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Financial Purchase Incentives for Battery Electric Vehicles – A Review of the Evidence

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Summary

Plug-in electric vehicles (PEVs) are in an early stage of market entry. Nevertheless, there are now more than 1 million PEVs in use globally. PEVs result in lower energy consumption, greenhouse gas emissions and urban air pollution compared to internal combustion engine vehicles (ICEVs). For these reasons policy makers are eager to see PEVs purchased by consumers in larger numbers. Many policy makers have introduced financial purchase incentives to nurture the growth of PEV markets. These incentives range in value from around US$2,500 to US$20,000 per vehicle. Whether these incentives are effective in increasing PEV sales is not well understood at present. There are several studies that either directly consider the effectiveness of purchase incentives or at least include analysis of these incentives are part of a larger study. The results of these studies have not been assimilated in one place to gain an understanding of whether purchase incentives are effective in promoting PEV sales. This paper systematically reviews the literature with the aim of understanding whether purchase incentives are effective tools to increase PEV sales. In doing so this paper builds a deeper understanding of purchase incentives than has been possible before. This in-depth understanding allows recommendations to be made on how to design purchase incentives so that they are most effective in promoting PEV market growth. Incentives should be applied when someone is buying a PEV, not afterwards, incentives should promote BEVs more than PHEVs, VAT and purchase tax exemptions for PEVs are most effective, incentives should not be available on high-end BEVs (e.g Tesla Model S), education and awards campaigns should promotive incentives to consumers. Finally the premature removal of incentives could negatively affect PEVs therefore incentives should be designed with longevity in mind.

Keywords: Electric vehicles, policy, purchase incentives, literature review

1. Introduction

Plug-in electric vehicles (PEVs) are one solution to creating a transportation system that is more energy efficient, less polluting, and has greater energy security. Compared to the current transportation system which is dominated by gasoline and diesel internal combustion engine vehicles (ICEVs), PEVs are more efficient, produce zero tailpipe emissions, and have far greater well-to-wheel efficiencies (Stimming & Ramachandran 2015; Nordelöf et al. 2014; Offer et al. 2011). Many governments are eager to see PEVs adopted in greater numbers for these reasons. Some governments are using policy measures such as financial purchase incentives to encourage consumers to purchase PEVs over internal combustion engine vehicles (ICEVs). Research into the impact of these incentives on PEV sales has been ongoing since 2008. However, within the literature there is currently no single study that reviews this research to better understand under what conditions financial purchase incentives are an effective tool to increase PEV market shares. Previous reviews have covered purchase incentives along with benefits such as free parking, HOV lane access and infrastructure development along with other issues such as private motivations and the socio-economic profile of PEV buyers. These reviews do not take an in-depth look at financial purchase incentives meaning a thorough understanding of the issue does not yet exist. Furthermore, they do not contain recent studies that are the first to include evidence form the developing PEV markets. The aim of this paper is to review this literature in detail to understand the effectiveness of financial purchase incentives in the promotion of PEVs. The in-depth review considers all studies that investigate the impact of financial purchase incentives on the uptake of PEVs. Previous studies have reviewed literature mostly containing aggregate sales data which is unable to accurately detect reasons behind trends in the data. The early literature contained mostly choice experiments that aim to predict which factors may influence consumers to choose PEVs. These studies are less representative of actual purchase behaviour than questionnaires that survey consumers who have purchased a PEV. This review adds to the literature due to it containing these recently published studies, along with studies that use choice experiments and statistical analysis. This review therefore brings greater clarity to this topic than has previously been possible. The review contains studies that analyse different types of financial incentives in different regions. This review is therefore able to observe differences in the effectiveness of the different types of incentives and to detect common themes relating to incentive schemes which may have been picked up in individual studies but were not highlighted as significant factors. By detecting these nuances this review can make policy recommendations explicitly stating which purchase incentives are the most effective, how they should be administered, and which vehicle types should be targeted.

This review paper covers any literature that conducts empirical research on the impact of purchase incentives on PEV market uptake. This review does not include a financial analysis to discover whether purchase incentives reduce the price of PEVs so that they reach price parity with ICEVs. It also does not review any literature that use these kind of techniques, such as papers that use total cost of ownership (TCO) models to calculate whether PEVs are financially beneficial for consumers. These publications do not offer a full analysis of alternative fuel vehicle (AFV) purchase motivations. They focus on the cost difference and on the cost of technologies only. It has long been understood that consumers in general, and early adopters of technologies particularly, are not entirely economically rational in their decision behaviours. This has also been found to be true for the automotive sector, even for buyers of hybrid or electric vehicles (Turrentine & Kurani 2007; Hardman & Tal 2016). Consumers purchase PEVs for a variety of reasons including technological, performance, environmental and symbolic motivations (Hardman et al. 2016; Heffner et al. 2006; Caperello et al. 2015; Plötz et al. 2014; Axsen & Kurani 2013; Lane et al. 2014; Bühler et al. 2014). Some consumers have been found to purchase PEVs for financial reasons, though consumers do not undertake TCO calculations themselves. The impact of purchase incentives is more closely related to how consumers interact with price discounts or coupons. In the case of consumer products discounts increase interest in products, increase sales and increase perceptions of value (Grewal et al. 1998; Gupta & Cooper 1992). Therefore, purchase incentives do not attract consumers to PEVs due to them having calculated the financial savings they may or may not achieve. Consumers have been shown to be unable to make these kinds of forecasts and as a result they often make flawed or biased decisions (Thaler et al. 2012). However, according to Thaler et al. consumers can be ‘nudged’ to make a decision through changing the choice architecture around a decision. This is how purchase incentives attract car buyers to PEVs. As a result of the financial incentives consumers perceive PEVs as having greater value. Therefore, even though incentives have been designed to lower purchase prices of PEVs so

that their TCO is close to an ICEV their impact on the purchase decision is not related to consumers making economic calculations. This paper therefore explores the effectiveness of purchase incentives in encouraging consumer to purchase a PEV or in increasing PEV market shares. It does not consider why these incentives are effective or whether consumes will save money by purchasing a PEV.

