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Exploring the Impact of the Federal Tax Credit and the California Rebate on the Decision to Lease or Purchase a PEV in California

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Executive Summary

This research explores the impact of the federal tax credit and the California Clean Vehicle Rebate Project (CVRP), on plug-in electric vehicle (PEV) adoption using stated choice data of PEV owners in California. A novel addition to existing research is the explicit consideration of the impact of incentives on purchasers and lessees, as there is a limited understanding of whether changes to incentive eligibility criteria may affect the PEV lease or purchase market differently. We attempt to fill these gaps by first modelling the impact of the federal tax credit separately for lessees and purchasers. We then combine lessees and purchasers to model the impact of the CVRP, controlling for finance method. All the models control for vehicle and contract characteristics, socio-demographics, and household characteristics. Our findings indicate that the absence of the federal tax credit or CVRP could have an impact on California's goal of reaching 100% ZEV sales by 2035.

Keywords: Logistic regression, Choice modeling, PEV adoption, PEV incentives

1 Introduction

The state of California has been a leading state in growing the market share of plug-in electric vehicles (PEVs) (1). Several policy tools have been utilized in the state and the US to help support the PEV market. The California Air Resources Board (CARB) offers both financial incentives, including the California Clean Vehicle Rebate Program (CVRP), in addition to administering a mandate which requires automakers to sell a portion of their vehicles as PEVs or fuel cell vehicles. These state policies are supplemented by the federal government providing up to a $7,500 tax credit for financing a battery electric vehicle (BEV) or plug-in hybrid electric vehicle (PHEV) (2).

The original iteration of the federal tax credit phased out at the beginning of the second calendar quarter after a vehicle manufacturer had sold 200,000 eligible PEVs. The incentive halves to $3,750 for two quarters, halves again to $1,875 for two quarters, and then becomes $0. Both Tesla and Chevrolet had reached this point and as of the beginning of 2020 buyers of neither make were eligible to receive credits. Recent changes through the 2022 Inflation Reduction Act removed the 200,000 vehicle cap which means Tesla and Chevrolet vehicle buyers will be eligible for up $7,500 beginning in January 2023. Incentives will be available until 2032, but new

stipulations on where batteries are produced, vehicle purchase price, and buyer income. These mean more than half of PEVs may receive no incentive, and the ones that do will receive only half of the full amount (3). These policy changes may have implications for PEV market growth, particularly California's goal of 100% ZEV sales by 2035.

In regard to the CVRP, which launched in 2010, eligibility criteria were first enacted in 2016 Ito help increase the rebate allocation to lower income and disadvantaged communities. As of February 2022, new income caps include a maximum income of $135,000 for single filers and $200,000 for joint filers, and vehicle price caps at $44,000; these caps were lowered from a previous $200,000 for single filers and $300,000 for joint filers. Lower income households may additionally be eligible to receive higher rebate amounts(4). These measures have been found to improve the incentive effectiveness in terms of dollars spent per PEV sold, by providing more rebates to households which otherwise would not have purchased a PEV, and who have a higher marginal value of incentives. Prior to the first income caps in 2016, it was found that the bottom 75% of census tracts based on income received only 37% of the rebate benefits, and disadvantaged communities received 6% (5). As of 2022, CARB reported that 52% of rebates benefited low-income communities, and 17% benefited disadvantaged communities (6).

The distribution of these financial incentives can vary based on whether a PEV is purchased or leased. Leasing is alternative acquisition method to purchasing which allows consumers to limit their vehicle ownership period to most commonly a 36-month long contract. Whereas the CVRP is applied to the upfront costs both for lessees and purchasers, the federal tax credit is applied differently based on finance method. Since auto dealerships are the owners of leased PEVs, the dealer receives the full credit, which is then assumed to be reflected in lower down and monthly lease payments. Lessees therefore in theory receive the full benefits of the federal tax credit sooner since purchasers don't receive the credit until they file taxes for that year, and may not apply for the full amount if their tax liability is less than the amount of the tax credit. This delay in receiving the incentive and uncertainty in the value received could limit how effective the incentive is for purchasers, while an immediate discount for lessees could mean the incentive is more impactful.

