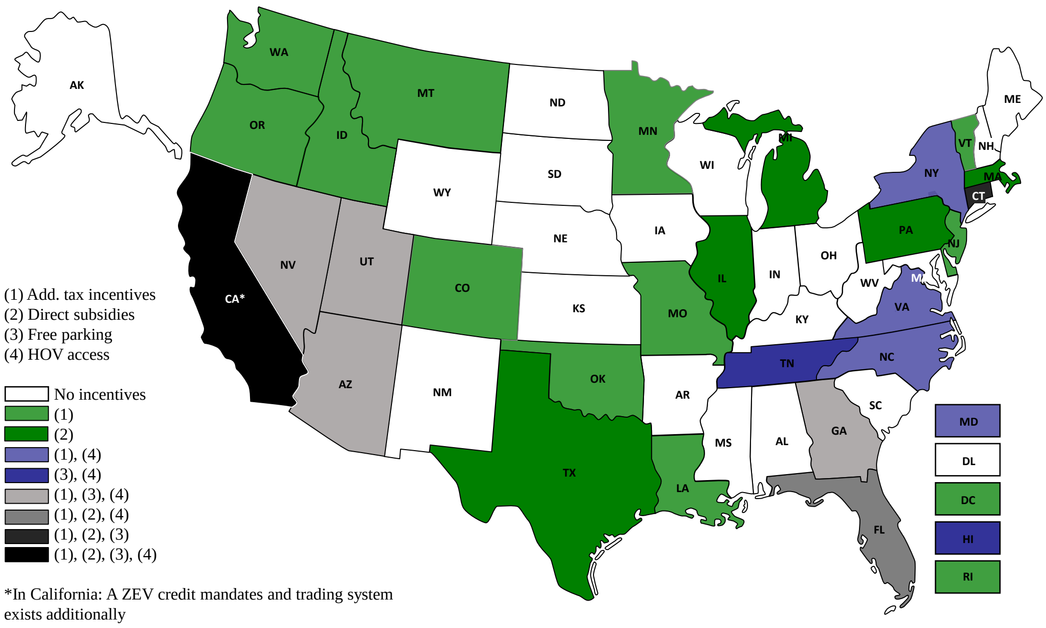

Figure 2: Diverse incentives across the different states in the United States (U. S. Department of Energy, nd)

In China, R&D on EV technology has been included in the 863 Program (a national project to develop high-technology) as a key national project by the Ministry of Science and Technology since the tenth Five-Year Plan period (2001-2005). The Chinese government established the *Three Transverses* (multienergy powertrain control system, electric engine and control system, battery and battery management system) *and Three Longitudes* (HEV, BEV and FCEV) strategy for EV development. The *Plan on Shaping and Revitalizing the Auto Industry* was announced in China in 2009, which launched a demonstration program of

EV deployment in 13 cities, known as the *Ten cities, thousand vehicles* program. This program underlines the Chinese government's ambition to favor EV technology compared to other alternative fuel technologies and to boost the development from R&D to mass production. Large amounts of financial support were provided by the central government for the purchase of demonstration vehicles in pilot cities while the construction of infrastructure and the vehicles' maintenance were set to be municipal governments' responsibility. The 1^{st} stage direct rebate was determined by vehicle battery capacity including both HEVs and EVs. However, the 2^{nd} stage rebate applies only for BEVs, PHEVs and FCEVs with the amount specified by vehicle range. The program expanded to a total of 25 pilot cities in August 2010 and 88 cities in 2013. Besides, the Chinese government has strong power in promoting EV adoption in public sectors such as urban transits, taxis, government fleet, airport fleet etc., and purchases by the government itself show demonstration effects for the private market. Five pilot cities, Shanghai, Changchun, Shenzhen, Hangzhou and Hefei, started to deploy EVs in the private market under the framework of another demonstration program in June 2010. In 2012, the State Council announced a target for EV adoption according to which cumulative NEV sales should reach 500,000 by 2015 and 5 million by 2020. Besides, governments were determined to establish a rapid charging network by four vertical lines and four horizontal lines by 2020. In addition to these incentives set by the federal government, local governments are authorized to provide additional incentives to promote EVs. As Chinese big cities face high pressure regarding traffic congestion and pollution due to high populations, plate registration has been introduced to control the growing volume of vehicles either by lottery or by auction. Several big cities such as Beijing, Shanghai and Guangzhou apply preferential plate registration incentives stimulating large number of EV purchases. In Beijing, EVs benefit from no plate lottery compared to a winning rate of about 0.52 % for CVs in December 2015. In Shanghai, plates for EVs are free instead of auctioned which recently costs around CNY 10,000. Consequently, Shanghai has promoted the adoption of 55,406 EVs between 2013 and the end of 2015 (Shanghai Government, 2016). However, the direct subsidies for EV are planned to phase out gradually starting with a 20 % drop by the end of 2016. Another decrease of 40 % is to follow between 2019 and 2020 as China's Ministry of Finance announced

(Xinhua, 2016). The main reason for this sharp reduction is subsidies is that they were initially designed to initiate a market for new-energy vehicles. However, several companies recently depend too much on these subsidies by only focusing on government incentives for their newly designed vehicles implying negative impacts on technological advances. Moreover, the EV market is growing significantly in China and might be able to persist without government any intervention.

Based on all five countries' policy scenarios and applied incentives, which are summarized in Table 1, a classification of incentives to promote EV adoption is established. The categorization, which is shown in Table 2, follows the vehicle lifecycle from R&D to production, purchase and usage stage and takes into account all stakeholders in the market.

Table 2: Incentive structure across countries

	R&D	**Production**	**Purchase**	**Usage**
Customer			Direct rebates, Tax credits, Tax exemption and reduction for purchase and registration, Preferential plate registration	Annual tax exemption and reduction, Road and city toll exemption, Free parking, Access to HOV and bus lanes, Parking privileges, Charging facilities, Free from traffic control
OEM	Research funding	Regulation of fuel efficiency, Tax credits, Government concessional loan	Sales mandates, Credit Trading System	
Other stakeholders*	Research funding		Direct rebate for taxis and delivery vans, Government fleet purchase	Bonus for charging infrastructure

Financial incentives are marked in blue color while non-financial incentives are marked in green color.

*Other stakeholders are research institutes, universities, infrastructure providers, etc.

Focusing on the customer-specific incentives, the incentives in this group can be further divided according to the intended target of these measures, namely the vehicle itself or supporting facilities, as shown in Table 3. The table reveals the different emphases these countries put on customer-specific incentives. China focuses on incentives for customers entirely with regard to the vehicle itself while Norway and the Netherlands choose a balance between the vehicle and supporting facilities.

Table 3: Consumer specific incentives: cross country comparison

	Vehicle itself	**Supporting facilities**
All 5 Countries	Direct rebate, Tax credits, Tax exemption and reduction, Preferential plate restriction, Free from traffic control	Access to HOV and bus lanes, Parking privileges, Free road ferries, Free parking, Charging facilities
Norway	Tax exemption and reduction	Access to bus lanes, Free road ferries, Free parking,Charging facilities
Netherlands	Direct rebate for special vehicles, Tax credits, Tax exemption and reduction, Free from traffic control in Utrecht	Parking privileges, Charging facilities
Germany	Tax exemption and reduction, Direct rebate	Federal government permitted access to bus lines and parking privileges
United States	Tax exemption and reduction, Direct rebate	Access to HOV / bus lanes, Parking privileges, Free parking, Charging facilities
China	Direct rebate, Tax exemption and reduction, Preferential plate restriction, Temporarily free from traffic control in Beijing	

Financial incentives are marked in blue color while non-financial incentives are marked in green color.

