UNIVERSITY OF CALIFORNIA

An Examination of the Impact That Electric Vehicle Incentives Have on Consumer Purchase Decisions Over Time

A Research Report from the University of California Institute of Transportation Studies

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16. Abstract

We investigate the impacts of a combination of incentives on the purchase decisions of electric vehicle (EV) buyers in California from 2010 through 2017. We employ a comprehensive survey on over 14,000 purchasers of EVs in California. The survey covers a range of purchase intentions, general demographics, and the importance of various incentives. Our results indicate that the most important incentives for plug-in electric vehicle (PEV) owners are the federal tax credit, the state rebate, and HOV lane access. In addition, the importance of the incentives and their associated effect on purchase behaviour has been changing over time: respondents are more likely to change their decisions and to not buy a vehicle at all as time passes and the technology moves away from early adopters.

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Executive Summary

We investigate the impacts of a combination of incentives on the purchase decision of electric vehicle buyers in California from 2010 through 2017. We employ a comprehensive survey of over 14,000 purchasers of electric vehicles in California. The survey covers a range of purchase intentions, general demographics, and the importance of various incentives. Our results indicate that the most important incentives for plug-in electric vehicle (PEV) owners are the federal tax credit, state rebate, and HOV lane access. In addition, the importance of the incentives and their associated effect on purchase behavior has been changing over time: respondents are more likely to change their decision and m to not buy a vehicle at all as time passes and the technology moves away from early adopters. This indicates that incentives are increasingly import over time and specifically more important for buyers in 2017 than they were in 2010.

Introduction

Over the last decade, the market share of plug-in electric vehicles (PEVs, which include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)) has been gradually increasing across the world. This relatively new technology shifts energy usage in the light-duty transportation sector away from gasoline and towards electricity. Policy makers have been motivated to increase PEV sales due to their potential to reduce urban air pollution and decarbonize road transportation. As a result, a number of policy mechanisms (both regulatory and market-based) have been applied in an attempt to spur the adoption of the new technology. In the United States, California remains a leader in the push for the technology. The state requires the sale of electric vehicles through the Zero Emission Vehicle (ZEV) mandate, which requires automakers to sell a portion of their vehicles as PEVs or fuel cell vehicles. Additionally, the state provides a number of large incentives, such as the Clean Vehicle Rebate Program (CVRP) and high-occupancy vehicle lane stickers (HOV access stickers), on top of the federal incentive for electric vehicle purchases.

The aim of this paper is to provide insights into the importance of incentives. This is the first study to use multi-year post-purchase survey data to examine the influence of incentives on the decision to purchase a vehicle. While other studies have examined the impact of incentives on adoption of electric vehicles, our work is the first to examine the heterogeneity of actual PEV owners and classify them with latent profile analyses. In addition, this study leverages the multi-year aspect of the survey to understand how the importance of incentives has been changing over time. These two focuses of our study directly address critical policy questions related to incentives: 1) how incentive policy can be structured to target specific populations, and 2) when should incentives for PEVs expire so that expiration minimally affects PEV adoption.

Introduction to Incentives

Incentives are being used to promote PEV sales in many regions. Incentives can be grouped into two categories, those that are applied to the purchase of the vehicle (purchase incentives) and those that are received during ownership of the vehicle (reoccurring incentives). This study focuses on purchase incentives and on one reoccurring incentive; high-occupancy vehicle (HOV) lane access.

Purchase incentives are intended to reduce the purchase price of a PEV. These incentives are applied in different ways. In all states of the U.S. buyers of PEVs receive a federal tax credit of up to $7,500 when they purchase an eligible vehicle. This incentive is received by consumers when they file their tax returns after the financial year in which they purchase their PEV. The maximum value of the incentive is dependent on the size of the battery in the PEV and whether the applicant has a tax liability of at least $7,500. In some states, buyers receive state rebates. In California, car buyers typically receive $2,500 when they purchase a BEV (California Clean Vehicle Rebate Project, 2017). This incentive is received by car buyers when they apply for the rebate after purchasing their vehicle; they often receive this incentive via a bank check.

Recurring incentives differ from purchase incentives as they are often received throughout the entire period of PEV ownership. Incentives can include free or discounted parking, access to restricted lanes, free charging, road toll exemptions, or annual road fee exemptions. Of interest particular in this study was access to high occupancy vehicle (HOV) lanes, because this incentive was available throughout the area of study. California, Maryland, Colorado, Arizona, Florida, New Jersey, New York, Tennessee, Utah, and Virginia are among states that have HOV lanes with exemptions that allow PHEVs or BEVs to drive in the lanes with a single occupant in the vehicle. This can be beneficial to PEV drivers who reside in regions with HOV lanes, and it may reduce traffic congestion.

Table 1. Details of the CVRP, federal tax credit, and HOV lane access for PEVs.

Incentive	Information
Clean Vehicle Rebate Project (CVRP)	• Rebates are provided to buyers of PEVs in the form of a check after they purchase the vehicles and after they apply for the rebate • Provides a $2,500 for buyers of BEVs • Provides a $1,500 for buyers of PHEVs • Includes a $1,500 additional rebate for low income households
Plug-In Electric Drive Vehicle Credit (Federal Tax Credit)	• Provides a tax credit to buyers of BEVs, fuel cell vehicles, and PHEVs of $2,500 to $7,500 • The value of the credit depends on the kWh size of the PEV battery • The credit is claimed from the federal Internal Revenue Service when filing a tax return.
High Occupancy Vehicle (HOV) Lane Access	• Allows BEVs and fuel cell vehicles with White Clean Air Vehicle Decals to drive in HOV lanes until January 1, 2019 • Allows PHEVs with Green Clean Air Vehicle Decals to drive in HOV lanes until January 1, 2019

Literature Review

There is a wide body of literature on the impact of incentives on the adoption of new technology vehicles (such as PEVs). The earliest studies examining these policies were either qualitative in nature (Bakker and Trip) or were part of larger choice models that looked at adoption as a whole (Hackbarth and Madlener). Sierzchula et al. is the first study focused specifically on understanding the effect of financial incentives. The authors measure this econometrically and find a fairly low elasticity with a $1000 incentive corresponding to just 0.06% increase in market share. The use of more sophisticated data, methodologies, and longer time frames of study has led to a confluence of research that find relative agreement in price elasticities: Vergis's econometric approach treating incentives holistically showed a 22% increase in market share attributed to the purchase incentive (Vergis and Chen); DeShazo's focus on the California CVRP revealed 7% increase in PEV market share corresponding to an average $1,838 incentives (DeShazo, Sheldon and Carson); Tal's survey-based study of federal incentives found a 32.5% increase corresponding to the $7,500 incentive (Tal and Nicholas); and Jenn's panel study of incentives coupled with knowledge of the technology and incentives revealed a 2.6% increase in sales corresponding to $1,000 in incentives (Jenn, Springel and Gopal). While these studies have some variation in their results, these can likely be attributed to differences in modeling approaches as well as discrepancies in region and the time period of examination. Hardman et al. provides a more comprehensive review of these purchase incentive effects (Hardman, Chandan and Tal), and finds general agreement in the magnitude of the incentive effects. There has also been some work to understand the differences in how a purchase incentive is structured and, for example, how a point-of-sale incentive can be more effective than a rebate credit (Matthews, Lynes and Riemer).