Leasing is an important segment for the PEV market for several reasons: it may encourage more consumers to adopt PEVs at a lower acquisition cost and allow buyers to try a PEV over a set time which could lower the perceived uncertainties of PEV adoption as the technology matures. In theory, this could make PEVs more accessible to a wider group of consumers, and create a supply of used PEVs faster than purchasing. In the unweighted sample of vehicles surveyed in the 2019 California Vehicle Survey, approximately 33% of the PEVs of model year "2015 and later" were leased new compared to 22% of conventional gas vehicles. The share of leased BEVs rises to 60% when we consider the subsample of surveyed PEVs without Tesla. Tesla did not initially offer vehicles for lease, and they tend to not offer discounted lease rates.

Existing research on the impact of financial incentives does not directly explore PEV leasing- either by not differentiating purchasers from lessees, or by focusing only on purchasers. This presents a gap in the literature on understanding of how the absence of financial incentives, including the tax credit and the CVRP may uniquely impact the attractiveness of leasing a PEV. While there is limited research on the PEV leasing, Hoogland et al. (7) found that PEV owners are more likely to lease PEVs with discounted lease rates relative to purchasing. However, due to recent changes in vehicle and income eligibility for both the federal tax credit and CVRP, it will be critical to understand how the absence of these incentives could impact future PEV adoption. Furthermore, this research provides insights into PEV market characteristics segmented by finance method. This research explores how socio-demographics, household and vehicle characteristics impact consumers' decision to lease or purchase a PEV in the absence of either the tax credit or the CVRP. Separate logistic regression models are specified for lessees and purchasers to analyse responses to the question of what they would do in the absence of the federal tax credit; another logistic regression model combining purchasers and lessees is specified to analyse adoption decisions in the absence of the CVRP.

2 Literature Review

There are several relevant areas of literature to this study. This includes studies which explore the factors associated with PEV adoption; the impact of financial incentives on PEV adoption, particularly the impact of the federal tax credit and CVRP; as well as those which explore contract choice (purchase or lease) in both the internal combustion engine vehicle (ICEV) and PEV market.

Revealed preference as well as stated preference data in the U.S., Canada, and Switzerland have demonstrated that PEV adopters are more likely to be in a higher income class, well-educated, male, homeowners, residing in a single-family home, and are also more likely to have previously owned a hybrid vehicle, and be technology enthusiasts (8–14). Lee et al. (14) characterized PEV adopters in California from 2010 to 2017 by identifying four unique clusters of adopter groups: high income families, mid/high income young families, mid/high income old families, and middle-income renters. Authors conclude that more middle-income renters need to adopt PEVs at a higher rate for PEV market growth to continue.

Financial incentives have also been found in both stated and revealed preference studies to be effective in increasing PEV adoption. (10,15,16). Gong et al. (17) explored the impact of government incentives on the market penetration of PEVs in Australia. Authors found that incentives which decrease the upfront costs are the most preferred financial incentive. In a literature review of PEV financial incentives. Hardman et al. (18) additionally found that for adopters of high-end PEVs, financial incentives are not important in consumers' adoption decision, recommending that financial incentives not be applied to high-end PEVs, but on lower MSRP PEVs in order to attract more consumers. Jenn et al. 2018 examined the effectiveness of financial and non-financial incentives on PEV adoption in the U.S. Authors conclude that for every $1,000 offered as a rebate or tax credit, average PEV sales increase by 2.6%. Tal and Nicholas (19) utilized a stated preference survey of PEV owners to examine the impact of the federal tax credit, and found that more than 30% of PEV sales could be attributed to the $7,500 incentive. Jenn et al (20) found that incentives are growing in importance over time in regard to determining consumers' stated preference decision to adopt a PEV or not, but that for particular groups of consumers, such as older and wealthier consumers, the absence of the federal tax credit is less likely to change their purchase decision.

There is limited literature on contract choice in the PEV market. Liao et al. (21) explored the potential of leasing in promoting the transition from ICEVs to PEVs. Results from latent transition analysis showed that leasing could facilitate PEV adoption for the subset of consumers with pro-leasing and pro-convenience preferences. In another stated choice experiment examining consumer preference for various PEV business models, Liao et al. (22) found that consumers perceived leasing as attractive for BEVs, and purchasing attractive for PHEVs. The authors also find that PEV market share increases when financial incentives are offered to both PEV lease and purchase contracts, rather than just purchases. Lastly, Hoogland et al. (7) explored the factors associated with the decision to lease, rather than purchase a PEV in California, and found that PEV leasing was associated with renting, rather than owning their home, as well as with living in a non-single-family home.