3 Literature Review

3.1 Literature on consumers' purchasing motivations

Previous research in the field of political incentives' impact on EV adoption is mainly conducted for HEVs. Heffner et al. (2005) perform an extensive survey on HEV owners in California and identify environmental and economic motives to be crucial for consumers' buying decisions. Similar results are obtained by Ozaki and Sevastyanova (2011), who also find social norms to play a crucial role in customers' buying motives. Zhang et al. (2013) define the major four drivers of general NEVs' acceptance to be financial benefits, performance attributes, environmental awareness and psychological needs in China.

PHEVs and BEVs have not been in the focus of many quantitative analyses so far. One important reason being the short presence of EVs on the market and the resulting limited availability of empirical data. Instead, rather general studies on potential obstacles for EV adoption and surveys among potential consumers are performed often on a regional basis or for the comparison of different states within one country revealing amongst others that attitudes towards EV adoption depend on age, gender and education of individuals (Egbue and Long, 2012).

3.2 Related literature on HEVs

Study results reveal a controversy concerning the impact of political incentives on consumers' willingness to purchase. Depending on the countries under consideration, the time frame and the exact policy incentives and model specification, some authors find policy instruments to be main drivers of HEV adoption (Gallagher and Muehlegger, 2011) while others identify only a small effect with other factors such as gasoline prices constituting a higher importance in increasing HEVs' market share (Kahn, 2007; Diamond, 2009).

Investigating six cities in California, Kahn (2007) identify environmentalism to have a significant impact on consumers' buying patterns of HEVs. Chandra et al. (2010) discover a strong and positive relationship between tax incentives provided in Canadian provinces and the market share of HEVs. Gallagher and Muehlegger (2011) investigate quarterly data on the state level in the United States for eleven HEV models between 2000 and 2006 and confirm policy incentives as well as gasoline prices to be important drivers of HEV adoption. Diamond (2009), who investigate the HEV market share in the United States by means of cross-sectional data for individual years as well as panel data from 2001 until 2006, determine gasoline price to be the main driver of HEV adoption. Still, his results do not reveal any significant positive correlation between financial incentives and HEVs market share.

Jen et al. (2013) evaluate the effect of the Energy Policy Act of 2005 in the United States and – as an enhancement to previous research – take into account positive network externalities that may arise in the adoption and diffusion phase of HEVs by explicitly including lagged sales as a regressor. The Energy Policy Act of 2005 is found to enhance HEV sales between 3 % and 20 % depending on the empirical model used. In accordance with Gallagher and Muehlegger (2011) the authors demonstrate that the effectiveness of incentives depends on the financial amount of the incentive provided to consumers.

3.3 Related literature on PHEVs and BEVs

The more innovations differ technologically from commonly known products, the higher consumers' uncertainty (Anderson and Tushman, 1990). Since EVs are a much more radical innovation than HEVs, the effect of incentives cannot be assumed to be the same for the two technologies. Consumers' willingness to pay, government involvement as well as the profitability of a technology highly depend on the uncertainty among consumers (Nelson and Winter, 1977; Jaffe et al., 2005). Consequently, existing studies on HEV adoption are not representative of the effects financial incentives may have on EV sales.

Previous research about the effect of political incentives on EV adoption is mainly based on surveys and thus focuses on potential consumers' attitudes and preferences. Conducting an internet-based survey among technically versed potential consumers, Egbue and Long (2012) show that technological barriers such as battery range, high costs of EVs and insufficient charging infrastructure are the main obstacles in EV adoption within this group. Additional relevant contributions to EV adoption, which are also based on surveys and scenario simulations, include Wolf et al. (2015), who employ an agent-based model to simulate the impact of political incentives on consumers' preferred transport modes and underline the importance of non-financial incentives. Lieven (2015) conduct a global survey in 20 countries and reveal different groups of consumers' responsiveness to different types of incentives stressing the crucial role of charging infrastructure. A similar result is achieved by Langbroek et al. (2016), who identify free parking and bus lane access as essential non-financial incentives. Bjerkan et al. (2016) and Gass et al. (2012) obtain results which are in line with previous research, and both stress the superiority of direct rebates as a driver for EV adoption.

Nevertheless, the phenomenon of the $attitude - action\ gap$ points out the substantial difference between potential willingness and the actual action of purchasing an EV and hence, the limited informational value of surveys (Lane and Potter, 2007). Sierzchula et al. (2014) use cross-sectional data of 30 countries' EV market shares in 2012 to perform a regression analysis and find financial incentives, charging infrastructure and the existence of a local EV production facility to positively affect EV market shares with established charging infrastructure being the most crucial factor. Their descriptive analyses underline the high importance of country-specific factors.

Even though a considerable amount of research exists for HEVs, profound economic analysis of political incentives' effects on EV adoption is still missing. To our knowledge, there is no empirical analysis for either PHEVs or BEVs which captures their market shares' reaction to political interventions over time and compares them with each other. Taking China and the Netherlands as examples, this paper contributes to close this research gap and identifies how bundles of political incentives affect the EV market in different countries by TS analysis.

4 Empirical Study of China and Netherlands

4.1 Data and methodology

TS analysis is chosen to study each of the two country's adoption pattern separately over time since EVs are at different developing stages in these countries and the applied incentives and policy portfolios differ substantially. A crucial difference constitutes the clear distinction between BEVs and PHEVs in the Netherlands which is expressed in separate incentive schemes while the two vehicle types are treated equally in China. A cross-sectional analysis of various countries is difficult as the comparability between them is highly limited due to completely different tax systems, incentive schemes, the variation over time as well as the progress and the dynamic and fast development within each country. Figure 3 shows the market shares of BEV and PHEV along with the time-line of government incentives in China while Figures 4 and 5 separately show the market shares and government incentives for the two vehicle types in the Netherlands during the investigated time period. The graphs reveal some fundamentally different developments of BEVs' and PHEVs' market shares as well as some apparent peaks in particular months and give a hint of potential correlations with financial incentives. There are three outstanding peaks for ms_PHEV in the Netherlands, which occur at the end of the year and probably outline announcement effects of incentive reductions, which are also captured and explained by the model.