In addition to the previously mentioned studies that focus primarily on PEV sales in the United States, several studies have also been published on other strong electric vehicle markets such as Norway and China. Both Aaness et al. and Figenbaum et al. provide qualitative and comprehensive overviews on the importance of incentives in Norway and Europe (Aasness and Odeck; Figenbaum, Fearnley and Pfaffenbichler). Others have attempted to measure elasticities with methods comparable to the U.S. studies: Langbroek finds a range of elasticities from −0.03 to −0.04 (Langbroek, Franklin and Susilo) while Zhang et al. identifies heterogeneity in elasticities, with higher income buyers having smaller magnitude elasticities than lower income buyers (Zhang, Qian and Sprei). In China, the incentives with the largest impact on market share are from restriction policies with exemptions for PEVs. A number of studies have found that these policies are strong contributors to adoption: a 1% suppressed demand leads to a 1.2% increase in PEV market share (Ma, Fan and Feng); a Beijing restriction policy led to a 38.7% increase in PEVs; a Shanghai license cap led to a 51.9% increase in PEVs (Wang, Pan and Zheng); and a corresponding willingness to pay for getting around the restriction (which is construed to be equivalent to adopting a PEV) of 100,000-120,000 CNY. While these incentives are not strictly analogous to the purchase incentives commonly seen in the U.S., they provide important points of comparison in understanding the relative effectiveness of different types of policy levers.

Our study seeks to contribute to the rich literature on the impact of incentives. In particular, we provide, first, a more detailed approach in characterizing the heterogeneity in the adoption of PEVs across different groups of consumers in California and, second, an analysis on the importance of incentives over time in order to understand whether these effects have been changing over the last decade.

Data and Methods

Survey Description

The Plug-in Hybrid & Electric Vehicle (PH&EV) Center, part of the Institute of Transportation Studies at the University of California, Davis has been conducting a cohort survey of electric vehicle owners in California every year over the last four years (2015-2018). For the purposes of this study, we include phases 1-3 of the survey effort:

- Phase 1-1.5: Purchasers of electric vehicles from 2010-2015
- Phase 2-2.5: Purchasers of electric vehicles from 2015-2016
- Phase 3: Purchasers of electric vehicles from 2016-2017

The respondents to the survey are selected from the California Clean Vehicle Rebate Project (CVRP), a rebate program for purchasers and leasers of electric vehicles within California. The CVRP is administered by the Center for Sustainable Energy, which has an agreement with the University to provide contacts (e-mail) for solicitation for the purposes of disseminating and gathering respondents for the survey. Altogether, phases 1-3 include 15,275 respondents, all of whom had applied for the CVRP rebate following the purchase or lease of a plug-in electric vehicle (PEV).

One unique contribution of our survey analysis is the ability to provide a greater level of insight into claims for PEV incentives. In Figure 1, we reveal that the actual price paid for the vehicle (post-CVRP incentive) varies quite dramatically. This variation is in turn due to variations in the following: prices for different trim configurations for identical models, local dealership offers, negotiations on sticker price, and fees in different regions. A relatively large number of respondents attempted to claim CVRP but were denied due to eligibility reasons (their income was too high). Since the CVRP is a post-purchase rebate, lack of knowledge on eligibility may lead to increased PEV sales by persons who did not know they were ineligible at the time of purchase. Even in the absence of the incentive, we find that the majority of consumers are paying less than sticker price for their vehicles.

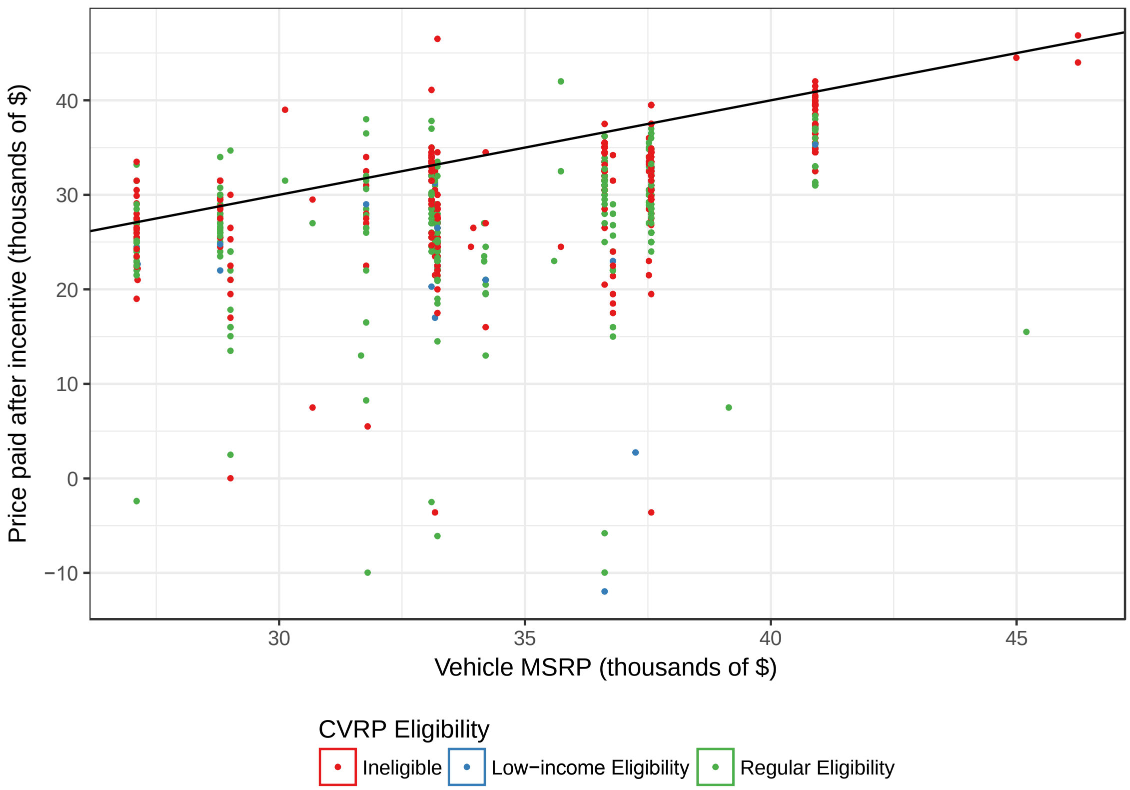

Figure 1. The electric vehicle MSRP of vehicles (by trim) owned by survey respondents in the 2017 survey versus what they paid for them after factoring both the federal tax credit and the CVRP rebate. The eligibility of respondents who applied for a rebate is denoted by the color of each point, with red indicating ineligibility due to household income, and green and blue points indicating regular eligibility and low-income eligibility (higher rebate amounts), respectively.