Even for the ICEV market, there is limited research on consumer contract choice, and its influence on vehicle choice, as this Mannering et al. (23) used a random sample of 654 households to jointly model the vehicle finance method and vehicle choice. The authors found leasing to be associated with high income consumers, authors hypothesize that leasing could be a mechanism for this group of households to upgrade their vehicle every few years or to lower transaction costs associated with vehicle disposal. Authors also find consumers are more likely to lease a vehicle if they had previously leased one, referred to as exhibiting lease loyalty. Dasgupta et al. (24) implemented a structural model using transaction data for new vehicle sales from the entry-luxury segment of the U.S. auto market. Authors conclude that leasing allows consumers to drive two new vehicles over the average vehicle ownership period, while also having lower disposal costs relative to purchasing. Trocchia and Beatty (25) found through exploratory interviews, that desire for variety and desire for easier maintenance motivated consumers to lease a vehicle.

3 Data Description

We use results from a cohort survey of PEV owners in California conducted in 2018 and 2019. Respondents of the survey are sampled from the pool of CVRP recipients administered by the Center for Sustainable Energy & California Air Resources Board, who have an agreement with the University to provide contacts (e-mail) for solicitation for the purposes of disseminating and gathering respondents for the survey. Altogether, phase 4 & 5 include 7,357 and 7,078 respondents respectively, all of whom have applied for the CVRP rebate following the purchase or lease of a PEV.

The data for our analysis includes PEVs which were either purchased or leased new from 2018 to 2019[1]. The data screening process varies by finance method (purchase vs lease) for the federal tax credit models, but is the same for the combined CVRP model.

Participants first rate the stated importance of financial and non-financial incentives, which is used to create a rank order of incentives. The choice alternative questions are then asked only to those participants who ranked the federal tax or the CVRP as their number one financial incentive:

"If the [incentive] were not available when buying my PEV (or any other plug-in vehicle) I would have chosen:

- *A conventional or hybrid vehicle (non-plug in vehicle)*
- *Another plug-in vehicle*
- *Not to [purchase/lease] a vehicle at all*
- *The [same] PEV*
- *Other*

All lessees however, with the exception of Chevrolet and Tesla lessees[2] are asked the choice alternative question for the federal tax credit model:

The US federal tax incentive is applied to your lease price. Without the tax credit we estimate your down payment would have been [X] rather than [Y] and your monthly payments [W] rather than [Z] for [N] months. If that would have been the lease payment for my PEV, I would have chosen:

- *A conventional or hybrid vehicle (non-plug-in vehicle)*
- *Another plug-in vehicle*
- *Not to lease a vehicle at all*
- *The [same] PEV*
- *Purchase the PEV*
- *Other*

4 Methods

Figures 4 and 5 provide a distribution of the choice alternatives in the absence of the federal tax credit and CVRP, respectively, separated by finance method. Regarding the federal tax credit, there is a smaller proportion of lessees choosing the same PEV (no change) compared to purchasers, and a larger proportion of lessees choosing another PEV or a conventional vehicle. There are roughly the same proportion of lessees and purchasers choosing

[2] The phase-out of the federal tax credit began for the Tesla Model 3 and Chevrolet Bolt in 2018 and 2019 respectively. Due to the uncertainty regarding the discount amount received during this period of phase-out, Tesla and Chevrolet lessees were not asked the response variable question.

no vehicle at all. Less than ten percent of lessees would choose to purchase the PEV. In regard to the CVRP, there is a larger proportion of lessees choosing the same PEV (no change), or another PEV, compared with purchasers, and a smaller proportion of lessees choosing no vehicle or a conventional vehicle.

