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Understanding the Influence of the Clean Vehicle Assistance Program on Buyers of Electric Vehicles in California

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Executive Summary

Monetary incentives offered by the state of California have historically played an important role in driving electric vehicle (EV) adoption. The Clean Vehicle Assistance Program (CVAP) launched in 2018, is given as a point-of-sale financial incentive and provides grants and affordable financing to help income-qualified Californians purchase or lease a new or used alternative fuel vehicle. Since CVAP is a relatively new program, there is less research on its effectiveness on low-to-moderate-income buyer decisions. In this study, we analyze whether buyers would purchase a zero-emission vehicle (ZEV) without the CVAP grant and the heterogeneity in the sample across income groups and census tracts in California using binary logistic regression. The study is based on survey responses from 2253 CVAP grant recipients for 2018 to 2022.

Keywords: incentive, ZEV (zero emission vehicle), mandate, finance, user behaviour

1 Introduction

Governor Newsom's Executive Order (N-79-20) established a target to move to 100% zero-emission vehicle (ZEV) sales by 2035 to achieve carbon neutrality in the transportation sector by 2045 [1]. ZEVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel cell electric vehicles (FCEVs). In California, the market share of zero-emission light-duty vehicle sales in the year 2022 (annual sales) was 18.84 percent of the total light-duty vehicle (LDV) sales with the highest sales belonging to the category of BEVs with a range greater than 200 miles [2]. But there are concerns about barriers to adoption including higher upfront purchase price of ZEVs compared to ICEVs [3]. Research on ZEV adoption and diffusion has showcased that among various factors financial incentives are an effective driver of ZEV adoption [4]. This research aims to investigate whether recipients of CVAP grants would purchase their clean vehicle or ZEV without the grant. We will meet that aim using responses to the survey question: "Would you have purchased your clean vehicle if you did not receive a grant through the Clean Vehicle Assistance Program?" The CVAP grant is applicable to low-income buyers who purchase ZEVs or clean vehicles in California. Buyers need to meet an income eligibility criterion that varies based on

household size starting from a maximum gross annual income of $51,520 for household with 1 member to a maximum of $178,640 gross annual income for a household size of twelve. The grant is given at the time of purchase; hence an online application needs to be complete, and the approval letter received before the purchase.

Incentive programs in California include the Clean Vehicles Rebate Program (CVRP), the Enhanced Fleet Modernization Program (EFMP), the Clean Cars 4 All, and the Replace Your Ride Program. In recent years, financial incentives, including the CVRP have been phased out for certain groups including ZEV buyers with household income greater than $135,000 for single filers, $175,000 for head-of-household, and $200,000 (joint filers) [5]. The CVAP launched in the year 2018, is an income-eligibility-based program where the eligibility criteria is based on income and household size (Table 1). In addition to the grant for vehicle there is a grant for charging station in the form of charge card, portable EV charger, and home charger. The grant funds setting up a level 2 charging station of up to $2000 value or a $1000 prepaid charge credit valid at EVGO public charging stations along with a low-speed portable charger [6].

Income cap implications on the CVRP has been captured in the study by [7] where they considered four equal income intervals (less than $ 50,000, $50,000 - $ 100,000, $ 100,000 - $ 150,000, and over $ 150,000) and observed that the moderate to high income group received the greatest share of rebates. Their study was based on CVRP program data from 2010 to 2018. After the income-cap policy implementation in year 2016 where PHEV and BEV consumers with a gross annual individual income greater than $150,000 were no longer eligible to apply for rebate under CVRP, the share of rebates per capita increased in both lower- and middle-income communities and DACs at the 95% confidence level based on their empirical analysis. For both ZEV types the rate of adoption was higher during the quarters that preceded the income-cap policy implementation date. The rate dropped after the policy was implemented, hinting that higher income groups predominantly used the rebates. The results of difference-in difference study by [8], before and after introduction of the RYR program suggested that in 2015, it was successful in promoting the adoption of clean vehicles with evidence that a majority of ZEV purchases made under the program in the South Coast Air Quality Management District (SCAQMD) were additional and would not have occurred without the policy.