We also observed among survey respondents an inconsistency in the federal credit received. Since the federal credit can be entered manually, we find that several respondents are able to claim a higher amount than should be awarded. In **Figure 2** below, the straight line indicates the federal credit that should have been awarded. While the clear majority of federal credits received are correct (i.e., lie on this line), some receive more credit (illegitimate) and some receive less credit (likely due to maxing out their tax liability). These discrepancies with the correct credit point to inconsistencies in the value of the credit for consumers.

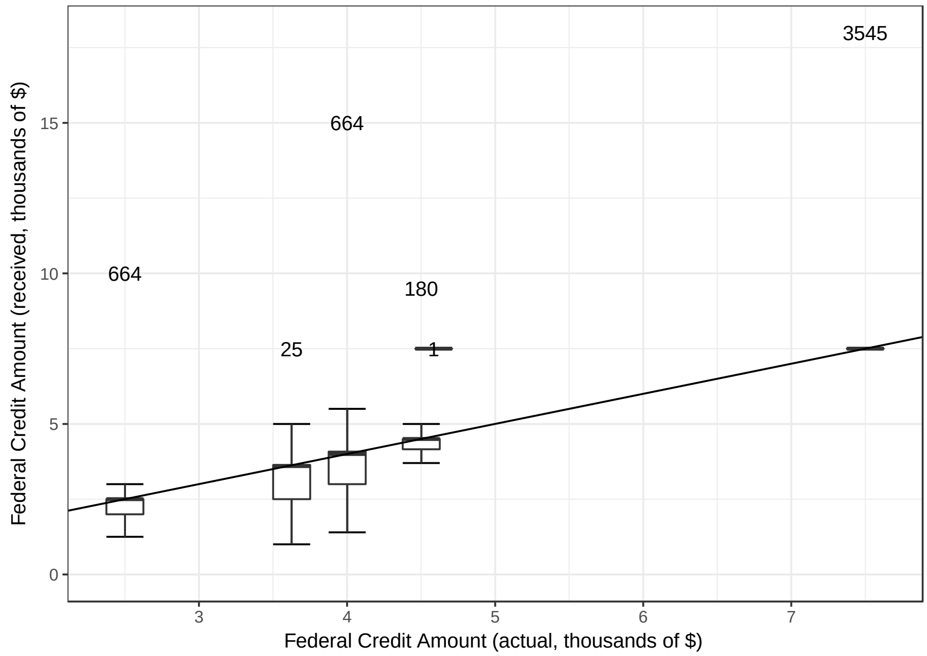

Figure 2. Comparison of the federal tax credit requested versus what should have been received based on each respondents' corresponding electric vehicle. For the majority of credit requests, the respondents filed for the correct amount but there is significant variation both above and below the correct amount.

Figure 1 and **Figure 2** provide important considerations for incentive analysis: not all PEV users are able to claim the incentives and the incentive amounts claimed and received (particularly federal) do not always correspond to the correct amount that should be provided for the vehicle. Misconceptions in the value of the incentive (which can vary between incentives such as federal and state) can lead to biases in the true effect of the incentive, if not considered within the analysis.

We also observe the stated importance of the incentives from our survey respondents. A matrix of the top two incentives for our respondents is shown in Figure 3. By far the most prevalent response was the federal tax credit (most important) plus the state rebate (second most important), followed by the federal tax credit (most important) plus HOV lane access (second most important). The remaining combinations almost always included the federal tax credit, the state rebate, or the HOV lane access as one of the top two incentives across the full set of respondents. The inclusion of the monetary incentives and the HOV lane access (in California) is critical to understanding consumer adoption of electric vehicles. While other incentives are available, respondents have consistently shown that other incentives such as workplace charging or preferred/discounted parking are not as important as the direct monetary benefits of the federal and state credits or the value of reducing driving time via HOV lane access.