1.1. Introduction to PEV Markets

PEVs include both battery electric vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). Both BEVs and PHEVs are more efficient and less polluting than ICEVs. PHEVs get their motive power from both an internal combustion engine (ICE), and the vehicles batteries and electric motor. They are a hybrid vehicle and their overall efficiency is lower than that of a BEV, but higher than a non-plug-in hybrid electric vehicle (HEV). BEVs are the most efficient vehicle type, their motive power comes only from their on-board batteries and electric motor. They have no ICE and therefore have zero tailpipe emissions. The most recent introduction of BEVs began around 2008 when Tesla introduced the Tesla Roadster. Although this vehicle was a low-volume vehicle, selling 2450 units between 2008-2012, it marked the start of the recent growth of BEV sales. The next significant market introduction was the Nissan Leaf BEV in 2010, after which many automotive original equipment manufacturer (OEMs) released vehicles to the market. More than 225,000 Nissan Leafs have now been sold. In 2011, the Chevrolet Volt PHEV was introduced. To date over 130,000 of these have been sold. In 2012, the Tesla Model S was introduced. Tesla have now delivered over 150,000 Model S BEVs making it the second best-selling PEV. Figure 1 shows the recent growth in all PEVs from 2012-2016. The chart includes BEV and PHEV sales. The chart shows a breakdown of PEV sales in the top 9 markets globally. These are China, USA, Japan, Netherlands, Norway, France, United Kingdom, Germany and Canada. China is seeing a more rapid growth in PEV sales than the US. During 2015 vehicle sales of PEVs in China overtook vehicle sales in the US making China the largest market for PEVs by volume. According to ICCT in January 2017 the size of the global PEV surpassed 2 million vehicles (Lutsey 2017).

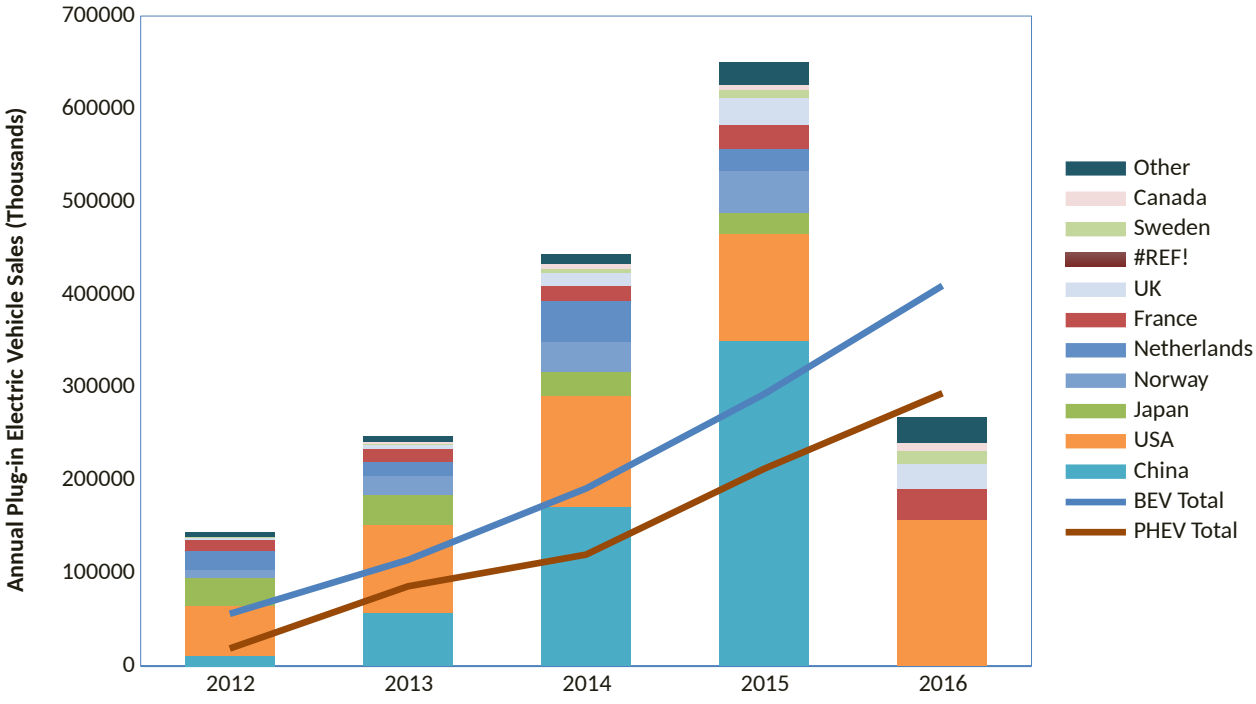

Figure 1: Global Battery Electric and Plug-in Hybrid Electric Vehicle Markets 2012-2016.