Past research on the diffusion of ZEVs has suggested that the demographics of adopters are changing, with the market moving from innovators or the early adopters with high incomes to more price-sensitive segments like renters and multi-unit dwellers for whom monetary incentives can significantly impact the adoption decision [9], [10]. High-income consumers may need less policy support to purchase a PEV, they are also likely to have a place where they can charge their vehicle at home [11]. Studies on the demographics of buyers suggest that the largest cluster (47.9%) consists of higher-income, middle-aged, mostly male, home-owning, highly educated households, with more people in the household [12]. Middle-income renters may need more support with purchase incentives, are less likely to have access to home charging, and may not be able to install a home charger themselves (most Middle-income renters live in multi-unit dwellings) [11]. In the study by [12] middle-income renters are the smallest cluster at 2.1% in 2012 and 7.9% in 2017. This shows that this cluster has experienced the fastest growth. But, in this context it should be remembered that an income-cap of $250,000 for single filers, $340,000 for head-of-household filers, or $500,000 for joint filers was introduced in the CVRP program (in 2016) based on which a large portion of higher-income buyers were not eligible to apply for the rebate post March 2016[13].

Identifying the heterogenous PEV adopters is an important contribution for policymakers, automakers, and academic[12]. While supply-side regulations focus on automakers, demand-side initiatives focus on consumers, providing financial incentives to buy PEVs [14]. Since the cost of the PEV is one of the primary barriers to adoption for consumers belonging to the middle-income group, financial incentives have been introduced to reduce the upfront cost of ZEVs in comparison to their Internal Combustion Engine Vehicle (ICEV) counterparts [14]. Given the widespread availability of the incentive programs and the potentially high cost of offering incentives worth thousands of dollars per vehicle, it is important to understand consumer response to these subsidies and to quantify the benefits and costs of their implementation.

Policy incentives, including the federal tax credit and numerous state and local incentives stimulated BEV adoption in California [15]. Though both rebate importance and distributional concerns associated with rebate allocation has been studied in the past in relation to the CVRP program, this study will evaluate the effectiveness of the point-of-sale CVAP with recent data starting from 2018 and going up to 2022.

Disadvantaged and low-to-moderate income communities are being prioritized for climate mitigation projects as they suffer from the negative externalities of transportation[16]. This study shall offer insights on how the rebate offered by the program varies spatially across income groups allowing for a more targeted incentive structure. Second, the distributional analysis will allow for a better understanding of how the income-eligibility based program will impact the allocation of rebates more equitably across income groups in the counties of California. It is essential to analyse where the grants are concentrated since the motivation of this study is to observe whether the income-eligible grant is reaching the intended recipients.

Table 1: Household size and Corresponding Maximum Gross Annual Income for CVA Program Eligibility

Household Size (Number of People)	**Maximum Gross Annual Income**
1	$51,520
2	$69,680
3	$87,840
4	$106,000
5	$124,160
6	$142,320
7	$160,480
8	$178,640

2 Data and Method

2.1 Data Overview

The CVAP was launched in 2018. The program is administered by the California Air Resources Board (CARB) and to improve the understanding of the effectiveness of the monetary incentive a voluntary consumer survey has been conducted since 2018 to 2022 for ZEV buyers who applied and were approved recipients of the grant. The consumer survey covers topics including interest in and research on ZEVs, sources of information used, decision making process, dealership experience, rebate essentiality, socio-economic, and sociodemographic characteristics. For this study we will leverage data from surveys administered from 2018 to 2022, focusing only on BEV, Hybrid, and PHEV buyers. The number of observations is 2253 responses. Eighty six percent responded that without the incentive was they would not have purchased their ZEV and only about fourteen percent responded that they would have purchased a ZEV without the grant. This study will allow us to capture the impact of the incentive over the last 5 years based on the sample.