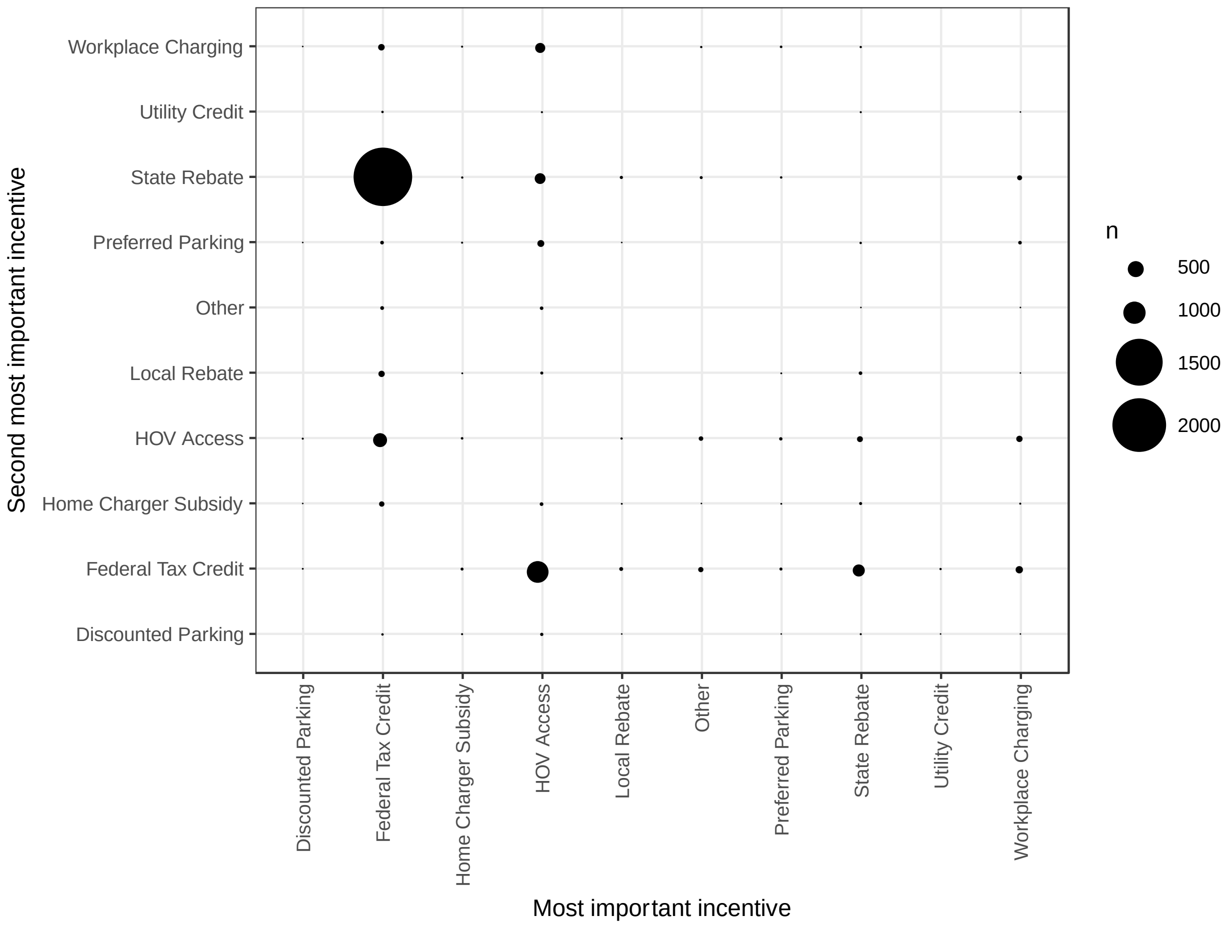

Figure 3. A matrix indicating the top two most important incentives reported by survey respondents with the size of each dot indicating the number of responses. Across the ten listed incentives, the most important for respondents were the federal tax credit, the state rebate, and HOV lane access.

Latent Class Analysis of Incentive Importance

Latent class cluster analysis was used to classify PEV consumers based on their responses to a question regarding the importance of a number of different incentives: federal rebate, state rebate, local rebate, home charger installation support, discounted parking rate, workplace charging support, and high occupancy vehicle (HOV) lane access. Responses are based on a bounded continuous scale from -3 to 3 with the option to choose "not applicable." In total, 14 additional dummy variables were included in this analysis. Once these dummy variables were included, Euclidean distance based clustering methods were not applicable, as they do not fully capture the meaning of the dummy variables. In order account for this, we used a model based cluster analysis: latent class cluster analysis.

Equation **Error! Reference source not found.** illustrates a latent class analysis model without covariates (Vermunt and Magidson):

$$f\left(y_i\right)=\sum_{k=1}^{K} P\left(x\right)\prod_{t=1}^{T}\left(y_{it} \mid x\right), \tag{1}$$

where *x* is a single nominal latent variable, y_{it} denotes the response variable, and *T* is the number of individuals, and $f(y_{it}|x)$ is the conditional probability density for response variable i of individual t given condition of the membership *x*. In this analysis, the class membership is a function of individuals' perceived importance of a variety of PEV incentives in California. Therefore, y_{it} is an individual's perceived importance of the incentives, *x* is the class membership of the perceived incentive importance patterns.

To estimate the model, we employ the Expectation–Maximization (EM) algorithm along with the Newton–Raphson Maximum Likelihood Estimation (Vermunt and Magidson). Although the estimation results from the two algorithms are quite stable, this model is very sensitive to local maxima of the likelihood function. Testing multiple models with different sets of parameter start values helps to resolve this issue (Goulias). Another operational issue for estimation is that the degrees of freedom are rapidly exhausted as the number of parameters is increased (usually by increasing the number of classes). In this regard, model identification (i.e., the ability to estimate parameters) and convergence (i.e., when subsequent estimation step parameters are not close enough) can be difficult to achieve. Therefore, we employ a hierarchical approach to address this issue:

a) A model with only one class assumption is estimated.
b) Increasing the number of latent classes until the model is impossible to identify and the resulting classes become too small.
c) A suitable number of classes is selected based on multiple goodness of fit criteria, including Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and the Consistent Akaike Information Criterion (CAIC). Although AIC, BIC, and CAIC do not measure the goodness of fit directly, they can be used to compare the number of parameters in each model and therefore serve as relative model fit indices for latent class analysis (McCutcheon; Nylund, Asparouhov and Muthen).

As a result of this model estimation, probabilistic cluster membership for each respondent is provided. This provision is one of the most importance advantages of using latent class cluster analysis, as the probabilistic cluster membership can be used to relate latent class clusters to external variables (Vermunt and Magidson). To understand the relationship between the perceived importance of PEV incentives and individuals' socio-demographic characteristics, we used a multinomial logistic regression model (also called a "step-three model" in latent class analysis). The socio-demographic varaibles tested were: income, education, age, gender, homeownership, number of vehicles in the household, household size, number of drivers in the household, whether the PEV was a Tesla (as dummy indicator), and PEV purchase year.

Multinomial Analysis of Purchase Decisions

One of the key points of interest is how different factors (both regarding the respondent and the vehicle) are related to how incentives would have changed a PEV adopters' decision to purchase the vehicle. Though our study may suffer from response bias, it focuses on a question that would be difficult to approach econometrically. That question is: "If the federal tax credit were not available when buying my PEV or any other PEV, I would have chosen:

- A conventional vehicle
- Another plug-in vehicle
- A hybrid non-plug-in vehicle
- Not to buy/lease a vehicle at all
- No change
- Don't know"

We used a multinomial logistic regression (MNL) to calculate the probability corresponding to the vehicle purchasing decisions for existing PEV owners responding to the survey. This approach allowed us to consider not only the effect of the incentive, but also a number of controls such as vehicle attributes (MSRP, technology type) and demographic information. The probability that a respondent considers the absence of the federal tax credit to have a specific outcome on their purchase decision can be modeled as follows:

$$p\left(y_j\right)=\frac{\exp\left(\beta_{ij}\mathbf{x}_j\right)}{\sum_k \exp\left(\beta_{ik}\mathbf{x}_k\right)}, \tag{2}$$

where the federal incentive effect on the PEV purchase, y_j, consists of the following decisions: no change in purchase behavior, would have bought another PEV, would have bought a non-PEV, would not have bought/leased a vehicle, and don't know. (Note that these categories are grouped slightly differently than above.) The vector $\mathbf{x}_j$ describes the control variables: education, income, age, household size, PEV type, the percentage incentive discount of vehicle purchase price, and the year in which the PEV was bought. Using the MNL model, we are able to estimate the relative probability that a respondent (given their input factors) would choose each of the decisions. We are also able to characterize differences in demographics and vehicle attributes and their relationship to the final PEV purchase decision when removing the federal tax credit. In this way we are able to capture heterogeneity in consumer self-reported dependence on purchase incentives.

Results

The results of our study are presented in two sections below. The first describes the clustering of PEV adopters based on their purchase intentions and demographics. The second describes the MNL results measuring the impact of incentives on purchase decisions for PEV owners.