1.2. Introduction to Purchase Incentives

Purchase incentives take several different forms; they can be grouped into four different types of incentive. All incentives work towards the same common goal which is the reduction of the price consumers pay for a

PEV. The incentives are administered in several ways, some at the time of purchase and others after. The four types of incentive are:

- Point of Sale Grant Incentives- Point of sale grants reduce the purchase price of a BEV when a consumer buys the vehicle. These reductions come in the form of government purchase discounts or grants. These types of incentive are applied at the time of purchase. In the United Kingdom for example GBP£4,500 (US$5,800) is available off the purchase price of BEVs.
- VAT and Purchase Tax Exemptions- These exemptions allow buyers of BEVs to pay lower or zero VAT or pay no purchase tax that is applied to some vehicles. These types of incentives are applied at the time of purchase. In the Netherlands for example purchase tax is calculated based on the CO_2 emissions of the vehicles, whereas BEVs do not pay any tax. Buyers of ICEVs can pay anywhere between €1,000 (US$1,100) (Toyota Aygo) to over €20,000 (US$22,000) (Audi A8) in purchase taxes. These incentives reduce the upfront purchase price of PEVs in comparison to their ICEV counter parts. Some schemes use the additional revenue generated from high CO_2 emitting ICEVs to reduce the purchase price of BEVs by providing an additional rebate (e.g France). Schemes that use a combination of high VAT or purchase tax for ICEVs and rebates for PEVs are known as fee-bates.
- Post purchase rebates- Post purchase rebates come in the form of financial incentives being given to consumers after they have purchased the vehicle. This is usually in the form of a cheque. This means consumers receive a monetary payment after they have purchased a BEV. These incentives are used in several US states. In California BEV buyers can apply for a US$2,500 rebate and buyers of PHEVs a US$1,500 rebate.
- Income tax credits- These are the least common financial purchase incentive. These incentives allow buyers of BEVs to pay a reduced income tax bill at the end of the financial year. In the United States for example a US$7,500 credit is available for buyers of BEVs. This means that at the end of the financial year buyers can pay US$7,500 less in tax. If a buyer does not have a tax liability of this amount they can only claim up to the level of their liability, this means that not all buyers will claim back the full amount.

Table 1 shows a breakdown of these incentives by country for the top 9 markets for PEVs (as shown in Figure 1). The table shows the type of incentive and their total value in the local currency and standardised to US$. Canada offers point of sale incentives which are administered at the Provincial level. This means that PEVs do not receive incentives in all Canadian Provinces. The incentives are available in British Columbia, Quebec and Ontario. Between CA$5,000-8,500 is available. In China BEVs benefit from point of sale incentives and sales tax exemptions with up to US$9,800 being available. In France PEVs are exempt from purchase tax and can receive a total of €6,300 in incentives. In 2016, the German government introduced a €5,000 incentive for PEVs, this is 4/5 funded by the government and 1/5 funded by automotive OEMs. The incentive is only available on vehicles costing less than €60,000. In the Netherlands PEVs are exempt from sales tax which is calculated based on the cars CO_2 emissions. For an ICEV the sales tax can amount to a sum anywhere between €1,000 and to figures over €60,000 for vehicles with high CO_2 emissions. Typically, this figure is between €1,000 and €20,000 though. In Norway buyers of electric vehicles do not pay any VAT, which is 25% or purchase tax which can be 100% of the vehicles purchase price. In the United Kingdom, a GBP£4,500 grant is applied to the purchase price of any BEV at the point of sale. PHEVs receive a GBP£2,500 grant. PHEVs that cost more than GBP£60,000 (US$73,500) are not eligible. Finally, in the United States buyers of battery electric vehicles receive a US$7,500 federal tax credit. In some states, for example California, buyers of BEVs also receive a US$2,500 state rebate meaning a total of US$10,000 is available.

Table 1: Breakdown of purchase incentives for the top 9 markets for BEVs including the value of the incentives. Note: The value of incentives does not consider other incentives that are available when owning BEVs, for example free parking, or yearly tax exemptions, the table therefore only considers the value of incentives related to the purchase of a BEV.

	Point of sale Grant	Sales Tax and VAT Exemptions	Post Purchase Rebates	Income Tax Credits	Value of Incentives (Local Currency)	Value of Incentives (US$)
Canada	✓				CA$5,000-8,500[1]	US$3,850-6,850
China	✓	✓			CN¥65,000	US$9,800
France	✓	✓			€6,300	US$1,000-7,000
Germany	✓				€5,000	US$5,500
Japan	✓	✓			JP¥800,000	US$7,800
Netherlands		✓			€1,000-20,000[3]	US$1,110-22,000
Norway		✓	✓		90,000kr	US$11,000-20,000[4]
United Kingdom	✓				£4,500	US$5,800
United States			✓	✓	US$7,500-10,000[5]	US$7,500-10,000[5]

[1] Rebates in Canada are administered at the Provincial level and different incentives available between provinces

[2] Incentives differ between vehicle sizes, and whether a vehicle older than 13 years old is being scrapped. They also include a 2.4% VAT reduction.

[3] These estimates are based on the difference in sales tax paid for a BEV and an ICEV.

[4] Saving based on 25% Vat Exemption and Purchase Tax.