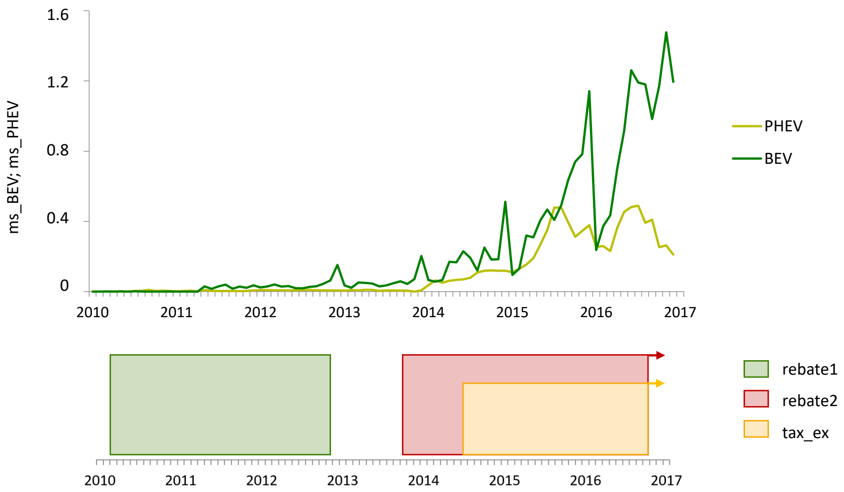

Figure 3: BEV and PHEV market share in % in China with financial government incentives, 2010–2017 (Marklines, 2017a); (Ministry of Industry and Information Technology of the People's Republic of China, 2017)

Potential drawbacks of TS analysis arise from the fact that as the monthly market share many independent variables have increased over time, which makes it more difficult to determine the true effect specific variables have on EV market share. Thus, requirements for regressor variables are stricter for TS analysis compared to cross-sectional or panel data analysis. Additionally, even though corrected for seasonality, monthly market share data show some sharp short-term fluctuations, e.g. due to supply constraints or external influences, which are irrelevant to the analysis (Diamond, 2009). Nevertheless, at this point in time, monthly data is the only option for an empirical analysis due to the limited availability of data as a consequence of the short market presence of EVs. The time series under investigation are trend stationary series which are characterized by a deterministic time trend and a stochastic stationary component. As TS data must in general be assumed stationary, a time trend is included in the model to generate a remaining series which is stationary[2].

[2]In Augmented Dickey-Fuller (ADF) tests the hypotheses of unit-roots are rejected in fa-

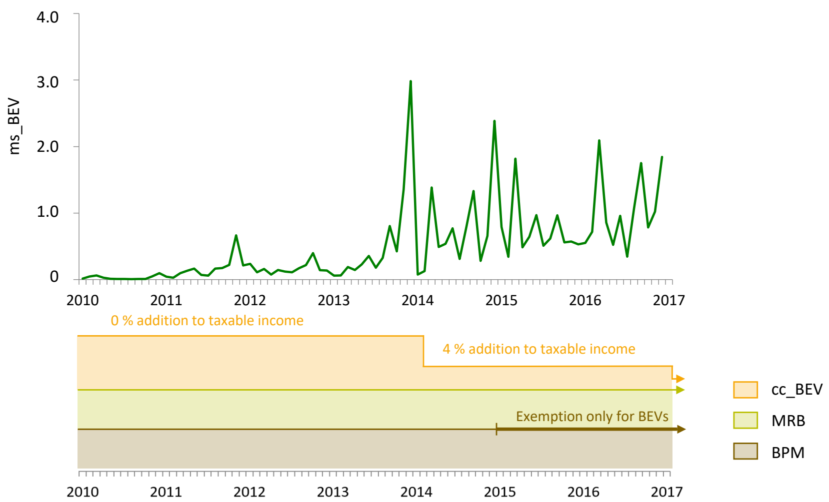

Figure 4: BEV market share in % in the Netherlands with financial government incentives, 2010–2017 (Raivereniging, 2017)

China and the Netherlands were chosen as case study as one is the largest EV market representing emerging economies and the other has experienced outstanding growth in recent years. There has been an obvious difference between BEVs' and PHEVs' presence in the market, which makes a separate study especially interesting. Besides, these two countries continue to put high emphasis on e–mobility by means of strong and diverse incentives.

Apart from policy variables, other variables are included based on previous research and the hypotheses shown in Table A2. Incentives, which act as an intervention in the market, are represented by dummies. An attempt to estimate their respective monetary savings for consumers was not pursued due to considerable difficulties of quantification on the one hand and lack of comparability of different incentives on the other hand. An exemplary model calculation for the Volkswagen Golf (BEV, PHEV and CV derivatives) reveals the incurred taxes and resulting expenses for each vehicle type in the Netherlands over the last eight years and is provided in Table A1. As most non-financial incentives are introduced by local governments, they are not included in the regression because single regional policies cannot be assumed to have an impact on the national level. Gasoline price

vor of the alternative, that the variable was generated by a stationary process allowing for a deterministic trend.

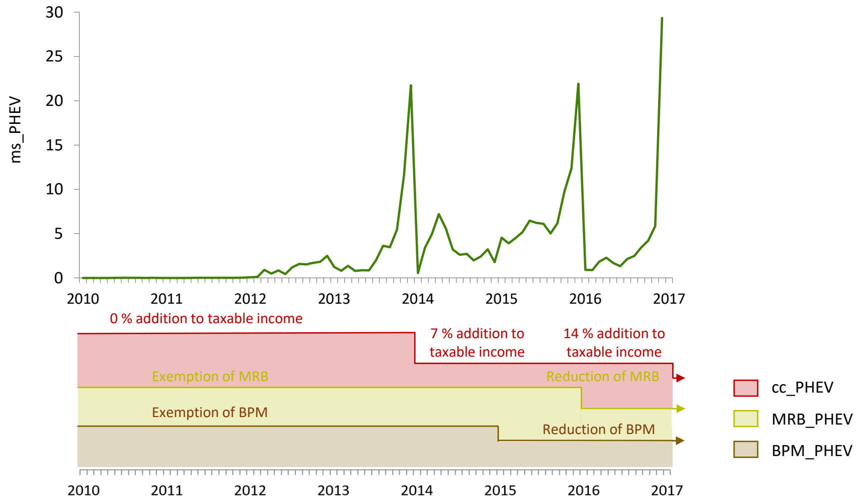

Figure 5: PHEV market share in % in the Netherlands with financial government incentives, 2010–2017 (Raivereniging, 2017)

was found to be significant in several studies on HEVs and is thus included as a regressor in the model. In a previous study, Busse et al. (2013) investigated how myopic consumers behave when buying CVs. One crucial result of this study is that increasing gasoline price by \$ 1 causes an increase in the market share of the highest fuel economy quartile of cars by 21.2 % and a decrease in the market share of the lowest fuel economy quartile of cars by 27.1 %, which constitutes a considerable amount. CCI, the consumer confidence index, is a monthly indicator for the consumption environment and defines consumers' tendency of saving and spending as well as their attitude towards the actual and future condition of their economy relative to other periods. In addition, we assume EV adoption all over the world is still in the first stage of development implying that there is a long–term growing trend of the monthly market share, expressed as technology diffusion (Jen et al., 2013). This trend is captured by t. Including the growth rates of the number of models present in the market, defined by $diff\_models\_BEV$ and $diff\_models\_PHEV$ is intuitive and circumvents the strong pairwise correlation between the number of models and t in the model.[3] All data were derived from

[3]Pairwise correlations between the number of models and t are 0.9714 (BEV) and 0.9559 (PHEV) in China and 0.9069 (BEV) and 0.9759 (PHEV) in the Netherlands.

open access data bases.