Classifying PEV Purchaser Heterogeneity

We clustered the survey respondents based on the relative importance of all incentives available to them as PEV purchasers. **Figure 4** illustrates the average importance of PEV incentives in each cluster. The second and third cluster show the most distinctive patterns. All incentives, except discounted parking rates, were more important to the respondents in the second cluster (marked in dark blue color) than to the respondents in any other cluster. Among the different types of incentives, federal and state rebates were the most significant incentives to this group of respondents. HOV lane access and workplace charging were also perceived as important factors, but the differences in their importance across clusters were smaller than the financial incentives. The third cluster (marked in yellow color) perceived the importance of incentives, except for HOV lane access, to be much smaller than other clusters did. The respondents in this cluster percieved the importance of federal and state rebates in a neutral way, and perceived local rebates, home charging, and discounted parking as unimportant. The other two clusters (first and fourth) perceived federal and state rebates as slightly important on the slider bar scale (between 1.5 and 1.7 on a scale of -3 “not important” to +3 “important”), but the local rebate, home charging, and discounted parking incentives as not important to their decisions to adopt eletric vehicles. The respondents in these two clusters had not answered these questions or expressed that these incentives did not affect their purchase decision. Although the first cluster perceived workplace charging and HOV lane access as slightly important (0.3 and 1.1, respectively), the HOV lane access was slightly more important for the fourth cluster (0.4 compared to 0.3 for the first cluster).

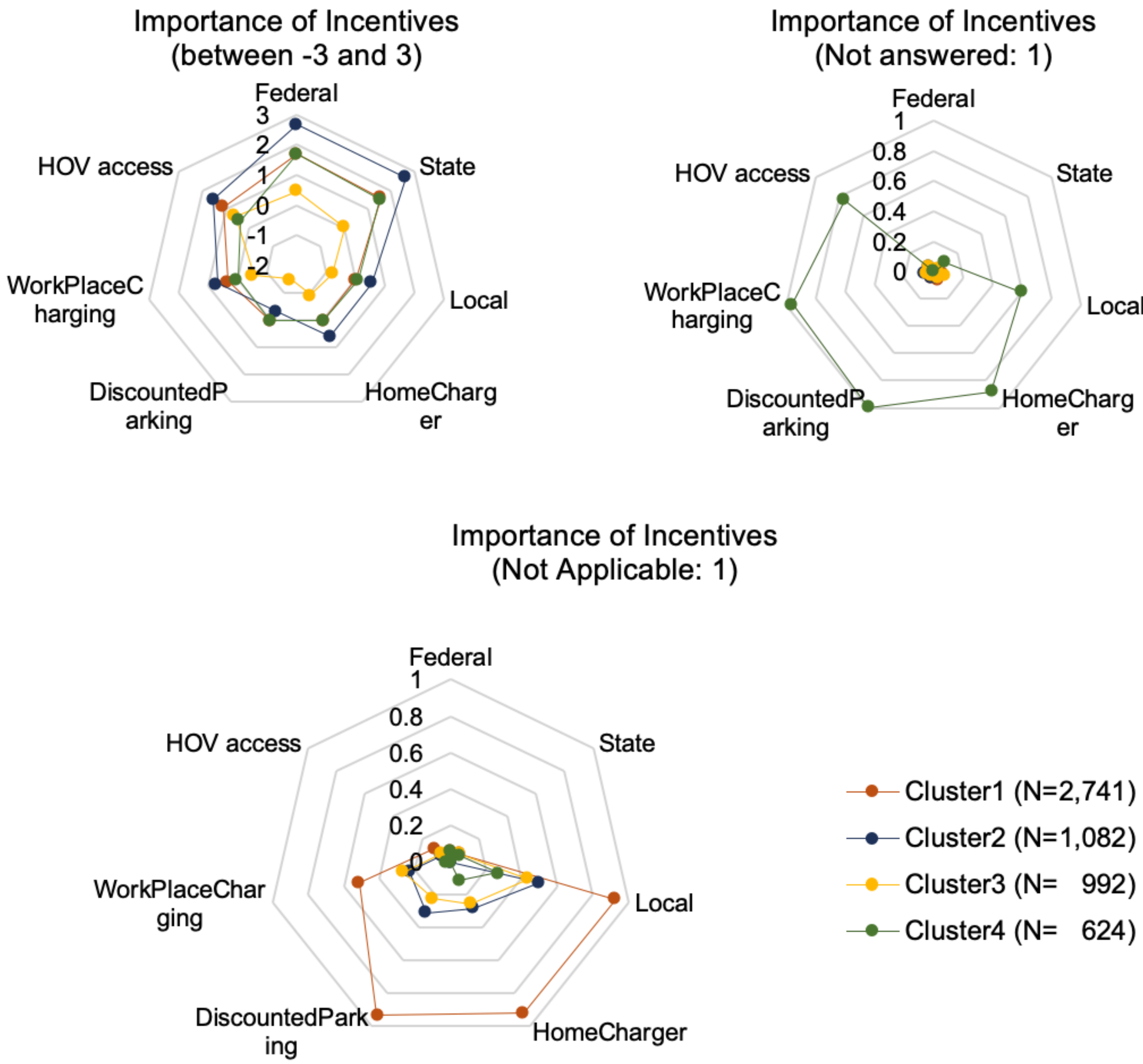

Figure 4. Separate cluster results from the latent class analysis for respondents (top left), respondents who did not indicate the importance of the federal incentive (top right), and respondents for which the federal incentive was not applicable (bottom).

In order to understand the characteristics of the respondents in each cluster, we used a multinomial logit model with socio-demographic variables and vehicle charateristic variables (Table 2). Overall, age, gender, homeownership, number of vehicles, Tesla ownership, and the year in which a PEV was bought were significant variables to classify respondents into different groups based on Wald statistics. The respondents in the second cluster, who perceived most incentives as important, consisted of relatively lower income, younger, homeowning males. They were not likely Tesla owners but they were more likely to have purchased a PEV recently. On the other hand, the third cluster perceived most incentives, except for the federal and state rebate, in a neutral or negative way. In comparison to the respondents in other clusters, they were characterized by older age, higher incomes, home ownership, and a greater likelihood of owning a Tesla. The first and largest cluster perceived federal and state rebates, workplace charging, and HOV lane access as relatively more important. Respondents in this cluster compared to other clusters tended to be younger and male, with fewer vehicles in their households, and their PEVs were more likely to be Teslas. Lastly, the respondents in the fourth cluster were more likely than those in other clusters to be older and female, and have more vehicles per household.