[5] Based on the US$7,500 federal tax credit and US$2,500 that is available in California

2. Method

The methodology used in this paper is one of a systematic review. A systematic review is a review that aims to answer a specific question. Some review papers work towards understanding an area of research more generally. Systematic reviews build on existing knowledge by understanding a specific issue. The issue that this paper aims to clarify is whether financial purchase incentives are effective in promoting PEV sales. Once the aim is defined specific search protocol are used to collect papers. The titles and abstracts of these papers are then reviewed to ensure the papers are relevant for this study. Irrelevant papers that are discarded from the study. Papers that are relevant are then reviewed in detail and the relevant information is extracted and recorded.

2.1. Scope

PEVs are the main consideration of this paper. PEVs include both PHEVs and BEVs. Some studies consider just PHEVs or BEVs whilst others consider both vehicles types. This paper also includes studies investigating whether purchase incentives were successful in promoting sales of hybrid electric vehicles (HEVs). Studies that investigate HEVs are included due to the similarities they have with BEVs and PHEVs. The vehicles are all new automotive technologies, with greater efficiencies, lower emissions than ICEVs and all vehicle types have benefited from financial incentives. The major difference is that HEVs cannot be plugged in. The PHEV, BEV and HEV papers must investigate financial purchase incentives to

be included in the study. They must also use an empirical methodology, therefore studies that present information based on authors opinions or anecdotal data are not included. Some papers explore only this topic whilst others consider financial purchase incentives as part of a wider study. For example, some studies consider all types of incentive, including incentives such as free parking for PEVs. Other studies investigate why people buy new automotive technologies. Studies that only consider financial purchase incentives and studies that explore them as part of a wider study are both included in this study.

2.2. Incentives Considered

This paper only includes one type of incentive related to PEVs. These are financial purchase incentives. The incentives are monetary and applied only when purchasing a PEV. The review therefore does not include incentives such as free parking, access to infrastructure, bus lane access, high occupancy vehicle (HOV) lane access, toll road access or any other benefits PEVs drivers receive when using their vehicles. Some of these incentives may be financial in nature but they are not applied at point of sale and are known as reoccurring or indirect incentives. This paper also does not include incentives offered by private companies. For example, some companies in the United States have incentivised employees to purchase BEVs, PHEVs or BEVs. Companies such as Google, Bank of America and Timberland have offered employees rebates up to a value of US$5,000 (Gallagher & Muehlegger 2011). Some utility companies also offer incentives to consumers who purchase PEVs. These are not considered here. Automotive OEMs have also incentivised consumers to purchase PEVs, often by offering vastly reduced lease deals. The effect these have is not considered here. Summary of Results & Discussion

The literature is consistent in finding that incentives are effective in promoting market growth of HEVs, PHEVs and BEVs. There are only 3 exceptions to this (figure 1). There are reasons why the 3 studies found this not to be true. 2 of studies uses statistical analysis to understand which variables have the strongest correlation to PEV market growth. Another study gathered data from people who had not purchased a HEV or PEV and found that incentives are not effective because people are not aware of them. 31 studies found that purchase incentives are an effective method in increasing HEV and PEV market shares. These studies come to similar conclusions and use a variety of methods including statistical analysis and questionnaire surveys with consumer who have purchased a HEV or PEV.

3. Literature Review

In total 35 different studies that investigate the effect of financial purchase incentives on PEV adoption were identified and are included in this review. These studies mostly consist of data gathering using questionnaire surveys or analysis of PEV market data to understand the relationship between PEV sales and financial purchase incentives. There are 12 studies that use questionnaire survey or interview data and 13 studies that analyse PEV market data. There are 10 studies that use other methodologies including qualitative analyses or literature or policy reviews, most of which are white papers. Some of these studies consider only the impact of the financial purchase incentives. Most studies though include the importance of purchase incentives only as part of their analysis. These studies consider other aspects related to PEV adoption which are not considered in this review. Table 2 shows the literature that are included in this review. The table shows; the authors of each study, the methods they use, the vehicle types they cover (HEV, PHEV or BEV), the region they are investigating, the type of incentive they are analysing and the value of the incentives considered. Finally, the table shows a brief summation of the conclusions of each paper and whether the studies find purchase incentives to be effective in increasing PEV sale or not. Some cells are blank because the papers do not specify the region they are analysing, the incentives they are considering or the value of them.