The final model specifications for the two vehicle types are given as

$$\log(ms\_BEV_t) = \beta_0 + \beta_1 * \log(ms\_BEV_{t-1}) + \beta_2 * incentives_t + \beta_3 * \log(diff\_models\_BEV_t) + \beta_4 * \log(price\_diff_t) + \beta_5 * log(CCI_t) + \beta_6 * t + \epsilon_t \quad (1)$$

and

$$\log(ms\_PHEV_t) = \beta_0 + \beta_1 * \log(ms\_PHEV_{t-1}) + \beta_2 * incentives_t + \beta_3 * \log(diff\_models\_PHEV_t) + \beta_4 * \log(price\_diff_t) + \beta_5 * log(CCI_t) + \beta_6 * t + \epsilon_t \quad (2)$$

where the subscripts indicate an observation at time t, *incentives* represent the combination of policy dummies and ϵ_t is the stochastic error term. The log–log specification allows the interpretation of the coefficients as the elasticity of market share with respect to each regressor and reduces the harm of outliers as well as of heteroscedasticity. For the PHEV regression in the Netherlands, an additional seasonal dummy (pre_inc_PHEV) is added to the model in order to capture the announcement effects of incentive reductions. Besides, all variables are positive-valued (the first month of the regression is chosen such that ms_BEV or ms_PHEV are continuously above zero) so that there will be no missing data.

Ordinary Least Squares (OLS) estimation producing consistent unbiased estimates of the coefficients was applied as the model specification only requires weak exogeneity of the number of models (Becketti, 2013). This means that there should be no correlation between the market share at time t and all present and past values of the number of models, which is fulfilled. If there is a reverse dependency of the number of models on the market share, this will concern the future number of models instead. Moreover, the model specification including the lagged dependent variable of log_ms as a regressor solves the problem of autocorrelation in the error terms which is otherwise present as indicated in Figure 6[4]. Similar to

[4]Durbin's alternative test for autocorrelation additionally reveals a strong rejection of the null hypothesis of no serial correlation at 1 % significance for both vehicle types. Breusch-Godfrey

the approach of Jen et al. (2013), this allows the baseline market share from which growth occurs to change in each period. This model specification distinguishes this paper from the majority of previous research in this field described in Section 3, which generally does not take the positive network externalities in EV adoption into account and thus tends to obtain positively biased results. Each regression starts from a baseline model. Sensitivity tests ensure a reasonable modification of the models as well as the reliability and robustness of the main conclusions.

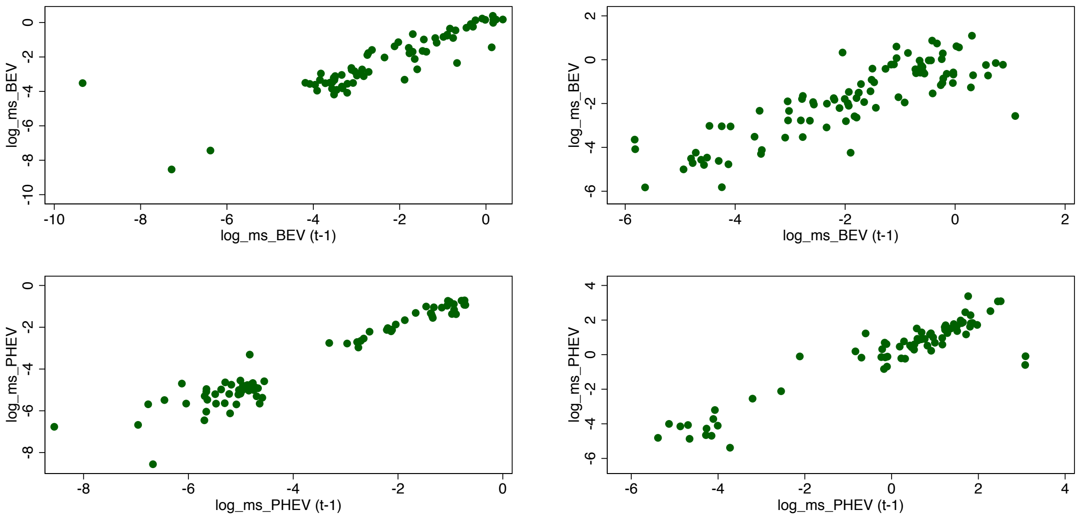

Figure 6: Scatterplot of *log_ms* versus lagged *log_ms* for BEV and PHEV in China (*left*) and the Netherlands (*right*)

4.2 China case

4.2.1 Pre-analysis

Figure 7 shows BEV and PHEV market shares with multiple over-layed lines and reveals that each year for BEVs, values are much higher in December than in other months, which implies a seasonal shape. PHEV market share, however, shows no seasonal shape. One potential reason is that PHEV sales are more naturally growing but do not boom by the pressure to reach sales targets of governments at the end of the year. Consequently, a dummy variable for December is included for

tests confirm that autocorrelation is no longer present when including one lag.

the regression of BEV, namely *Ddec*.

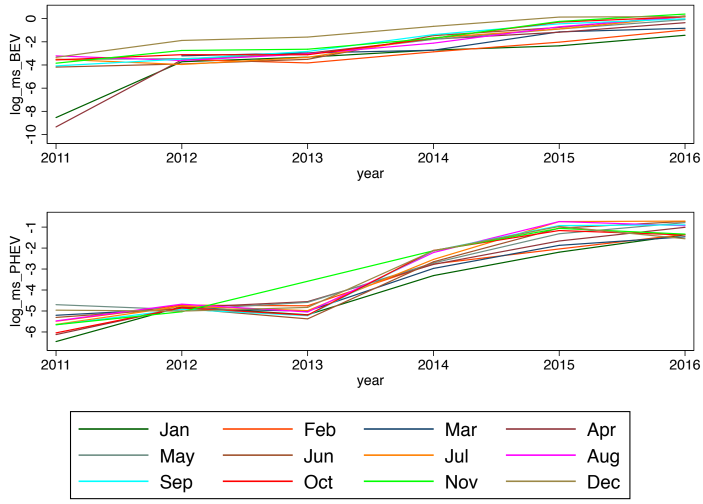

Figure 7: Over-layed lines for BEV (top) and PHEV (bottom) in China

The 1^{st} stage direct rebate (lasting from June 2010 to December 2012) is not modeled in the regression because HEVs were included as well and received the same amount of rebates as PHEVs[5] (Hao et al., 2014). Additionally, data limitations before June 2010 prevented the investigation of the effect. The exemption of the annual Vehicle and Vessel Tax (VVT) is not considered due to its limited effect compared to the one-time Vehicle Purchase Tax (VPT). VPT usually amounts to more than CNY 10,000 whereas VVT lies between CNY 300 and CNY 1,200 for most passenger vehicles per year.

First data analysis confirms the assumed effects and relevance of the two incentives. Separate t-tests were conducted for each vehicle type and each incentive and reveal that mean values of both the market share and its log are significantly higher if the respective incentive is in place as opposed to the situation in which it is not. As both incentives were introduced in a particular year and remained in effect since then, this result may be biased by the technology diffusion process. To achieve more meaningful results, Chow tests were conducted to test for structural breaks in both the market share and its log for both vehicle types. While structural breaks are confirmed for both incentives at least at 5 % significance for

[5] HEVs and PHEVs obtained rebates up to CNY 50,000; BEVs up to CNY 60,000.

BEVs, only $rebate2$ is found to cause a structural break for PHEVs.