The trend for the stated impact of CVAP on the decision to purchase an EV is shown in Figure 1 over the period of 2018 to 2022. The figure suggests that majority of respondents report they would not have purchased their EV without the grant (Yes = 14%, No = 86%). Table 2 summarizes descriptive statistics of ZEV buyers who received the CVAP grant. We present descriptive statistics for whole survey sample and for response groups who mentioned they would not have purchased their clean vehicle without the CVAP grant (category 0) and those who indicated they would purchase a clean vehicle without the grant (category 1).

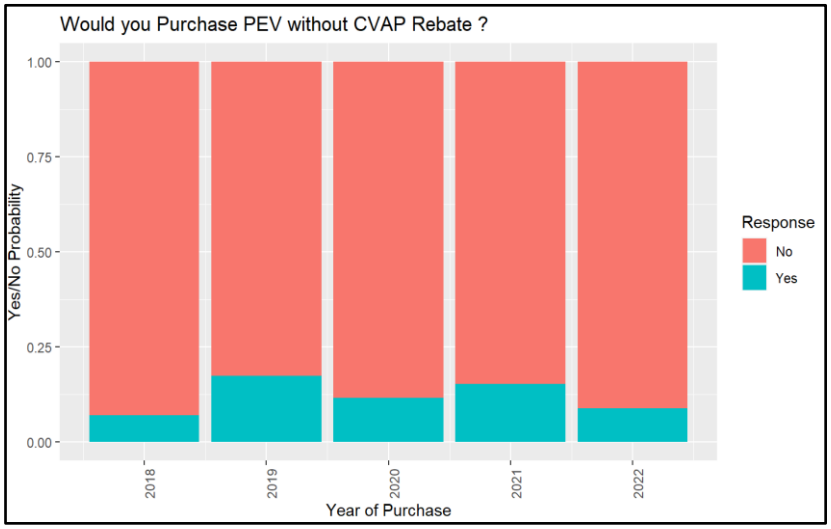

Figure 1: Response Statistics for the Dependent Variable

Table 2 shows that BEVs dominate the sample with 71% share in the full sample and 73.38% and 70.64% in category 1 and category 0 respectively, followed closely by the PHEVs which had a share of 25.61% in the full sample and 23.38% and 25.96% in category 1 and category 0, respectively. The program offers incentive for both new and used vehicles and we can see that new vehicles comprise 67% of the total share in the full sample. Within each response groups, new vehicles' share is higher. On investigating the share of leased and purchased vehicles, 86.15 % of the vehicles for which the grant was approved were purchased and 13.85% leased.

Descriptive statistics show that most rebate recipients live in rented homes (~60%) and the remaining owned their residence. A possible reason might be that the targeted audience are lower-income households. As the targeted recipients are lower-income communities and disadvantaged communities, we did a data exploration on the sample and found that almost 81% of the recipients did not belong to disadvantaged community (DAC) and almost 59% of the total respondents did not belong to low-to-moderate income (LMI) community. The variable for DAC in the sample is consistent with the definition in the CalEnviroScreen adopted by the CalEPA [17]. The low income category is defined as these households earning less than 80% of the local area median family income, and the moderate income category is defined as these households earning between 80% and 120% of the local median family income [18]. Among the rebate recipients for the full sample, it was observed that 58% were male and the remaining 42% we female/binary/undisclosed identity. Education level descriptive statistics show that 66% of the full sample had a college degree (Associate/Bachelor/Postgraduate). We found that the Tesla Model 3 and Model Y are the most common ZEVs with an individual share of 22.59% and 19.44%, respectively.

Table 3 gives statistics of the age, household size, income, loan amount, and the grant received for charging infrastructure to understand the socio-economic characteristics of the buyers as we consider them to be of importance in the evaluation of equitable distribution of the grant. We also considered vehicle mpg and total cost of vehicle for the vehicle characteristics. The average age of the grant recipients is around 41 and the average household income is $42,337, indicating that the recipients belong to lower-income communities. The median value for the charging infrastructure grant is $2000 which suggests that most of this grant was given for setting up a home charger.