Table 2. Estimated parameters for the STEP-3 (MNL) model (z-score in parentheses)

	Cluster1	Cluster2	Cluster3	Cluster4	Wald	p-value
Intercept	-20.862 (-0.706)	-145.835 (-3.531)	162.258 (3.802)	4.439 (0.099)	19.331	0.000
Income	0.000 (0.652)	-0.001* (-2.391)	0.001** (3.387)	0.000 (-1.183)	13.854	0.003**
Education level	-0.014 (-0.355)	0.017 (0.319)	0.020 (0.371)	-0.022 (-0.359)	0.407	0.940
Age	-0.006** (-3.334)	-0.018** (-7.668)	0.007** (2.710)	0.017** (5.806)	74.007	0.000**
Female (1)	-0.021 (-0.425)	-0.261** (-3.947)	0.021 (0.321)	0.261** (3.532)	19.612	0.000**
Homeowner (1)	-0.246** (-3.371)	0.416** (3.941)	0.045 (0.420)	-0.215 (-1.773)	26.152	0.000**
No. of Vehicles in HH	-0.089** (-3.201)	-0.026 (-0.699)	-0.026 (-0.708)	0.141** (3.297)	15.403	0.002**
HH size	-0.006 (-0.243)	-0.009 (-0.274)	-0.002 (-0.068)	0.017 (0.435)	0.213	0.980
Tesla (1)	0.145** (2.829)	-0.321** (-4.568)	0.203** (3.026)	-0.027 (-0.333)	28.982	0.000**
No. of Drivers	0.037 (0.889)	0.018 (0.331)	0.009 (0.151)	-0.064 (-0.950)	1.224	0.750
Buy Year	0.011 (0.755)	0.073** (3.549)	-0.081** (3.821)	-0.003 (-0.127)	19.577	0.000**

HH indicates household; P-value <0.05*, <0.01**, <0.001***

We calculated the percentage of the total sample for each year that was in each cluster to understand the change in the importance of PEV incentives for new PEV buyers over time (Figure 5). The proportion of people requiring incentives (cluster 2) was stable between 2012 and 2015 (between 17.6% and 22.2%), but grew in the last two years (23.6% and 27.2%). However, the proportion of people who did not consider the incentives to be important gradually decreased over time from 38.5% to 16%. Additionally, we provide a breakdown of cluster by vehicle model ownership in order to identify whether there are any differences among specific PEV technology types (**Error! Reference source not found.**).

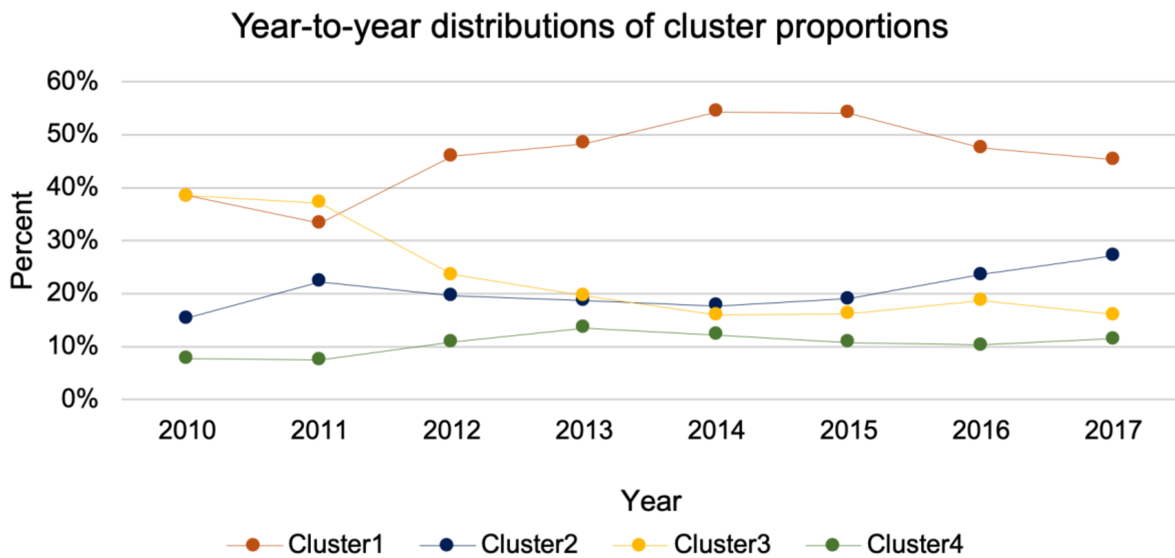

Figure 5. Year-to-year distributions of respondents among clusters

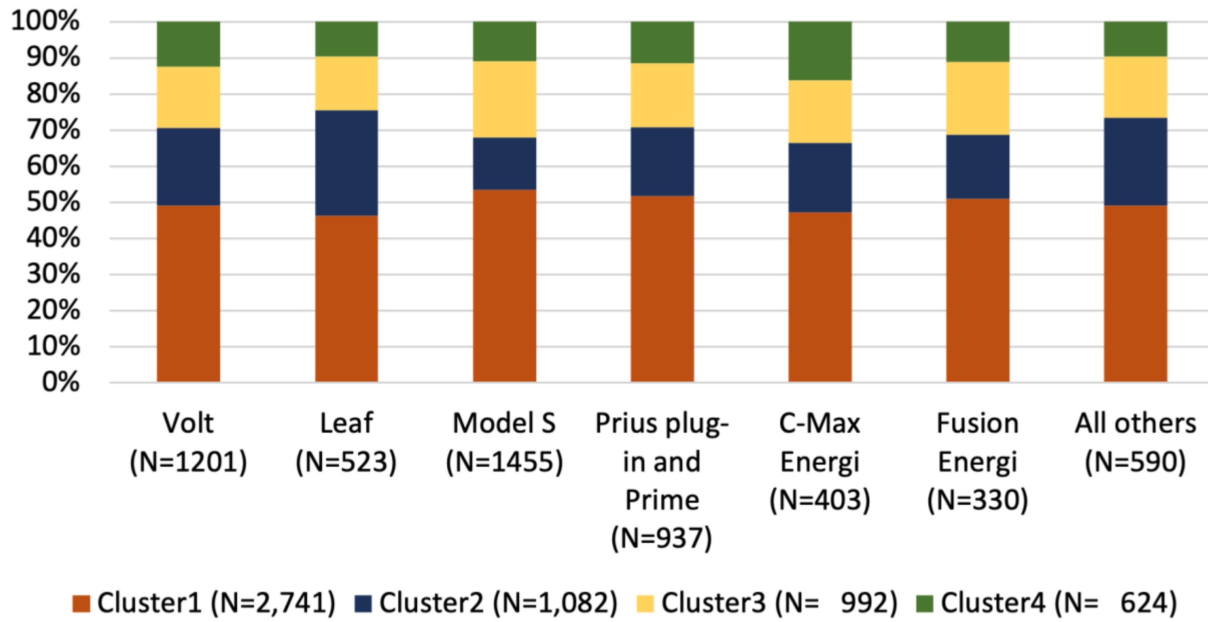

Figure 6. Distribution of respondents among clusters according to PEV model.