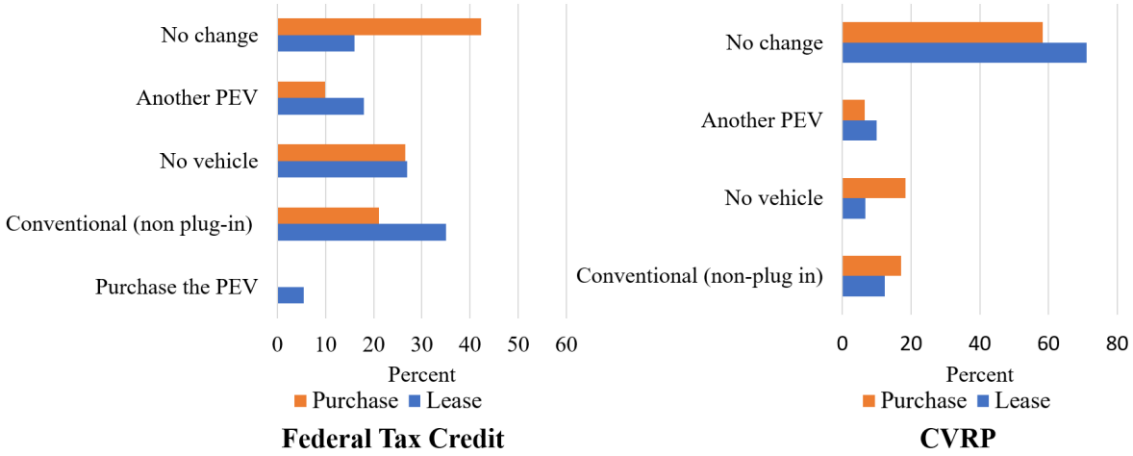

Figure 2: Distribution of choice alternatives by finance type: federal tax credit

A multinomial logistic regression model (MNL) is used to model the decision to purchase or lease a PEV in the absence of incentives. This allows us to control not only for the incentive discount, but also for other vehicle characteristics in addition to socio-demographic factors.

Figure 4 shows the alternatives in the choice set for each of the models. We model the impact of the federal tax credit separately for purchasers and lessees to control for the differences in how the credit is administered for the various finance methods. We combine lessees and purchasers to model the impact of the CVRP, and control for finance method. All of the models capture change in consumers' adoption behavior in the absence of either the federal tax credit or CVRP, with each choice alternative having a vector of parameters which are alternative specific. Focusing on the federal tax credit model, for purchasers, the reference category captures adopting the same PEV (no change), relative to purchasing another PEV, no vehicle, or a conventional (non-plug-in) vehicle. Due to the low number of observations for lessees, the choice alternatives "no change", and "another PEV", are combined to form the reference category referred to as "leasing a PEV", relative to leasing no vehicle at all, a conventional (non-plug-in) vehicle[3]. Lessees have the additional choice alternative of purchasing/financing the PEV, of which there is no equivalent choice for purchasers. Regarding the combined CVRP model, the reference category for both purchasers and lessees is "no change" (adopting the same PEV), relative to purchasing another PEV, no vehicle, or a conventional (non-plug-in) vehicle.

Table 1 provides an overview of the models' control variables, based on literature of PEV adoption (14,20). We ensured that variables included in the same model were not correlated with each other.

[3] Results of likelihood ratio test showed that there was no statistical difference between the lease model with the combined reference category and the single reference category.