Authors	Methods	Vehicle Type	Region	Incentive Type	Total Incentive Value	Conclusions	Are incentives effective?
(Aasness & Odeck 2015)	PEV Market Analysis	BEV	Norway	VAT Exemption, Registration Tax Exemption		VAT and registration tax exemptions are effective in increasing PEV sales. Toll fee waivers, free parking and bus lane access are also a factor.	Yes
(Berestenau & Li 2008)	PEV Market Analysis	HEV	USA	Federal Tax Credit	US$3,400	Financial incentives did increase rates of adoption for HEVs. Petrol prices are also an important factor.	Yes
(Bjerkan et al. 2016)	Questionnaire Survey	BEV	Norway	Vehicle Registration Tax Exemption and VAT Exemption	US$6,000-70,000	VAT and purchase price reductions are the strongest incentives for encouraging BEV adoption. Bus lane access and toll exemptions are also important factors.	Yes
(Center for Sustainable Energy 2016)	Questionnaire Survey	BEV	California	Federal Tax Credit and California State Rebate	US$10,000	The federal tax credit and the state rebate have been effective in promoting PEV market development.	Yes
(Clinton et al. 2015)	PEV Market Analysis	BEV	USA	Federal Tax Credit and State Rebates	US$10,000	Financial incentives and the presence of recharging infrastructure both correlated to BEV market update.	Yes
(Collantes & Eggert 2014)	Review	BEV & PHEV	USA	Federal Tax Credit and State Rebates	US$10,000	Financial incentives are effective in supporting the early market, however they need to be properly designed and communicated to consumers.	Yes
(DeShazo 2016)	Review	BEV, PHEV & HEV	California	Federal Tax Credit and California State Rebate	US$10,000	Incentives are effective, but inefficient. Incentives should be applied at point of sale, rather than as a rebate or tax credit. Incentives should be higher for BEVs than PHEVs.	Yes
(DeShazo et al. 2014)	Questionnaire Survey	BEV & PHEV	California	California State Rebate	US$2,500	Current incentives are inefficient. It is possible to design more efficient incentives that reduce budget costs but maintain the size of the BEV market. It is also possible to maintain budget size but develop more effective incentives to increase rates of adoption.	Yes
(Diamond 2009)	PEV Market Analysis	HEV	USA	Federal Tax Credit and State Rebates	US$2,000-6,000	No relationship between incentives and HEV adoption. Adoption is related to vehicle mileage, petrol prices and income. Incentives that provide money upfront may be more effective.	No
(Fearnley et al. 2015)	Questionnaire Survey	BEV	Norway and Austria	VAT Exemption, Registration Tax Exemption		Incentives are effective in increasing electric vehicle markets Bus lane access is also effective and low cost but can have a negative impact on bus journey times.	Yes
(Figenbaum &	Questionnaire	BEV	Norway	VAT Exemption, Registration		Incentives have played a large role in the diffusion of BEVs in Norway. Free	Yes

Kolbenstvedt 2016)	Survey			Tax Exemption		parking, bus lane use, free toll road use and reduced rates on ferries have also had an impact.	
(Gallagher & Muehlegger 2011)	PEV Market Analysis	HEV	USA	Federal Tax Credit and State Rebates	US$2,000-6,500	Financial incentives did increase rates of adoption for HEVs. Petrol prices are also an important factor.	Yes
(Green et al. 2014)	Communication	BEV & PHEV	USA			Incentives are inefficient and costly at present. They need to be more targeted.	Yes
(Hardman & Tal 2016)	Interviews	BEV	California	Federal Tax Credit and California State Rebate	US$10,000	Incentives not important for purchases or high end BEVs. They are effective for low-end BEVs though.	Yes
(Helveston et al. 2015)	Questionnaire Survey	BEV & PHEV	USA & China	Hypothetical Subsidies	US$0-20,000	Subsidies increase rates of adoption for PHEVs and BEVs. BEVs may need larger subsidies than PHEVs.	Yes
(International Energy Agency 2016)	Review	BEV & PHEV	Global			The presence of financial purchase incentives is correlated to high BEV market shares. The presence of charging infrastructure is also an important factor.	Yes
(Jenn et al. 2013)	PEV Market Analysis	HEV	USA	Federal Tax Credit	US$7,500	Financial incentives have increased rates of adoption for HEVs. Incentives are only effective is they are larger than US$1,000.	Yes
(Jin et al. 2014)	PEV Market Analysis	BEV & PHEV	USA	State Rebates	US$2,000-6,000	Financial incentives increase rates of adoption of BEVs. However, some regions have high incentives but low market shares of BEVs.	Yes
(Kurani et al. 2016)	Questionnaire Survey	BEV & PHEV	USA	Federal Tax Credit	US$7,500	Purchase incentives increase likelihood of purchase only for consumers who are aware of PEVs.	Yes
(Krause et al. 2013)	Questionnaire Survey	BEV & PHEV	USA	Federal Tax Credit and State Rebates	US$10,000	Most consumers are not aware of the current policies and incentives that are available. This means policies have a negligible impact on mainstream vehicle buyers.	No
(Langbroek et al. 2016)	Questionnaire Survey	BEV	Sweden	Various hypothetical incentives	US$4,340 (40,000 SEK)	Financial Incentives do increase rates of adoption. Free parking and bus lane access also has an impact.	Yes
(Larson et al. 2014)	Questionnaire Survey	BEV	Canada			Financial incentives are important in reducing purchase prices for consumers.	Yes
(Lutsey et al. 2015)	PEV Market Analysis	BEV & PHEV	USA	State Rebates	US$2,000-6,000	Financial incentives do increase rates of adoption. Automotive OEM marketing activities may also be a factor.	Yes
(Mersky et al. 2016)	PEV Market Analysis	BEV	Norway	Vehicle Registration Tax Exemption and VAT Exemption	US$6,000-70,000	Access to charging infrastructure, being near to major cities and household income are related to the adoption of BEVs.	No