Understanding Purchase Behavior in Response to Incentives

We investigated the influence of the federal tax credit on consumer purchase decisions. Using a multinomial logistic regression (MNL) model, we analyzed how the following independent variables correlated with responses to the following question: "If the federal tax credit were not offered, how would this influence your decision to buy a PEV? (a) "No change in decision"; (b) buy “Another plug-in vehicle”; (c) buy “A non plug-in vehicle”; (d) “Not to buy/lease a vehicle at all”; or (e) “Don’t know”. The independent variables (i.e., parameters) in the model were demographic factors, the PEV technology type, year of purchase, and amount of discount from using the federal tax credit incentive influence a purchasers’ decision to have The full results of the regression can be found in **Table 3**.

Table 3. Multinomial logistic regression results (standard error in parentheses) for change in purchase decision in the absence of the federal tax credit. The base scenario is no change in decision.

	Another plug-in vehicle (1)	**A non plug-in vehicle (2)**	**Not to buy/lease a vehicle at all (3)**	**Don't know (4)**
Constant	-4.25***	-2.67***	-2.48***	-6.23***
	(0.803)	(0.435)	(0.536)	(1.61)
Years of education	0.0747**	0.0408**	-0.0102	0.0808
	(0.032)	(0.0171)	(0.0212)	(0.0644)
Income ($)	-0.111*	-0.143***	-0.163***	-0.07
	(0.0624)	(0.0354)	(0.0447)	(0.124)
Age (Years)	-0.0182***	-0.0118***	-0.0117***	0.00264
	(0.00565)	(0.00307)	(0.0038)	(0.0112)
Household Size	0.0869	0.0783**	0.0465	-0.106
	(0.06)	(0.0338)	(0.0421)	(0.136)
PEV Type (PHEV)	-0.00794	0.562***	-0.201**	0.0598
	(0.15)	(0.0855)	(0.102)	(0.3)
Incentive Discount	4.48***	4.59***	5.67***	6.49***
	(0.9)	(0.548)	(0.611)	(1.45)
Model Year	0.0778	0.061**	0.131***	0.00232
	(0.0477)	(0.0259)	(0.0328)	(0.0916)
Akaike Inf. Crit.	9154.23205	9154.23205	9154.23205	9154.23205

HH indicates household; <0.05*, <0.01**, <0.001***

We translate the results of the MNL model to display the corresponding probability outcomes in Figure 7, focusing specifically on the role of PEV technology type. On average, over 60% of respondents stated they would not have changed their decision if the federal tax credit were removed. The frequency of this ‘no change’ response was only slightly higher among BEV than PEV owners, though the difference was statistically significant. This particular result confirms previous studies that have derived elasticities of the purchase incentive (Tal and Nicholas; Jenn, Springel and Gopal).

Additionally, BEV owners were significantly less likely than PHEV owners to state that they would purchase a non-plug-in vehicle (15% vs. 23%) in the absence of the federal incentive. We hypothesize that PHEV adopters likely have greater concerns about range issues (whether real or perceived), which may lead to this result. The probability that a respondent would state that they would not purchase or lease a vehicle at all if the federal incentive were removed was approximately 10% for both BEV and PHEV owners.

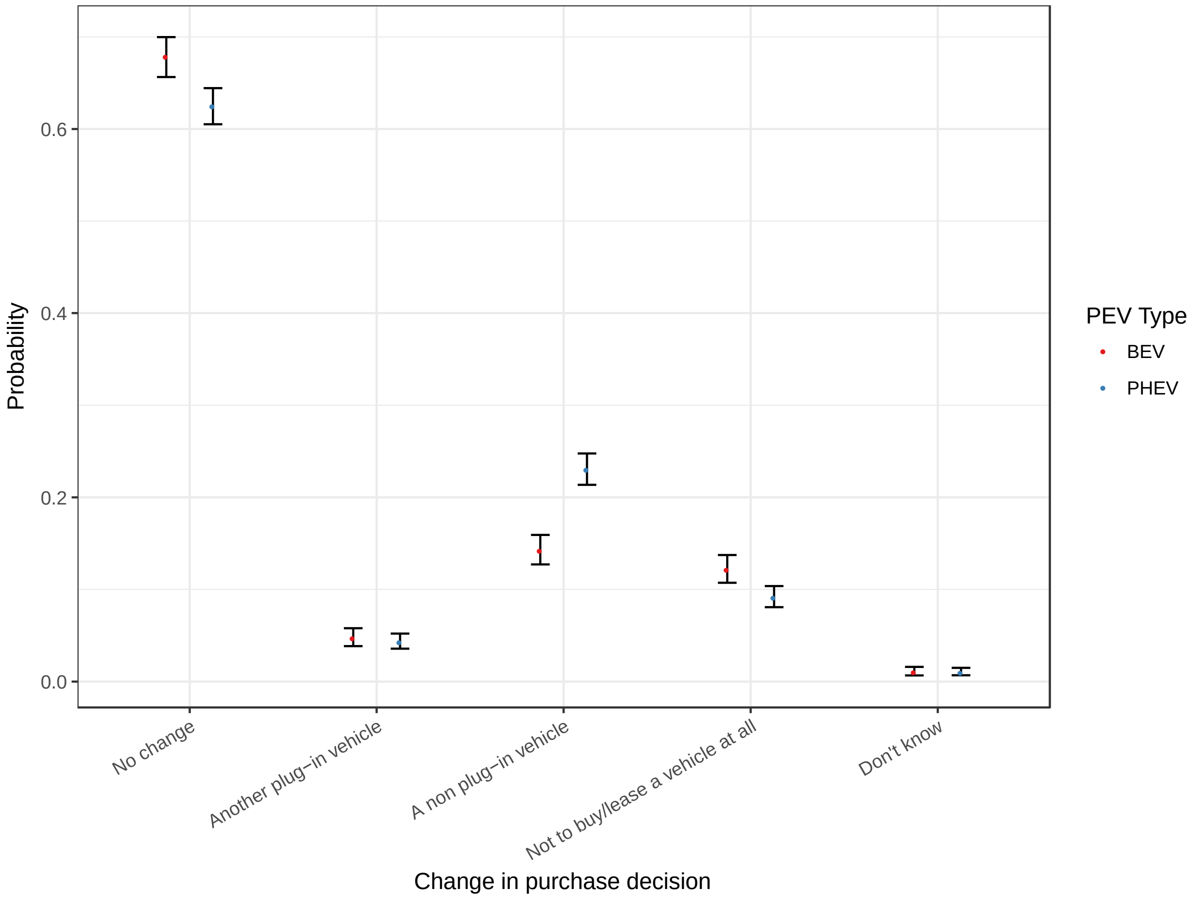

Figure 7. Average probabilities of responses from BEV and PHEV owners to the question of how their decision to buy a PEV would be affected if the federal tax incentive were removed. Different possible responses are shown along the x-axis. The results shown are according to the MNL model.