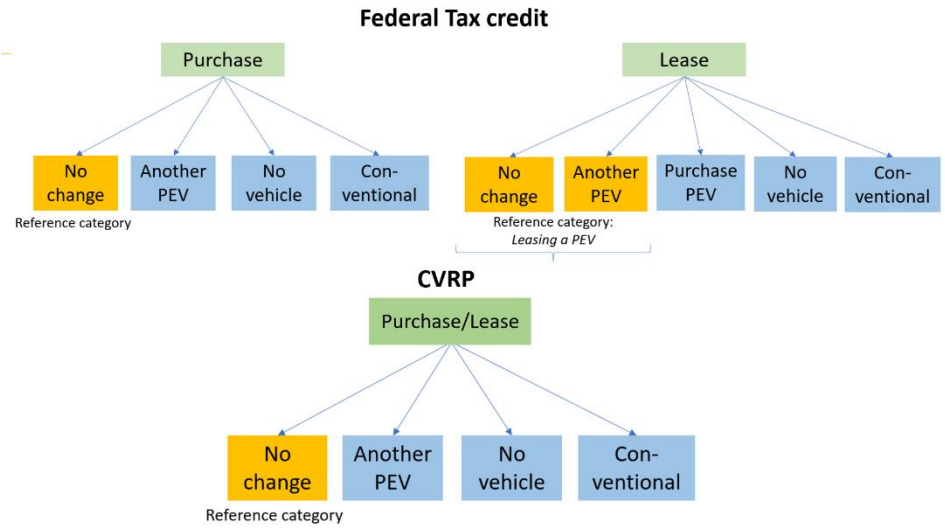

Figure 3: Choice alternatives for federal tax credit and CVRP models

Table 1: Variables included in MNL models and description of variable values

Variable	Description and values
PEV type	Dummy, (BEV = 1, PHEV =0)
Discount percent	*Combined CVRP model & purchasers' federal tax credit model:* The incentive discount reported by participant is divided by MSRP *Lessees' federal tax credit model:* the full applicable credit discount is divided by what the lease cost would have been without the incentive
Electric range	BEVs: 84 to 310 miles PHEVs: 17 to 84 miles
Finance year	*Combined CVRP model:* Dummy, (2017 =1, 2018 & 2019 = 0) *Separate models for federal tax credit:* Dummy, (2019 = 1, 2018 = 0)
Male distinction	Dummy, (Male = 1, Female = 0)
Age	Midpoint of age category (16.5, 24.5, 34.5, etc.)
Home ownership	Dummy, (Own =1, Rent =0)
Income above $200k	Dummy, (Yes = 1, No = 0)
Number of vehicles per driver	Discrete from 0.2 to 3.
Lease contract length	Discrete, from 24 to 60 months

5 Results

The results of the federal tax credit MNL regression models for lessees and purchasers are shown in Tables 3 and 4 respectively, and results of the combined CVRP model are shown in Table 5. Results are presented in the form of odds-ratio, which measures the odds of changing adoption behavior in the absence of either the federal tax credit or CVRP. An odds ratio of less than 1 represents a negative correlation and an odds ratio of more than 1 represents a positive correlation with the probability of choosing one of the alternatives relative to the reference category. The models' information and goodness of fit are shown in Table 6.

5.1 Federal Tax Credit

In regard to vehicle characteristics, results of the lease model demonstrate that for a one-unit increase in the discount percent, lessees are 1.020 times as likely not to lease any vehicle at all than to lease a PEV in the absence of the federal tax credits. For the purchase model, the discount ratio is positive and significant for all choice alternatives; as the discount percent increases, purchasers are more likely to choose another PEV, no vehicle, or a conventional vehicle, than to purchase the same PEV. Regarding finance year, results of the lease model show that relative to 2018, lessees in 2019 are less likely to switch finance methods from a lease to purchase contract. Results of the purchase model show that relative to 2018, purchasers in 2019 are more likely to choose another PEV or a conventional vehicle, rather than purchase the same PEV. There are also effects for the interaction between PEV type and electric range. Results of the purchase model show that the probability of choosing the same PEV, rather than a conventional vehicle or another PEV, increases as the electric range of BEVs increases. Lastly, the lease contract length has a positive and significant effect for lessees choosing not to lease any vehicle; for a one-month increase in the contract length, lessees are 1.073 times as likely to not lease any vehicle at all than to lease a PEV.

In regard to socio-demographics, results of the lease federal tax credit model show that homeowners are 0.382 times as likely than renters to lease a conventional vehicle than to lease a PEV. In regard to the male/female distinction, the lease model show that males are 1.556 times as likely than females to lease a conventional vehicle than to lease a PEV. The purchase model shows that males are 1.273 times as likely than females to purchase no vehicle than to purchase the same PEV. Results from the lease model show that older lessees are more likely to purchase/finance the PEV, rather than leasing a PEV. For purchasers, results show that younger purchasers are more likely than older purchasers to change their purchase decision to another PEV, no vehicle, or a conventional vehicle, than to purchase the same PEV. Lastly, results from both models show that households with more vehicles available per driver are more likely than those with less vehicles available to not to lease or purchase any vehicle at all.