Table 2 : Descriptive statistics of the total sample and within responses to the question on rebate impact on buyers' decisions.

Variable	Subset	Will not Purchase without CVAP (0)	Will Purchase without CVAP (1)	Total Sample
#Respondents		1945(86.33%)	308(13.67%)	2253(100%)
Powertrain Technology	Electric	1374(70.64%)	226(73.38%)	1600(71.02%)
	FCEV	4(0.21%)	1(0.32%)	5(0.23%)
	Hybrid	61(3.14%)	9(2.92%)	70(3.11%)
	Plug-In-Hybrid	505(25.96%)	72(23.38%)	577(25.61%)
New/Used Vehicle	New	1292(66.43%)	219(71.10%)	1511(67.07%)
	Used	653(33.57%)	89(28.90%)	742(32.93%)
Leased (Yes/No)	Yes = Leased	278(14.29%)	34(11.04%)	312(13.85%)
	No = Purchased	1667(85.71%)	274(88.96%)	1941(86.15%)
Vehicle Make - Top 6 popular vehicle makes in the full sample	Tesla	814(41.85%)	160(51.95%)	974 (43%)
	Chevrolet	287(14.75%)	42(13.64%)	329(14.6%)
	Toyota	201(10.33%)	22(7.14%)	223(9.89%)
	Nissan	118(6.07%)	14(4.55%)	131(5.81%)
	Ford	104(5.35%)	11(3.57%)	115(5.1%)
	Kia	96(4.94%)	19(6.17%)	115(5.1%)
Vehicle Model - Top 5 popular vehicle models in the full sample	Tesla Model 3	425(21.84%)	84(27.27%)	509(22.59%)
	Tesla Model Y	369(18.97%)	70(22.72%)	438(19.44%)
	Chevy Bolt EV	164(8.43%)	24(7.79%)	188(8.34%)
	Prius Prime	148(7.61%)	16(5.19%)	164(7.3%)
	Nissan Leaf	118(6.07%)	14(4.55%)	132(5.86%)
Luxury Make	Audi	4(0.21%)	1(0.32%)	5(0.22%)
	BMW	51(2.62%)	10(3.25%)	61(2.71%)
	Lexus	4(0.21%)	0%	4(0.18%)
	Mercedes-Benz	51(2.62%)	0%	5(0.22%)
Home Ownership	Yes = Own	743(38.20%)	126(40.91%)	869(38.57%)
	No = Rent	1192(61.29%)	182(59.09%)	1374(60.99%)
Disadvantaged Community (Yes/No)	Yes	361(18.56%)	63(20.45%)	424(18.82%)
	No	1584(81.44%)	245(79.55%)	1829(81.18%)
Low-to-moderate Income Community (Yes/No)	Yes	802(41.23%)	120(38.96%)	922(40.92%)
	No	1143(58.77%)	188(61.04%)	1331(59.08%)
Gender	Male	1139(58.65%)	170(55.37%)	1309(58.2%)
	Female/ Binary/	803(41.35%)	137(44.63%)	940(41.8%)

	Undisclosed			
Education level	Associate/ Bachelors/ Postgraduate Degree	1485(66%)	202(65.8%)	1283(66.03%)
	High School/ No Degree/ No response	765(34%)	105(34.2%)	660(33.97%)

Table 3 : Statistical Summary of key variables

Variable	Min	Median	Mean	Std. Dev	Max
Age	17	39	41.46	13.9	87
Household size	1	2	2.364	1.54	12
Annual household income	0	38709	42337	27350.41	177759
Grant amount	1500	5000	4873	467.10	5000
Loan Amount	0	6500	10367	16450.44	91768
Grant for Charging infrastructure	0	2000	1358	901.52	2000
Vehicle mpg	28	120.5	120.1	21.06	142
Total vehicle cost	5753	40713	38053	17050.01	108499

The rebate concentration as per the CVAP recipients from the Survey by the CARB suggests that the rebates are concentrated more in the counties such as Sacramento, Santa Clara, Marin, San Mateo, San Francisco, Los Angeles, Orange County, San Bernardino, Riverside, and San Diego (Figure 2). The distribution of rebates is lesser in Humboldt, Trinity, Shasta, Tehama, Imperial, and Kings counties.