In Figure 8, we show, for four of the most popular PEV models, the different probabilities associated with a decision outcome when removing the federal tax credit incentive. Owners of the Tesla Model S had a statistically significantly higher probability of not changing their decision when the incentive is removed than did owners of the Chevrolet Volt, Nissan Leaf, and Prius Plug-in. This is probably due to the fact that the discounted amount relative to the price of the vehicle is much smaller for the Tesla than for other PEVs and therefore less valuable. We also find a significant trend in responses over time. There is a decrease, ranging from 10% to 20%, over a period of 7 years for respondents who would have chosen “No change” if the federal incentive were removed. Meanwhile, there is a marked corresponding increase (statistically significant) in PEV adopters who would have chosen "a non plug-in vehicle" or "not to buy/lease a vehicle at all" over time.

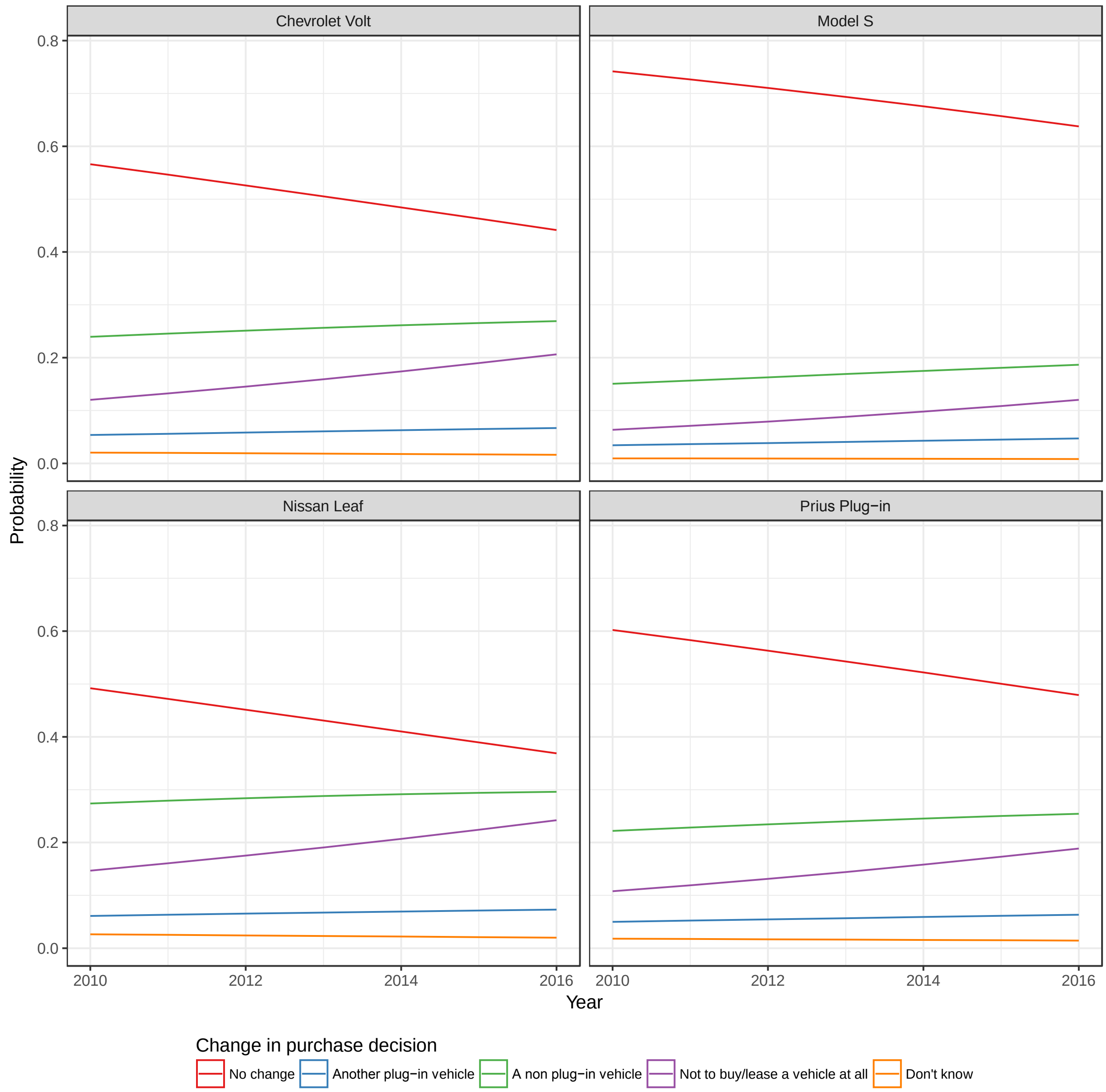

Figure 8. Change over time in the probabilities of responses to the question of how a respondent's decision to buy a PEV would be affected if the federal tax incentive were removed. The results are grouped according to the respondents' model of PEV and are derived from the MNL model. The "No change" category consistently decreases as time passes, indicating that removing the tax credit will cause a larger impact in later years.

Discussion and Conclusions

There is a broad array of literature addressing the efficacy of incentives. Our work seeks to contribute to two particularly relevant policy questions regarding incentives for electric vehicles. First, for whom are incentives most effective and for what demographics or vehicles can they be removed to improve their efficacy? Secondly, as the market segment for PEVs continues to grow, can we begin to phase out incentives, and what would the corresponding impact be? This study does not provide a definitive, final answer to these questions but does bring novel results to the discussion.

Regarding the first question, our work indicates that there are clear clusters among the heterogeneous population of PEV adopters. There are segments of this unique population that find the importance/value of the federal and state tax credits to be relatively low: older and wealthier purchasers who were statistically significantly more likely to own a Tesla Model S. This has already been reflected in changes in numerous incentive policies: California now has an income-based cap on applicants of the CVRP and many other states have introduced restrictions based on the MSRP of the vehicle. Nevertheless, we find that the large majority of PEV owners still rate the federal and state tax credits and the HOV lane access to be fairly important incentives in their purchasing decisions. This is reflected in both the latent class analysis and the MNL modeling approach.

The issue of incentive phase-out is critical to the sustainability of the electric vehicle market. The federal government has already provided $2.5 billion in subsidies through their federal tax credit and the state of California has provided $450 million in subsidies through the CVRP program. From a financing standpoint, it is unlikely that governments would be able to continue funding incentives indefinitely. As we begin to consider phasing out incentives, it is vital to consider the effect on the market to avoid a collapse of PEV adoption (as has been seen in empirical examples of Georgia in the U.S., the Netherlands, and Denmark). However, our findings indicate that the incentives have become increasingly important over time. The very first early adopters of the PEV technology were significantly less sensitive to the incentive availability. This is reflected in about a 20% increase, between 2010 and 2016, in PEV owners who stated that they would not have purchased a PEV if the federal incentive were removed. This trend is the opposite of what is necessary from a policy perspective and points to a necessity of a more sustainable funding mechanism for the incentive policy or a marked decrease in PEV prices to reliably phase out the incentives without drastically affecting the market.

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