Table 3: MNL regression results for lessees for change in finance decision in absence of federal tax credit. The reference group is leasing a PEV

Variable	Purchase the PEV		t-ratio	No vehicle		t-ratio	Conventional		t-ratio
Alternative specific constant	6.598		0.7792	0.021	**	-2.0287	3.706		0.7014
Home ownership dummy	0.496		-1.0889	0.657		-1.1830	0.382	***	-3.1331
Male dummy	0.780		-0.4944	1.081		0.2774	1.556	*	1.8597
Age	1.031	*	1.7282	1.000		-0.0143	0.991		-0.9048
Discount percent	0.961		-1.5336	1.020	**	1.9853	1.004		0.4242
Electric range x BEV	0.978		-1.1929	1.000		0.0838	0.998		-0.6612
Electric range x PHEV	0.997		-0.0834	1.007		0.3407	1.027		1.1012
Vehicles per driver	2.195		1.3122	2.358	***	3.1460	1.061		0.1693
Finance year- 2019	0.224	**	-2.5265	1.123		0.3656	1.028		0.1012
Lease contract length	0.930		-1.6279	1.073	*	1.7834	0.992		-0.2005

Table 4: MNL regression results for purchasers for change in purchase decision in absence of federal tax credit. The reference group is purchasing the same PEV.

	Another PEV		t-ratio	No vehicle		t-ratio	Conventional		t-ratio
Alternative specific constant	0.128	***	-3.455	0.242	***	-3.037	0.774		-0.529
Home ownership dummy	0.865		-0.701	1.147		0.955	0.808		-1.437
Male dummy	0.848		-1.024	1.273	*	1.973	1.009		0.068
Age	0.985	**	-2.834	0.976	****	-6.380	0.978	****	-5.450

Discount percent	1.139	****	6.783	1.110	****	6.732	1.134	****	8.112
Electric range x BEV	0.997	*	-1.737	1.001		0.157	0.997	*	-1.762
Electric range x PHEV	1.013		1.540	1.000		1.398	0.997		1.085
Vehicles per driver	1.499		0.750	1.471	***	3.245	0.831		-1.150
Finance year- 2019	1.456	**	2.267	1.060		0.457	1.239	**	2.013

5.2 CVRP

In regard to vehicle characteristics, results of the CVRP model show that for a one-unit increase in the discount percent, purchasers and lessees are more likely to switch to another PEV, no vehicle, or a conventional vehicle than to purchase or lease the same PEV. Regarding finance year, results show that relative to 2017, lessees and purchasers in 2018 and 2019 are more likely to choose another, rather than the same PEV. There are also effects for the interaction between PEV type and electric range. Results show that lessees and purchasers are more likely to choose the same PEV, rather than a conventional vehicle, another PEV, or no vehicle at all as the electric range of both BEVs and PHEVs increases. Lastly, results reveal that purchasers are more likely than lessees to change their adoption decision to another PEV, no vehicle at all, or a conventional vehicle.

In regard to socio-demographics, results show that homeowners are 0.420 times as likely than renters to switch to a conventional vehicle. Younger lessees and purchasers are also more likely to switch to a conventional or no vehicle at all than to choose the same PEV. There is also an income effect: those with an income above $200,000 are more likely than those with an income below that threshold to purchase or lease another PEV rather than the same PEV. Lastly, results show that households with more vehicles available per driver are more likely than those with less vehicles available to not to lease or purchase any vehicle at all.

Table 5: MNL regression results for lessees and purchasers for change in purchase decision in absence of CVRP. The reference group is leasing/purchasing the same PEV.