4.2.2 Regression results

Tables 4 and 5 show the regression results for the two vehicle types, respectively; columns (4) present the final model. BEV's market share seems to be solely growing with time and peaks in December while most regressors, including the incentives, remain insignificant. PHEVs' market share is also confirmed to be growing with t, which stays significant throughout the configurations. Moreover, $price\_diff$ is found to be insignificant for PHEVs, which seems reasonable as PHEVs still require a considerable amount of gasoline and only provide the option of driving a few kilometers electrically. Thus, the gasoline price itself does not affect the proportion of PHEVs on the market. While the exemption of VPT has no significant effect, the 2^{nd} stage direct rebate significantly increases PHEVs' market share which is in line with the structural break found in the pre-analysis.

Regression results for both vehicle types without the inclusion of the lagged market share as an independent variable are provided in Tables A3 and A4 as a reference. Moreover, the tables provide sensitivity and robustness checks of the original model testing a log–level specification, which does not fundamentally change the models' fit. Not including the lagged market share and t in the model falsely attributes significance to trending regressors. Overall, the analysis supports the hypothesis that at least $rebate2$ imposes some structural growth of the market share for PHEVs in China for the time period under examination, whereas tax_ex is not found to have a significant effect at all.

4.3 Netherlands case

4.3.1 Pre-analysis

As opposed to China, the EV market share in the Netherlands does not reveal any seasonal pattern for either type of vehicle (compare Figure 8) and it is thus not controlled for in the regression. Since incentives in the form of tax benefits have been present in the Netherlands for fuel-efficient vehicles for many years, the dummy

Table 4: OLS regression results of BEV in China

	(1) log_ms_BEV	(2) log_ms_BEV	(3) log_ms_BEV	(4) log_ms_BEV
tax_ex		0.414		0.416
		(1.35)		(1.35)
rebate2			0.00365	-0.0175
			(0.02)	(-0.08)
L.log_ms_BEV	0.00388	0.00192	0.00400	0.00135
	(0.06)	(0.03)	(0.06)	(0.02)
diff_log_models_BEV	1.001	0.704	0.999	0.716
	(1.24)	(0.85)	(1.20)	(0.84)
log_price_diff	-0.756	0.0730	-0.760	0.0938
	(-1.21)	(0.08)	(-1.14)	(0.10)
log_CCI	3.687**	2.657	3.683**	2.672
	(2.08)	(1.39)	(2.04)	(1.38)
Ddec	0.671***	0.682***	0.671***	0.682***
	(3.58)	(3.66)	(3.55)	(3.63)
t	0.0590***	0.0566***	0.0589***	0.0571***
	(7.96)	(7.47)	(5.76)	(5.58)
Observ.	68	68	68	68
R^2	0.913	0.915	0.913	0.915
$Adj.R^2$	0.904	0.905	0.902	0.904

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: OLS regression results of PHEV in China

	(1) log_ms_PHEV	(2) log_ms_PHEV	(3) log_ms_PHEV	(4) log_ms_PHEV
tax_ex		0.239		0.269
		(0.69)		(0.80)
rebate2			0.580**	0.587**
			(2.41)	(2.43)
L.log_ms_PHEV	0.670***	0.648***	0.620***	0.596***
	(7.45)	(6.81)	(6.94)	(6.30)
diff_log_models_PHEV	-0.570	-0.569	-0.656	-0.656
	(-0.98)	(-0.97)	(-1.16)	(-1.16)
log_price_diff	-0.486	-0.150	-0.532	-0.154
	(-0.94)	(-0.21)	(-1.06)	(-0.22)
log_CCI	2.164	1.810	0.975	0.562
	(1.12)	(0.90)	(0.50)	(0.28)
t	0.0229***	0.0221***	0.0161**	0.0151*
	(3.21)	(3.04)	(2.16)	(1.99)
Observ.	79	79	79	79
R^2	0.941	0.942	0.946	0.946
$Adj.R^2$	0.937	0.937	0.941	0.941

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

variables are defined differently. First, there is a distinction between incentives for BEVs and PHEVs (depending on their exact amount of emissions). Second, incentives have been tightened in past years implying stricter emission barriers for certain amounts of emissions. The dummies cc_BEV, cc_PHEV, BPM_PHEV and MRB_PHEV become one for the years in which stricter regulations were applied and are hypothesized to have negative effects on the respective market shares. Additionally, this set-up allows a cross-comparison for testing whether a reduction of incentives for PHEVs has a positive effect on BEVs' market share even though the direct incentives for BEVs stay unchanged.

As for China, first data analysis indicates a general relevance of government incentives. Separate t-tests conducted for each vehicle type and incentive reveal that mean values of both the market share and its log are in general higher when incentives are in place. Chow tests are not as distinct as for China but do confirm the hypothesis of a structural break of log_ms_PHEV for MRB_PHEV[6].

[6] The p-value of the Chow test is 0.0004 for MRB_PHEV.

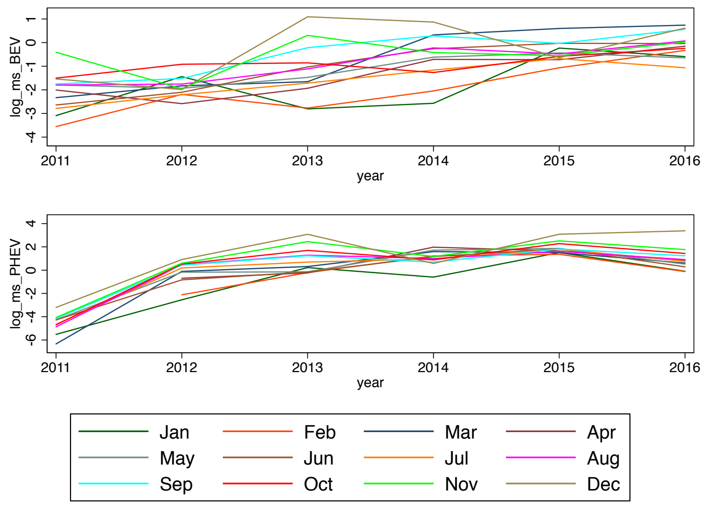

Figure 8: Over-layed lines for BEV (top) and PHEV (bottom) in the Netherlands

4.3.2 Regression results

Tables 6 and 7 show the regression results for BEVs and PHEVs in the Netherlands. The regression output in Table 6 reveals that the number of models and the lagged market share have a positive and significant influence on BEVs' market share while the price difference between gasoline and electricity remains insignificant. Similar to China, CCI is not significant throughout the model configurations. The only direct incentive for BEVs as company cars is significant in the final model, when controlling for the indirect incentives as well. As assumed, the reduction of the company car incentive has a negative effect on BEVs' market share. BPM_PHEV also negatively influences BEVs' market share. A potential explanation is the fact the tax system is quite complex in the Netherlands and depends on exact characteristics of the vehicle. If potential consumers are only superficially following the updates on the incentives schemes, they might have the impression that the stricter rules apply to all electric vehicles, i.e., instead of the information about a clear distinction between vehicles the general image of less support is effectively communicated to consumers. The data suggests that consumers who would have bought a PHEV do not change to BEVs if the incentives for PHEVs are reduced but rather buy CVs instead.