(Mock & Yang 2014)	PEV Market Analysis	BEV & PHEV	Global			Incentives are a powerful tool to entice people to purchase a BEV or PHEV. They are effective for both private car buyers and company car buyers.	Yes
(Nilsson & Nykvist 2015)	Modelling	BEV				Incentives, experience and familiarisation are all key factors in driving the transition to BEVs.	Yes
(Sheldon et al. 2016)	Questionnaire Survey	BEV & PHEV	USA			Incentives enable the gap between willingness to pay for a PHEV or BEV and their actual purchase price to be reduced. Existing incentives may encourage more PHEV adoption rather than BEV adoption.	Yes
(Sierzchula et al. 2014)	PEV Market Analysis	BEV & PHEV	Global			Financial Incentives do increase rates of adoption. Access to infrastructure is also related to adoption rates.	Yes
(Silvia & Krause 2016)	Modelling	BEV & PHEV	USA			Financial incentives have increased rates of adoption of BEVs by 300%.	Yes
(Slowik & Lutsey 2016)	PEV Market Analysis	BEV & PHEV	Global			Incentives have been successful in increasing early market growth. Incentives should be phased out over time as vehicle costs fall. Feebate or polluter pays schemes may are preferential.	Yes
(Tal & Nicholas 2016)	Questionnaire Survey	BEV & PHEV	USA	Federal Tax Credit	US$7,500	More than 30% of PHEV and BEV sales can be attributed to the federal tax credit. Some vehicles not reliant on tax credit though, especially Tesla BEVs and some PHEVs.	Yes
(Trl 2014)	Review	BEV, PHEV & HEV	Not specified			Financial incentives are important are effective policy interventions. Fuel prices may be more important though.	Yes
(Vergis and Chen, 2015)	PEV Market Analysis	BEV & PHEV	USA	State Rebates	US$2,000-6,000	Incentives are more important for buyers of PHEVs than BEVs. BEV market is related to education and awareness of BEVs, the presence of recharging infrastructure and gas and electricity costs.	Yes
(Zhou et al. 2014)	Review of Policies	HEV, BEV & PHEV	Global			Countries with higher BEV adoption rates have higher purchase incentives. Non-financial incentives are also important though.	Yes
(Zhou et al. 2016)	Review	BEV & PHEV	Global			Financial incentives are effective in increasing PEV markets. They should be paired with other incentives. Developing charging infrastructure is critical for PEV market development.	Yes

Table 2: Breakdown of literature that investigates the relationship between PEV or HEV adoption and financial incentives.

Studies investigating HEVs found that purchase incentives did increase rates of adoption. A caveat to this is that for incentives to be effective they should be sufficiently large. Jenn et al suggest that incentives for HEVs need to be a minimum of US$1,000 to influence the market. HEV market growth was also related to high petrol prices and high household incomes. One study found that incentives for HEVs were not effective (Diamond 2009). This study used statistical analysis of market data to reveal that HEV market growth was better correlated to high petrol prices and high income. The authors were unable to find any statistically significant relationships between HEV market growth and the presence of purchase incentives.

Studies investigating the market introduction of PHEVs and BEVs have found that incentives have been effective in increasing the market for these vehicle types. Whilst this is the prevailing sentiment many studies have revealed deficiencies with the incentives or ways in which they could be made more efficient or effective. These issues are discussed below along with how they could be solved. Evidence from (Gallagher & Muehlegger 2011; Zhou et al. 2014; DeShazo 2016) shows that the federal tax credit is inefficient. Data from (Center for Sustainable Energy 2016) supports these findings, they found that consumers rank the US$2,500 California rebate and the US$7,500 tax credit equally. The evidence indicates that rebates are more effective than tax credits. The literature does not suggest an explanation for this but it could be due a phenomenon known to behavioural economists as ‘Hyperbolic Discounting’. This is where consumers are known to value smaller-sooner rewards over larger-later rewards. The rebate is received sooner than the federal tax credit. Point of sale grants and sales tax and VAT exemptions for BEVs have been found to be the most effective. They are especially effective when sales tax and VAT are high for ICEVs. This is the case in Norway and the Netherlands. In the USA, transitioning the federal incentive from a tax credit to a rebate, VAT or tax exemption or grant has the potential to improve the effectiveness of the US federal incentive. It could also be more cost effective to supply the federal incentive at a lower amount closer to or at the time of vehicle purchase. Overall policy makers should look to introduce purchase incentives that are applied at the point of sale, rather than after the vehicle has been purchased. (Yang et al. 2016) came to similar conclusions in their analysis of different PEV policies. Of the invectives that are applied at/or close to the point of sale, rebates may be the least preferable. Rebates provide consumers with a cash payment after they have purchased their vehicles. Grants and tax or VAT exemptions assist consumers in the purchase of a BEV at the time of purchase, rather than providing ‘cash back’ after purchase. If rebates are used consumers still need to have the financial ability to initially purchase the vehicle. Rebates therefore may be effective in promoting BEV markets for higher income households, but not for household who could not afford the purchase price of a PEV.

Some incentives may cause consumers to preferentially selected PHEVs over BEVs. (Slowik & Lutsey 2016; Vergis & Chen 2015; Sheldon et al. 2016; DeShazo 2016) state that current incentives promote PHEV sales over BEV sales. This could be detrimental especially when consumers purchase PHEVs with low electric ranges. Households with PHEVs with ranges of 10 miles only use the electric range for 15% of their household’s mileage. PHEVs with ranges of 20 miles only use the eclectic range for 25% of their household mileage. This is a low share of electric miles. Households with PHEVs with ranges of 36-53 miles drive 45% of their household’s mileage on electric range. This figure is higher than it is for drivers of BEVs with 73-105 miles of range. Drivers of BEVs with 73-105 miles of range drive 43% of their household mileage using the electric range of their BEV (Nicholas et al. 2016). This data suggests that PHEVs with ranges of more than 36 miles could achieve the same benefits as BEVs. Therefor PHEVs with longer electric ranges should receive similar incentives as BEVs. PHEVs with low ranges, perhaps less than 30 miles, should receive a lower incentive. This is due to them having lower energy efficiency and emissions benefits. Some policies are already in place that incentivise BEVs more than PHEVs, for example in United Kingdom, Norway, California and France. Some markets offer the same level of incentive for a PHEV or a BEV. Policy makers should adjust these incentive programs so that BEVs receive a higher financial incentive than PHEVs with low driving ranges. For PHEVs, purchase incentives should be offered at different levels depending on the range of the PHEV.