	Another PEV		t-ratio	No vehicle		t-ratio	Conventional		t-ratio
Constant	0.279	**	-2.911	0.168	***	-3.239	1.588		0.919
Home ownership							0.420	****	-4.632
Age				0.973	****	-4.237	0.978	***	-3.402
Discount percent	1.072	*	1.708	1.076	**	2.271	1.069	**	2.040
Range X BEV	0.990	****	-5.340	-0.989	**	-2.175	0.993	****	-5.345
Range X PHEV	0.971	**	-2.945	0.982	*	-1.945	0.978	**	-2.374
Vehicles per driver				1.906	***	3.503			
Income above $200k	1.710	*	1.728						
Finance year 2017	0.258	**	-2.108						
Purchase dummy	1.746	**	2.079	4.060	****	5.516	2.830	****	4.980

Table 6: Model information

Model		Number of observations	Estimated parameters	Final log-likelihood	AIC
Federal tax credit -	Lease	442	42	-711.37	1295.3
-	Purchase	2,583	27	-3580.8	6279.47
CVRP -	Combined	1,131	20	-1109.11	2260.22

6 Discussion

The results of the models reveal useful insights into how lease and purchase behavior may change in the absence of the federal tax credit or CVRP. This was historically relevant as the federal tax credit phased out for Tesla and Chevrolet as they passed 200,000 PEV sales in the U.S., and is still relevant because changes to the tax credit have reduced the number of PEVs and PEV buyers that will be eligible to receive a tax credit due to the introduction of rules on where PEV batteries are made, vehicle purchase price caps, and income caps for buyers. In regard to the CVRP, new income and price caps have been also been introduced to increase the distribution of incentives to lower-income households, who are more sensitive to incentive discounts. We find that several vehicle characteristics such at the discount percent from the tax credit, and the year in which it was financed, in addition to socio-demographics and household characteristics such as home ownership, age, sex, and income are associated with consumers' decision to change their PEV adoption decision in the absence of the tax credit or the CVRP

6.1 Differences in Finance Method

Our findings indicate that as the discount percent increases from both financial incentives- the federal tax credit and CVRP, the probability of not leasing or purchasing any PEV at all increases. These findings indicate that these financial incentives support the adoption of PEVs and encouraged respondents to lease or purchase a PEV. This aligns with results from stated preference studies such as Tal et al. (19), which attributes more than 30% of PEV sales in the U.S. to the federal tax credit, as well as revealed preference studies such Jenn et al. (26), which attributes a 2.6% increase of PEV sales in the U.S. for every $1,000 offered as a financial incentive. We hypothesize that lessees choosing no vehicle in the absence of the federal tax credit may do so because of a large change in lease deposit and monthly costs. These findings align with literature which finds that consumers prefer financial incentives which are received at the time of payment rather than later (17,27,28). Alternatively, those choosing another PEV in the absence of either financial incentive may do so to finance a more affordable PEV. However, respondents were not asked which PEV they would choose in this case.

Our findings also indicate that in the absence of the CVRP, purchasers are more likely than lessees to change their adoption decision. This is a novel addition to the literature on incentive impacts which currently does not control for contract type, and provides insight as to how purchase contracts may be more sensitive to the absence of discounted upfront adoption costs. Previous literature has also found that favorable lease terms are associated with consumers deciding to lease, rather than purchase a PEV, further demonstrating the effectiveness of discounted lease contracts in driving the PEV lease market (7).

6.2 Vehicle Characteristics

Our results for the interaction variable for purchased BEVs and electric range indicates that longer range BEV adopters decisions are less dependent on incentives than lower range BEVs, with purchasers less likely to switch from a higher range BEV to a conventional vehicle or another PEV in the absence of the tax credit or CVRP. This aligns with other findings which have found consumers to prefer higher range BEVs (29).

Our results indicate that the importance of the tax credit may have increased for purchasers from 2018 to 2019. We find that in this time span, in the absence of the tax credit, the probability of purchasing a conventional vehicle rather than a PEV increases. This result aligns with results from Jenn et al. (20), which found from 2015 to 2018 that purchasers were more likely to purchase a conventional vehicle, or no vehicle at all in the absence of the tax credit; the authors suggest that earlier adopters belong to a latent group of innovative consumers who would have adopted a PEV with or without an incentive. However, we also find that the probability of purchasing another PEV, rather than the same PEV, increases in 2019. The CVRP model also reveals that the probability of leasing or purchasing another PEV increases in 2018 and 2019 compared with 2017. This result could reflect the wider variety of PEVs available on the market in that time span. Lastly, the federal tax credit model of lessees revealed that compared with 2018, lessees in 2019 are more likely to lease a PEV, rather than switching to a purchase contract for the PEV. We hypothesize this could be due to the generally lower upfront cost of leasing compared to purchasing, even without the federal tax credit. This could also support previous research which found PEV leasing to be increasing over time (7). Future research should explore PEV lease behavior over time,

such as if consumers continue with PEV technology once the lease term has ended, and if they exhibit PEV lease loyalty, or the tendency to lease a PEV if they have previously leased one, as is the case for the ICEV market.