Table 6: OLS regression results for BEV in the Netherlands

	(1) log_ms_BEV	(2) log_ms_BEV	(3) log_ms_BEV	(4) log_ms_BEV	(5) log_ms_BEV
cc_BEV		-0.505			-0.942**
		(-1.23)			(-2.16)
BPM_PHEV			-0.703*		-0.891**
			(-1.68)		(-2.08)
MRB_PHEV				-0.349	-0.480
				(-1.07)	(-1.45)
L.log_ms_BEV	0.347***	0.359***	0.338***	0.327***	0.330***
	(3.50)	(3.61)	(3.43)	(3.24)	(3.36)
diff_log_models_BEV	2.123*	2.012*	2.028*	2.175*	1.867
	(1.84)	(1.74)	(1.77)	(1.88)	(1.65)
log_price_diff	1.339	0.941	0.0751	0.999	-1.473
	(1.66)	(1.08)	(0.07)	(1.15)	(-1.16)
CCI	-0.00131	0.00479	0.000601	-0.00186	0.0117
	(-0.16)	(0.50)	(0.07)	(-0.23)	(1.21)
t	0.0336***	0.0400***	0.0436***	0.0376***	0.0637***
	(5.55)	(5.02)	(5.16)	(5.29)	(5.32)
Observ.	93	93	93	93	93
R^2	0.785	0.788	0.792	0.788	0.804
$Adj.R^2$	0.772	0.774	0.777	0.773	0.786

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: OLS regression results for PHEV in the Netherlands

	(1) log_ms_PHEV	(2) log_ms_PHEV	(3) log_ms_PHEV	(4) log_ms_PHEV	(5) log_ms_PHEV
cc_PHEV		-0.141			-0.667
		(-0.28)			(-1.13)
BPM_PHEV			0.692		0.322
			(1.40)		(0.60)
MRB_PHEV				-1.089***	-1.297***
				(-2.88)	(-3.03)
L.log_ms_PHEV	0.688***	0.692***	0.699***	0.546***	0.539***
	(8.74)	(8.62)	(8.90)	(6.09)	(5.93)
diff_log_models_PHEV	0.659	0.672	0.635	0.426	0.429
	(0.73)	(0.74)	(0.71)	(0.49)	(0.50)
log_price_diff	2.440*	2.434*	4.074**	2.187	2.874
	(1.75)	(1.73)	(2.25)	(1.65)	(1.55)
CCI	-0.0175*	-0.0149	-0.0173*	-0.0239**	-0.0125
	(-1.68)	(-1.06)	(-1.67)	(-2.36)	(-0.89)
t	0.0305***	0.0323***	0.0190	0.0558***	0.0639***
	(3.35)	(2.89)	(1.56)	(4.54)	(2.86)
pre_inc_PHEV	0.725***	0.695**	0.895***	0.663**	0.587*
	(2.72)	(2.40)	(3.07)	(2.61)	(1.71)
Observ.	72	72	72	72	72
R^2	0.894	0.894	0.897	0.907	0.911
$Adj.R^2$	0.885	0.883	0.886	0.896	0.898

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The regression output for PHEVs' market share reveals a positive significance for the lagged market share as well as a partial significance of CCI and the price difference between gasoline and electricity. The announcement effect is found to be significant and positive for the last three months before an incentive was reduced. The stricter regulations for company car taxes and BPM have no significant effect on the sales of PHEVs while the reduction of MRB tax savings has a highly significant and negative marginal effect as expected. Regression results for both vehicle types without the inclusion of the lagged market share as an independent variable are provided in Tables A5 and A6 as a reference. The tables also provide tests for the sensitivity of the model to its exact specification by regression a log–level specification. The coefficients are in line with the hypothesis but the slight variation reveals the problem of the limited data availability which is responsible for a certain degree of sensitivity of the model. As for China's case, not including the lagged market share and t falsely attributes significance to trending regressors. Overall, the analysis supports the hypothesis that some incentives, e.g. MRB_PHEV, have an effect on the market share of EVs in the Netherlands for the time period under examination.

5 Discussion and Conclusion

The case studies of China and the Netherlands show that depending on the actual size and exact application, political incentives can have effects on EV adoption. Nevertheless, the effect on EVs market share is not very distinct and consistent. Thus, the question remains whether incentives should be adapted or applied differently to further increase their effectiveness. As market shares are increasing but are still rather low in most countries, the effectiveness of incentives remains an important question. In order to investigate innovative measures to convince consumers of buying an EV, the purchasing process (Pezoldt et al., 2010) needs to be taken into account when designing incentives. Kotler et al. (2007) define five different steps in this process: the phase before purchase, which can be divided into problem identification, search for information and assessment of alternatives is especially important. In order to increase EV adoption more efficiently, it is necessary to understand the entire purchasing process. The price is only one aspect that might prevent consumers from buying EVs and there are different levers that can be approached.

The purchase of a vehicle constitutes an extensive buying decision process, which usually does not occur spontaneously but implies high consumer involvement, both emotionally and cognitively. It requires an active and conscious purchasing decision based on many complex criteria as opposed to other consumer goods such as soap and candies (Homburg, 2014). The fact that the consumer is both cognitively and emotionally involved makes any intervention and manipulation of this phase a complex process. Basic theories indicate why simply reducing taxes or the purchase price of an EV might not be enough to really increase EV adoption throughout the country. The question of how to expand consumers' openness for this new technology and how to truly initiate their mind-shift during the buying decision process needs to be further explored.

According to our model and the two countries under investigation, political incentives implemented to promote EV adoption in the early development stages do not always succeed in terms of significantly increasing EVs market share. Nevertheless, direct rebates as well as tax-reduction in the Netherlands seem to have measurable effects to some extent at least in the short run. However, this research has the limitation of the short time period that exists for the investigation so far. Moreover, representing all incentives by dummies prohibits the distinction based on the amount of savings due to particular incentives. As this amount highly depends on the car that is bought, the region within a country and many other factors, such as the customers' lack of knowledge of total savings at the time of purchase due to frequent policy changes, it is hard to quantify and would rely on a lot of assumptions. Despite all doubts and controversial results regarding political incentives, we believe that some kind of government intervention is definitely necessary for a promising new technology which is still in its initial development stage and which causes positive externalities. Nevertheless, the kind of intervention in a market must be considered and evaluated carefully and it needs to be adapted to the specific characteristics of the country keeping in mind the complex purchasing process of cars.

Further research needs to take into consideration other relevant variables such as vehicle-specific characteristics, charging points, price competitiveness etc. Besides, the examination of interactions among different policies is worth studying. In addition, local governments' diverse incentives, especially non-financial ones, might be interesting to investigate.