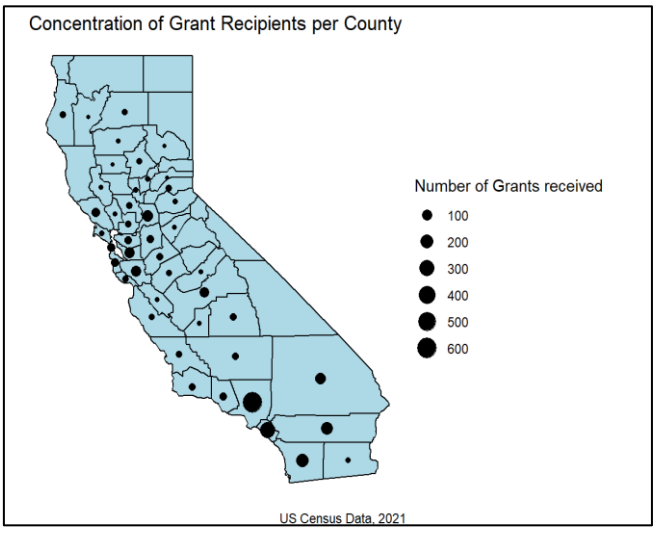

Figure 2: Rebate Concentration in Counties of California

2.2 Method

We developed a binary logistic stated preference choice model to examine the effect of socio-economic characteristics of the decision maker (buyer) and vehicle characteristics on the dependent/response variable. We used the apollo choice modelling package of R programming language to run our model. The response variable is a binary variable indicating whether consumers "Would not have purchased the clean vehicle without the CVAP grant" (coded as 0) or "Would have purchased the clean vehicle without the CVAP grant" (coded as 1), based on survey responses to the question, "Would you purchase a Clean Vehicle without the Grant through the Clean Vehicle Assistance Program?". The explanatory variables in the model include:

- vehicle attributes like miles per gallon equivalent and cost of the vehicle
- sociodemographic characteristics,
- socio-economic characteristics,
- census tract characteristics like disadvantaged community (DAC) or low-to-moderate (LMI) income community, and
- CVAP specific variables such as the grant for vehicle, grant given for the charging equipment, and the loan amount from Beneficial State banks and other lenders.

We excluded the data for FCEV in this study. We converted responses stated as "No data" under grant for charging infrastructure to $0 to capture the effect of other independent variables in the model. To interpret the coefficient for loan amount the variables were log-transformed. We observed the effect of home ownership (own/rent) as the program offers grant for setting up home charging infrastructure along with the grant for the vehicle [6]. The program is income eligibility based so we included the percentage below Federal poverty line in the model along with the indicator variable for disadvantaged communities [6]. We would like to understand how the reported recipients from disadvantaged communities are correlated to the response variable and whether there is statistical significance.

The likelihood estimation coefficients, the statistical significance level, and one-tailed robust t-statistics have been summarized in the results section in Table 4 After data cleaning, the sample size of the model (N) is 2246 unique survey responses. Correlation tests were conducted to address multicollinearity within the independent variables and to maximize the overall model's log-likelihood estimation.

The Kendall-tau correlation coefficients has been studied to define the null and alternative hypothesis and is used for non-parametric variables. For the continuous variables, the Pearson correlation coefficient is used to accept or reject a null and alternative hypothesis.

The Null and Alternative Hypotheses for the correlation test:

H_O: The variables are uncorrelated

H_A: The variables are correlated

The independent variable for the DAC indicator was correlated to the indicator for LMI buyers, hence we removed the variable for LMI and retained only the DAC indicator variable. The percentage below Federal poverty line(FPL), household size, and log-transformed income were found to be correlated with each other, so we dropped the income and household size variables from the model. The model was estimated, and results reported in (Table 4).