Two studies have found that purchase incentives are important for low-end BEVs, such as the Nissan Leaf but are not important for high-end BEVs such as the Tesla BEVs which cost in the region of US$68,000-135,000. Studies by (Tal & Nicholas 2016; Hardman & Tal 2016) used different sets of data and methodologies but came to this same conclusion. High-end BEV markets are not dependent upon financial purchase incentives. Adopters of these BEVs have exceptionally high incomes and are motivated

for factors beyond financial reasons, such as performance, technological and environmental preferences. In November 2016, changes to the California clean vehicle rebate came into effect. High income earners [1] are no longer eligible for the rebate. Low-income earners now get an additional US$2,000 on top of the US$2,500 rebate. In the United Kingdom PHEVs costing more than GBP£60,000 are not eligible for the plug-in car grant. BEVs costing more than GBP£60,000 are still eligible though. These exemptions could be expanded so that high-end BEV buyers do not receive the same level of incentive as low-end BEV buyers or high-end BEV adopters could receive a smaller incentive than low-end BEV adopters. A smaller incentive may be preferable than having no incentive as the studies by Hardman & Tal and Tal & Nicholas did detect that the incentives were still slightly important. The presence of the incentive will also give consumers a signal that they are making a socially responsible decision.

Studies have found that consumers are not aware that purchase incentives exist for PHEVs or BEVs (Krause et al. 2013; Vergis & Chen 2015; Kurani et al. 2016). This can result in incentives having a lower impact on the market. When any new technology is introduced awareness and rates of adoption are positively correlated (Rogers 2003). Low levels of awareness of financial purchase incentives for PEVs will results in lower rates of PEV adoption. When policy makers introduce incentives, they should also initiate education and awareness campaigns. These campaigns should raise awareness amongst car buyers that financial incentives are available when purchasing a PEV. They should also raise awareness of PEVs in general.

Several studies demonstrated the importance of purchase incentives for PEV buyers. At present purchase incentives are a significant determining factor in the purchase of a PEV (Hardman & Tal 2016; Tal & Nicholas 2016; Bjerkan et al. 2016; Center for Sustainable Energy 2016; Figenbaum & Kolbenstvedt 2016). The removal of incentives could have a negative impact on the market for the vehicles. Policy makers should seek to introductive policies that will be able to last. Incentives such as rebates and grants may lack longevity. This is due to budgetary constraints resulting from no direct source of revenue available to fund the schemes. Incentive schemes such as feebates have the potential to last far longer as the incentives for PEVs can be funded from additional revenue generated from high emitting ICEVs. Over time the purchase tax for ICEVs can be increased to dissuade consumers from buying ICEVs. This revenue is used to fund rebates for PEVs. At the beginning of a feebate scheme PEVs should receive larger rebates and as their market share increases this should be gradually reduced over time. Eventually PEVs may receive no rebates, but will pay zero tax. ICEVs will pay high tax meaning a price differential still exists which will continue to incentivise consumers to adopt PEVs.

1 US$150,000 for single filers, US$204,000 for head of household filers, US$300,000 for joint filers.

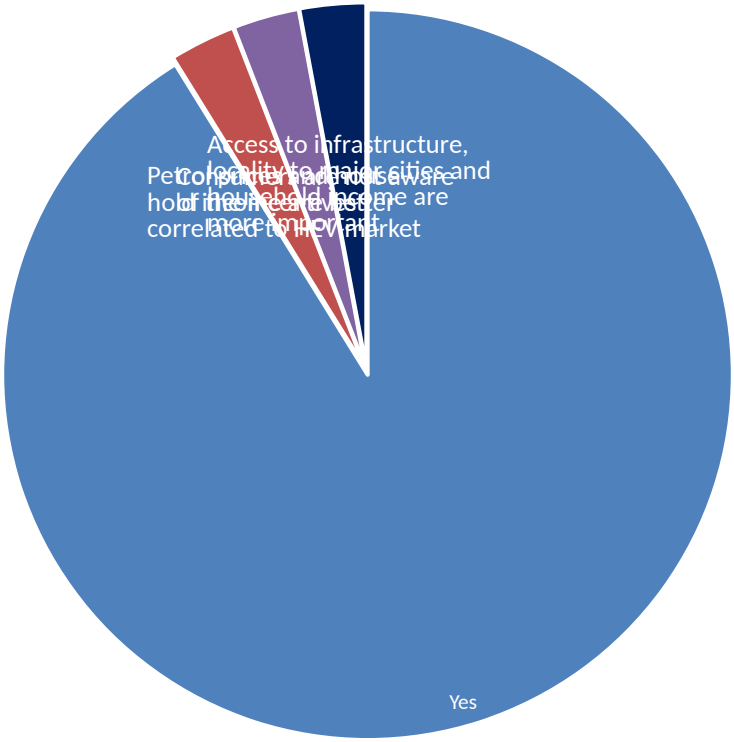

Figure 2: Summery of literature that explores the effectiveness of financial purchase incentives in promoting the growth of HEV, PHEV and BEV markets. The expanded portion of the chart shows the reasons why a small number of studies found the incentives to not be effective (n=34).