Acknowledgments

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A Appendix

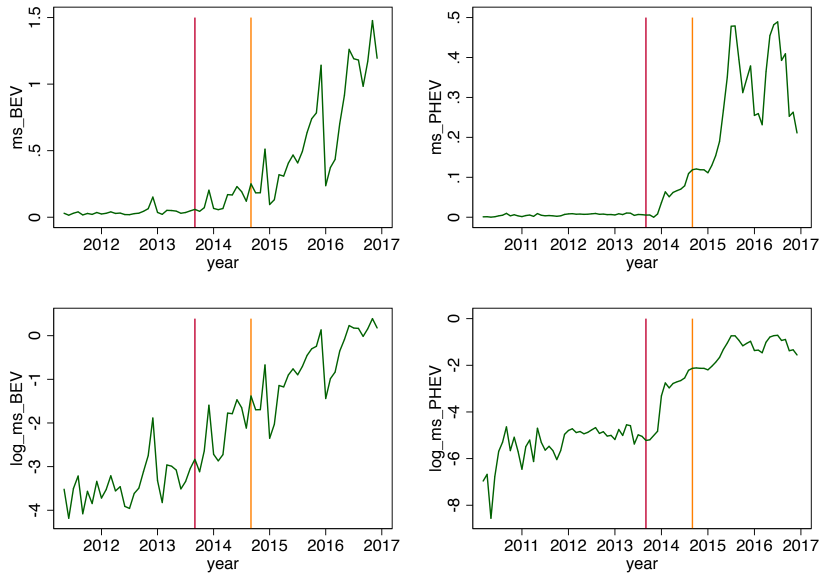

Figure A1: Market share in % in China with marked financial government incentives – tax_ex (*red*) and rebate2 (*orange*)

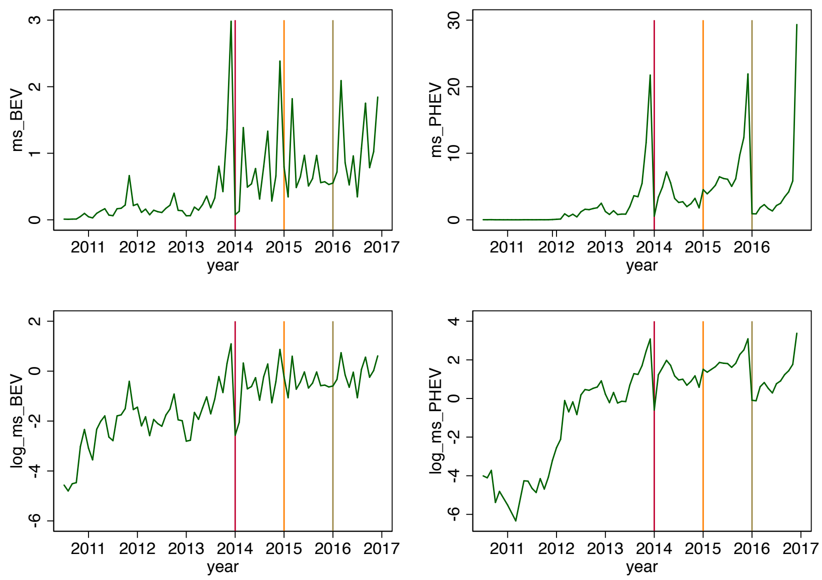

Figure A2: Market share in % in the Netherlands with financial government incentives – cc_BEV / cc_PHEV (*red*), BPM_PHEV (*orange*), MRB_PHEV (*brown*)

Table A1: Model calculation of tax incentives in the Netherlands for VW Golf

first registration 2009	Golf e	Golf GTI	Golf GTE	Golf GTD
CO2 Emission (in g/km)	0	148	34	122
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 19%	5,755 EUR	4,439 EUR	5,905 EUR	5,015 EUR
BPM	- EUR	8,457 EUR	- EUR	10,224 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,044 EUR**	**39,460 EUR**	**36,984 EUR**	**52,133 EUR**
first registration 2010				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 19%	5,755 EUR	4,439 EUR	5,905 EUR	5,015 EUR
BPM	- EUR	6,406 EUR	- EUR	9,227 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,044 EUR**	**39,329 EUR**	**38,776 EUR**	**51,135 EUR**
first registration 2011				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 19%	5,755 EUR	4,439 EUR	5,905 EUR	5,015 EUR
BPM	- EUR	5,933 EUR	- EUR	6,688 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,044 EUR**	**38,856 EUR**	**39,224 EUR**	**48,597 EUR**
company car tax	- EUR	8,434 EUR	- EUR	9,525 EUR
first registration 2012 (01.01-30.06)				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 19%	5,755 EUR	4,439 EUR	5,905 EUR	5,015 EUR
BPM	- EUR	5,715 EUR	- EUR	6,368 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,044 EUR**	**38,639 EUR**	**39,672 EUR**	**48,276 EUR**
company car tax	- EUR	8,379 EUR	- EUR	9,445 EUR
first registration 2012 (01.10-31.12)				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 21%	6,361 EUR	4,906 EUR	6,527 EUR	5,543 EUR
BPM	- EUR	6,789 EUR	- EUR	7,176 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,450 EUR**	**40,180 EUR**	**40,294 EUR**	**49,612 EUR**
company car tax	- EUR	8,765 EUR	- EUR	9,779 EUR
first registration 2013				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 21%	6,361 EUR	4,906 EUR	6,527 EUR	5,543 EUR
BPM	- EUR	6,809 EUR	- EUR	6,669 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,650 EUR**	**40,199 EUR**	**37,606 EUR**	**49,105 EUR**
company car tax	- EUR	8,770 EUR	- EUR	9,652 EUR

Assumptions: For MRB a depreciation rate of eight years is taken into account by consumers in their buying decision (no discounting). Exact MRB taxes vary by about 30 EUR per month between Netherlands' regions; North Holland is taken as an example. Net list prices are taken from the manufacturer's homepage. Calculation shows actual prices to be paid for the vehicles, which ars not always in line with the state of knowledge of customers at the time of buying due to incentive changes.
(Belastingdienst, 2017a,b)

first registration 2014				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 21%	6,361 EUR	4,906 EUR	6,527 EUR	5,543 EUR
BPM	- EUR	6,804 EUR	- EUR	7,719 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,650 EUR**	**40,194 EUR**	**41,190 EUR**	**50,156 EUR**
company car tax	1,466 EUR	8,769 EUR	2,632 EUR	9,915 EUR
first registration 2015	Golf e	Golf GTI	Golf GTE	Golf GTD
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 21%	6,361 EUR	4,906 EUR	6,527 EUR	5,543 EUR
BPM	- EUR	6,855 EUR	379 EUR	8,415 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,650 EUR**	**40,245 EUR**	**41,569 EUR**	**50,851 EUR**
company car tax	1,466 EUR	8,781 EUR	2,659 EUR	10,089 EUR
first registration 2016				
net price	30,289 EUR	23,364 EUR	31,079 EUR	26,397 EUR
BTW (VAT) 21%	6,361 EUR	4,906 EUR	6,527 EUR	5,543 EUR
BPM	- EUR	7,720 EUR	385 EUR	9,332 EUR
MRB per year (North-Holland)	- EUR	640 EUR	448 EUR	1,312 EUR
sum (incl. MRB)	**36,650 EUR**	**41,110 EUR**	**41,575 EUR**	**51,768 EUR**
company car tax	1,466 EUR	8,998 EUR	5,699 EUR	10,318 EUR