3 Results

We estimated the binary logistic choice model's response variable that answered the question whether the buyer would purchase the clean vehicle without the CVAP grant (Yes = 1, No = 0), and the independent variables mentioned in section 2.2. The model with maximized log-likelihood estimate is reported in (Table

4) along with the adjusted rho-square, AIC, and BIC values that indicate the goodness of fit of the model. The likelihood estimates and one-tailed robust t-statistics have been reported and analysed below.

It is important to note that if a decision maker in this model responds “Yes” (1 in the binary response) the grant reportedly did not impact their decision to buy the vehicle. If the decision maker responds “No” (0 in the binary response) the buyer would not have purchased their ZEV without the grant meaning the grant impacted their decision to buy a ZEV. Key findings from the model (Table 4) suggest that age of the buyer, gender, college degree, homeownership, percentage below the Federal poverty line, the grant received for installing a charger, and the total cost of the vehicle are statistically significantly correlated to the response variable at 5% significance level. The loan amount from Beneficial State Bank and other lenders is statistically significantly correlated to the response variable at 10% significance level. The CVAP specific independent variable for grant on vehicle purchase, vehicle characteristic such as miles per gallon equivalent, and neighbourhood effects such as buyers staying in census tracts defined as disadvantaged community are not statistically significantly correlated with the response variable.

The outcome of our model suggests that since age of the buyer is positively correlated to the response variable, if the age of the buyers of ZEVs is higher their likelihood of responding that they would have bought the clean vehicle without the grant increase. Male buyers had higher likelihood of responding that they would not purchase their ZEV without the grant since their coefficients are negatively correlated with the response variable. Buyers with at least an associate level college degree had higher likelihood of responding that they would not purchase their ZEV without the grant because their coefficients are negatively correlated with the response variable. Homeownership is negatively correlated with the response which suggests that homeowners had higher likelihood of responding in favour of the CVAP grant. The buyers of ZEVs who took additional loan from Beneficial State Banks and other lenders had higher likelihood of responding that they would have bought the clean vehicle without the grant, as loan amount is positively correlated to the response. The negative correlation of federal poverty line with the response indicates that as the percentage below federal poverty line increases, the likelihood of responding in favor of the grant is higher.

The buyers who received higher grant amount for charging infrastructure had higher likelihood of responding that they would have purchased their ZEV without the grant, based on the positive correlation with the response. When buyers purchased more expensive vehicles, the likelihood of responding that they would not have purchased without the grant is higher.

Table 4:Estimation results for whether the buyer will purchase without the CVAP grant (Yes = 1, No = 0)

Variable	**Estimate**	**t-ratio**
Constant	3.973829	0.869683
Age	0.012886**	2.516481
Gender	-0.25117**	-1.94934
Degree	-0.23764**	-1.76898
Homeownership	-0.22621**	-1.56573
Federal Poverty Line	-0.14738**	-2.33777

Disadvantaged Communities (DAC) (1 - Yes, 0 - No)	-0.17301	-1.09632
Grant amount	0.119346	0.222022
Loan amount	0.025409*	1.4499
Vehicle mpg equivalent	-0.00213	-0.56634
Grant for Charging Infrastructure	0.000168**	2.344731
Total Vehicle Cost	-0.29506**	-2.00904
Goodness-of-fit test results		
Log-likelihood	-875.05	
Number of parameters	12	
Adjusted Rho-Squared	0.4302	
AIC	1774.1	
BIC	1842.7	

Statistical significance: <0.05 '**' <0.1 '*'

4 Discussion of Policy Implications

The result in section 3 gives an understanding of the status of the CVAP grant and insights on the distribution of the monetary incentive. This will help policymakers evaluate any equity concerns that may still exist with the rebate allocation and develop more targeted programs if required. Taxation related policies such as carbon pricing, even though being debatable, can act as a catalyst for ZEV adoption for all income groups in the sample as overall money savings is one of the attitudinal questions mentioned in the adoption survey. Overall, we can say that most recipients considered the grant instrumental in their purchase decision. The spatial data exploration for the rebate distribution in the counties of California shows that rebate is spatially distributed with higher concentration in some counties and insignificantly distributed in many others, hence the need for more equal distribution and policy support. On contrasting with a past research on the CVRP survey from 2012 to 2015 around 75% respondents considered the state rebate very important. This percentage has increased to 86% for our sample but for a more recent data (2018-2022).