6.3 Socio-demographics and household characteristics

Our results show that in the absence of both the tax credit and CVRP, renters are more likely than home owners to choose a conventional vehicle rather than a PEV. This finding contributes to the literature which finds home ownership and access to charging at home to be associated with PEV adoption. Davis (30) explored PEV ownership in the U.S. and found that even after controlling for income, homeowners are three times as likely to own a PEVs than renters; authors conclude that renters may have less access to a reliable parking spot and less incentive to invest in home charging equipment. A report by Nicholas et al. (31) additionally found that more than half of the PEV owners charged only at home, while just 14% charged solely from workplace or fast charging opportunities. Hardman and Tal (32) examined PEV discontinuance in California and found that inconvenience of charging and not having access to level 2 charging at home was associated with PEV discontinuance. Consumers without access to home charging may therefore discontinue PEVs if access to charging was a disadvantage to them. As the PEV market shifts from predominantly high-income families to middle income renters, more efforts will be needed to increase charging access for renters who may not be able to install charging infrastructure at home.

The CVRP model also reveals an income effect: households with an income above $200,000, which aligns with the new joint filer income cap, are more likely than those below that threshold, to choose another, rather than the same PEV, in the absence of the CVRP. While this may conform to studies which find higher income households to be less sensitive to incentives, we find no evidence that higher income households are less likely than lower income households to choose no vehicle or a conventional vehicle in the absence of the CVRP.

We also find that having more household vehicles per driver increases the probability of not leasing or purchasing a PEV at all; we hypothesize that consumers making this choice could have other vehicles in their household to meet their travel demand, and perhaps are retaining their older vehicles. Our finding of older purchasers being less likely to change their PEV purchase decision in the absence of the federal tax credit and CVRP varies with stated preference studies which find older age to be negatively correlated with PEV adoption (9). Lastly, our finding of males being more likely to lease no vehicle, or purchase a conventional vehicle also varies from studies which find being male to be associated with PEV adoption (33).

7 Conclusion

This research explores the impact of two financial incentives, the federal tax credit and CVRP, on PEV adoption using stated choice data of PEV owners in California. Our findings indicate that the absence of the federal tax credit or CVRP could have an impact on California's goal of reaching 100% ZEV sales by 2035. Both purchased and leased PEVs will be needed in order to reach this goal; our findings demonstrate that without the federal tax credit or CVRP, both purchasers and lessees are more likely not to finance a PEV at all. Since PEV leasing increases the turnover of PEVs entering the used PEV market, the absence of both financial incentives could also have a negative impact on the variety and supply of PEVs available in the used PEV market. While there is limited research on the used PEV market, it is thought that it could serve a similar function as does the used ICEV market, increasing access to PEVs to lower- and middle-income consumers. Lastly, this research contributes to the literature which finds home ownership to be associated with PEV adoption, with the distinction of finding home ownership to be associated with adopting a PEV rather than a conventional vehicle in the absence of financial incentives.

8 Limitations and Future Work

There are several limitations to this work. The sample is not representative of the entire PEV owning population, since only CVRP recipients were recruited into the survey. Future work includes collecting data

from a more representative sample of PEV buyer in California to eliminate this sample bias. The study area for this research is also specific to California, however the framework used could be expanded and applied to other areas as well. Future research could also focus on and explore the used PEV market specifically.

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10 Presenter Biography

Kelly Hoogland is a PhD student at University of California, Davis, as a part of the Transportation Technology and Policy Graduate Group. She earned her M.S., also at UC Davis, in Energy Systems as part of the Energy Graduate Group. She is interested in consumer adoption of plug-in electric vehicles (PEVs), including researching topics such as consumer finance method, perception of incentives, and purchase intention. The overarching goals of Kelly's research are to investigate the barriers to widespread consumer adoption of PEVs, and the role of policy levers in guiding the transition to a more sustainable transportation system.

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