Table A2: Hypothesized effects of regression coefficients and data sources

Variable	Data	Hypothesized effect	Data source (China)	Data source (Netherlands)
ms_BEV **and** ms_PHEV	Market share of BEV and PHEV	Dependent variable	Ministry of Industry and Information Technology of the People's Republic of China (2017), Marklines (2017a)	Raivereniging (2017), European Automobile Manufacturers Association (2017a)
$rebate1$ **and** $rebate2$	Dummy for 1^{st} and 2^{nd} stage direct rebate in China	Positive		
tax_ex	Dummy for VPT tax exemption	Positive		
cc_BEV	Dummy for stricter rules of company car tax reduction for BEVs	Negative		
cc_PHEV	Dummy for stricter rules of company car tax reduction for PHEVs	Negative for PHEVs; positive for BEVs		
BPM_PHEV	Dummy for stricter rules of BPM tax reduction for PHEVs	Negative for PHEVs; positive for BEVs		
MRB_PHEV	Dummy for stricter rules of MRB tax reduction for PHEVs	Negative for PHEVs; positive for BEVs		
$models\_BEV$ **and** $models\_PHEV$	Number of models of BEV and PHEV	Positive	Marklines (2017b)	Raivereniging (2017), Marklines (2017c)
$price\_diff$*	Price difference between gasoline and electricity	Positive	Gasoline: Gold600 (2017); Electricity: National Development and Reform Commission of the People's Republic of China (2017)	Gasoline: Centraal Bureau voor de Statistiek (2017b); Electricity: Centraal Bureau voor de Statistiek (2017a)
CCI	Consumer confidence index	Positive	East Money Information (2017)	EU Commission (2017)
$Ddec$	Dummy for December in China	Positive for BEV		
pre_inc_PHEV	Dummy for period before incentive reduction for PHEVs in the Netherlands	Positive		
t	Time	Positive		

* $price\_diff$ = gasoline price – 2.5 * electricity price

Table A3: OLS regression results for BEV in China without lagged dependent variable and alternative model specifications

	(1) log_ms_BEV	(2) log_ms_BEV	(3) log_ms_BEV	(4) log_ms_BEV
tax_ex	0.356		0.306	0.523
	(1.00)		(0.88)	(1.54)
rebate2		0.492**	0.479**	0.00200
		(2.28)	(2.22)	(0.01)
L.log_ms_BEV				0.00563
				(0.08)
log_models_BEV	1.171***	0.946***	0.903***	
	(7.39)	(5.01)	(4.62)	
log_price_diff	-1.103	-2.000***	-1.411	
	(-1.14)	(-2.98)	(-1.49)	
log_CCI	3.883*	3.997*	3.221	2.478
	(1.72)	(1.98)	(1.46)	(1.25)
Ddec	0.639***	0.646***	0.650***	0.703***
	(2.94)	(3.08)	(3.09)	(3.74)
diff_models_BEV				0.000830
				(0.01)
price_diff				0.0684
				(0.37)
t				0.0556***
				(5.58)
Observ.	68	68	68	68
R^2	0.879	0.886	0.888	0.914
$Adj.R^2$	0.869	0.877	0.877	0.903

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A4: OLS regression results for PHEV in China without lagged dependent variable and alternative model specifications

	(1) log_ms_PHEV	(2) log_ms_PHEV	(3) log_ms_PHEV	(4) log_ms_PHEV
tax_ex	1.626***		1.626***	0.239
	(4.23)		(4.20)	(0.66)
rebate2		-0.0854	-0.000257	0.556**
		(-0.18)	(-0.00)	(2.23)
L.log_ms_PHEV				0.611***
				(6.47)
log_models_PHEV	1.335***	1.735***	1.335***	
	(10.42)	(6.76)	(5.32)	
log_price_diff	2.403***	0.193	2.403**	
	(2.72)	(0.22)	(2.56)	
log_CCI	-2.992	-1.276	-2.992	0.439
	(-1.22)	(-0.47)	(-1.20)	(0.21)
diff_models_BEV				0.0136
				(0.21)
price_diff				-0.0421
				(-0.32)
t				0.0141*
				(1.83)
Observ.	81	81	81	79
R^2	0.902	0.879	0.902	0.945
$Adj.R^2$	0.896	0.872	0.895	0.940

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A5: OLS regression results for BEV in the Netherlands without lagged dependent variable and alternative model specifications

	(1) log_ms_BEV	(2) log_ms_BEV	(3) log_ms_BEV	(4) log_ms_BEV	(5) log_ms_BEV	(6) log_ms_BEV	(7) log_ms_BEV	(8) log_ms_BEV
cc_BEV		-0.317	2.454***					
		(-0.78)	(8.45)					
cc_PHEV				0.0126			0.0188	-0.736*
				(0.04)			(0.05)	(-1.73)
BPM_PHEV					-0.647*		-0.719*	-0.859**
					(-1.73)		(-1.79)	(-2.02)
MRB_PHEV						-0.0315	0.160	-0.497
						(-0.11)	(0.52)	(-1.52)
L.log_ms_BEV		0.352***						0.321***
		(3.61)						(3.35)
log_models_BEV	2.255***			2.248***	2.629***	2.265***	2.610***	
	(14.64)			(8.87)	(9.95)	(12.60)	(7.83)	
log_price_diff	-3.267***	0.446	4.708***	-3.243***	-5.110***	-3.315***	-5.034***	
	(-3.64)	(0.54)	(5.16)	(-2.90)	(-3.69)	(-3.29)	(-3.26)	
CCI	0.00106	-0.00118	-0.0151	0.000879	0.00492	0.00112	0.00477	0.00545
	(0.14)	(-0.13)	(-1.25)	(0.10)	(0.63)	(0.15)	(0.51)	(0.60)
diff_models_BEV		0.355***						0.334***
		(2.75)						(2.65)
t		0.0376***						0.0607***
		(4.77)						(5.15)
price_diff								-1.634
								(-1.48)
Observ.	94	94	94	94	94	94	94	94
R^2	0.783	0.794	0.591	0.783	0.790	0.783	0.791	0.810
$Adj.R^2$	0.776	0.780	0.577	0.773	0.780	0.773	0.776	0.792

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A6: OLS regression results for PHEV in the Netherlands without lagged dependent variable and alternative model specifications

	(1) log_ms_PHEV	(2) log_ms_PHEV	(3) log_ms_PHEV	(4) log_ms_PHEV	(5) log_ms_PHEV	(6) log_ms_PHEV
cc_PHEV		-0.160			-1.565**	-1.277**
		(-0.21)			(-2.28)	(-2.64)
BPM_PHEV			-1.293*		-1.237*	-0.210
			(-1.77)		(-1.89)	(-0.47)
MRB_PHEV				-2.204***	-2.361***	-1.583***
				(-5.08)	(-5.38)	(-3.75)
L.log_ms_PHEV						0.518***
						(5.54)
log_models_PHEV	2.883***	2.948***	3.352***	3.401***	4.529***	
	(14.50)	(7.97)	(10.18)	(17.06)	(9.57)	
log_price_diff	8.928***	8.988***	6.131**	6.498***	4.237*	
	(4.51)	(4.46)	(2.44)	(3.67)	(1.97)	
CCI	-0.00121	0.00211	0.00426	-0.000809	0.0369*	-0.000267
	(-0.08)	(0.10)	(0.29)	(-0.06)	(1.90)	(-0.02)
diff_models_PHEV						0.00454
						(0.03)
price_diff						1.187
						(0.83)
t						0.0866***
						(4.54)
Observ.	75	75	75	75	75	72
R^2	0.758	0.758	0.768	0.823	0.839	0.906
$Adj.R^2$	0.747	0.744	0.755	0.813	0.825	0.894

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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