A similar study on the New York State's Drive Clean Rebate examined consumers who would not have purchased/leased their ZEV without the rebate [19]. The result of the study shows that additional financial incentives; besides the grant for the vehicle itself was considered instrumental in the buyer's response which stated that he/she would not have bought the clean vehicle without the grant. This outcome does not agree with our observations that the recipients of loan amount and charging station grants would have purchased the vehicle without the grant. A possible reason might be that these grants are provided as additional program features but in partnership with third parties such as GRID alternatives and Beneficial State Banks. A possible recommendation would be to spread awareness among the buyers from lower-income communities and DACs about the additional grants so that they can take advantage of these financial assistances.

Research on the impact of CVRP rebate showcase higher odds of a buyer being "rebate essential" (consider the grant instrumental in their decision to buy a ZEV) is associated with younger age and having a lower-income [20]. This finding does not agree with our results with respect to age of the buyer as we observed that the likelihood of responding that the buyer would not have purchased the ZEV without the CVAP grant was correlated with older age. We also observed as the buyer's income level below the FPL increased, they were more likely to respond that they would not have purchased without the grants and this agrees with the study on CVRP recipients discussed earlier. This can be a recommendation for policymakers that lower-income buyers need policy support for their transition to a clean vehicle.

5 Conclusions

To summarize we can say from the results that the grant is more influential in the decision to purchase a ZEV for the following buyers holding all else constant:

- Buyers of more expensive vehicles
- Older buyers
- Buyers with a college degree
- Buyers who are below the FPL
- Buyers who were homeowners
- Buyers who did not receive the grant for charging infrastructure.
- Buyers who did not receive loans from Beneficial State Banks and other lenders

Results from this study show the Clean Vehicle Assistance Program may be more efficient than the Clean Vehicle Rebate Program in terms of the buyer's response to the incentive [20]. This could be because the program is designed for lower-income communities and DACs or because it is delivered at the point of purchase. Yet, considering the huge amount of dollars invested in giving incentives it's important to observe the vertical equity of distribution of rebate amongst income groups as part of future analysis.

5.1 Limitations and Future Research

We would like to observe the impact of the charging station type on the buyer's response in addition to the grant they received for the charging station. Charging station types mentioned are charge cards (and portable chargers (provided to buyers by automakers), and home charging equipment. Charge card and portable charger are given to buyers who do not have the option to charge at home. We would like to observe the effect of adding this variable to the model and how it interacts with home ownership (own/rent) and the type of building, whether single detached home or multi-dwelling unit. This charging credit and portable charger option has been offered by the CVA program from the start of year 2020[6], hence observing the trend in buyer's response to this grant is significant. Homeownership has been observed to be significantly correlated with the buyer's response that they would not have purchased the vehicle without the grant. Hence the home charging station type is an important variable for future study.

We would also explore in the future the survey questions related to the attitude of the buyer, especially constructs such as environmental consciousness, energy savings, fuel cost savings, and overall savings of the buyers whether these constructs lead to a rational choice. Latent attitudinal variables such as interest towards vehicle performance would also be considered as part of finer nuances of the model. Survey questions related to awareness of the CVA program, dealership experience, and outreach efforts are other factors that we would explore as part of future research.

The distribution of the grant in low-to-moderate income census tracts and DACs needs to be studied to evaluate the success of the program in equitably distributing the funds. Using the suits coefficient, we intend to measure the equitable distribution of rebate across income groups as the program is based on income-eligibility criteria.

Homogeneity of the dataset is a possible limitation in capturing varied behavioural trends since eighty-six percent of the sample responded that they would not have purchased their clean vehicle without the CVAP grant.

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