4. Conclusion

Studies conducting statistical analysis of market data using both aggregate and disaggregate data have found that purchase incentives are correlated to PEV market shares. Further to this studies that use choice experiments have found that consumers are more likely to purchase a PEV if purchase incentives are available. None of these types of study actually ask consumers who have purchased a PEV whether the incentives were an important factor in their purchase decision. Fortunately, there are studies that that use post PEV purchase surveys to understand actual consumer purchase behaviours and have found that purchase incentives are important for buyers of PEVs. Due to the abundance of literature using diverse methodologies this literature review can confidently state that PEV incentives are an effective policy measure in increasing PEV sales. Policy makes wishing to reduce transportation related emissions can use purchase incentives to increase PEV sales.

4.1. Policy Recommendations

By reviewing research that assesses different types of purchase incentive this paper can make recommendations on the most effective ones. Purchase incentives should be applied upfront as a grant or as a VAT or purchase tax exemption. Tax credits have lower affectivity; these are the least effective incentives in changing the purchase decisions. However, they do still have an impact and should not be removed without an alternative subsidy being introduced. VAT or purchase tax exemptions should be employed in combination with high VAT or purchase tax for ICEVs. This system is already employed in some nations, for example Norway, Netherlands and France. The benefit of this type of system is that increased revenue from high taxation on ICEVs can be used to fund PEV incentive schemes. This system may be able to last far longer than a rebate, grant or federal tax program. Nevertheless, this system could be unfavourable due to political reasons, in which case PEV grants applied at the point of sale should be used. Such a system

currently operated in the United Kingdom. Incentive schemes should distinguish between low-end BEVs, high-end BEVs, short range PHEVs and long range PHEVs. Low-end BEVs should receive a higher incentive than high-end BEVs which should receive a small incentive. Long range PHEVs should receive an incentive similar to that of low-end BEVs due to them having similar environmental and energy benefits. short range PHEVs should receive a far smaller incentive due to them only having low environmental and energy benefits due to their small batteries which result in low electric driving ranges. The removal of grants too early in the introduction of PEVs would have a negative impact, ideally purchase incentives will be able to support early adopters and the early majority of PEV buyers. Once market penetration has reached the late majority of consumers it may be possible to begin reducing incentives whilst not effecting PEV market development. When incentive schemes are introduced education and awareness schemes should promote both BEVs and the nature of the purchase incentives. This will ensure incentives have a significant impact and do not go unnoticed by new car buyers. Finally, this review did not include other incentives such as HOV lane access, free parking, infrastructure etc. these incentives are still important considerations for policy makers. For incentive schemes to have the greatest impact of PEV sales they should be introduced alongside non-monetary and non-purchase incentives. The effectiveness of each of these incentives is not currently known and this it is the topic of a future review.

4.2. Future Research

In this review the effectiveness of incentives other than purchase incentives was not included. The review did not explore other reasons for PEV adoption, such as personal motivations. The benefit of this specific approach is an in-depth understanding of financial purchase incentives. Other incentive types though may also help promotive PEV sales. A future review will take an in-depth look at literature that studies the impact of non-financial incentives (e.g HOV lane access), reoccurring incentives (e.g yearly taxes) and other incentives (e.g free parking, toll road use). This review will develop an understanding of what additional incentives policy makers can introduce to nurture PEV market growth. The value of purchase incentives is usually between US$2,500 and US$20,000. No research has been undertaken to understand what value purchase incentives should be. Future research should look to calculate what value of incentive will have the greatest cost to benefit ratio. This will allow policy makers to decide what value of incentive they should offer to growth PEV markets most effectively. The existing literature concentrates heavily on the USA and especially California. Future studies should look to investigate regions where PEV incentives have not been investigated as thoroughly, for example the United Kingdom. Finally, some incentives schemes will not be able to last indefinitely, for example, the US federal tax credit has a cap to 200,000 vehicles per OEM, after which the incentives are phased out for that OEM. This means it may expire for high volume manufactures before 2020. In the UK, the plug-in car grant is only scheduled to run until 2018. An important research question is when can incentives be removed without this having a negative impact on PEV market growth. This will help policy makers understand how long they will need to run incentive programs for. This review did not include purchase motivations other than incentives. Consumers will also have private or personal motivations associated with the purchase of a PEV. This is an ongoing research area although no study has summarised this literature to understand personal or private motivations that attract consumers to PEVs. A future review should therefore aim to understand why consumer purchase PEVs. Most studies do not make distinctions between PHEVs and BEVs. Both vehicle types are significantly different and the literature has shown that consumers perceive these vehicles differently. They also use different sources of energy to power propulsion. Therefore, the policy implications of each vehicle type will be different. All future studies should make distinctions between PHEVs and BEVs to obtain more relevant results for each vehicle type. Finally future studies should consider the impact of purchase incentives on low-end BEVs with 200 miles of rang. This type of vehicle is now in production, is being purchased by consumers, and more OEMs are expected to introduce low cost 200 mile BEVs to the market.

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