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Understanding the Distributional Impacts of Vehicle Policy: Who Buys New and Used Alternative Vehicles?

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February 2018

A Research Report from the National Center for Sustainable Transportation

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EXECUTIVE SUMMARY

This research project explores the plug-in electric vehicle (PEV) market, including both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), and the sociodemographic characteristics of purchasing households. We use detailed micro-level data on PEV purchase records to answer two primary research questions.

1) We seek to provide evidence for or against conventional wisdom that suggests PEV adoption is more common among high income households and less common amongst minority groups. We use a detailed dataset that provides information about the demographic characteristics of the buyers allowing us to empirically confirm the extent to which adoption during this period was concentrated amongst particular demographic groups
2) To the extent that PEV adoption gaps exist, to what extent do adoption patterns support the possibility that low-income and minority ethnicity buyers of PEVs experience barriers to purchasing in the new and used market? Our dataset allows us to assess the relative difference in price and distance traveled to purchase a car between PEVs and conventional vehicles across ethnic and income categories.

Our results confirm that low-income households exhibit a lower share of PEV purchases than they do for conventional, internal combustion engine (ICE) vehicles. Households with annual income less than $50,000 comprise 33 percent of ICE purchases and only 14 percent of PEVS. By comparison, high-income households earning more than $150,000 annually comprise only 12 percent of ICE purchases and 35 percent of PEV purchases over our sample period. Similarly, unsurprising patterns can be seen across ethnicities. For example, non-Hispanic Whites represent 41 percent of ICE purchases but 55 percent of PEV purchases, as compared to Hispanics (38 percent of ICE and 10 percent of PEVs) and African Americans (3 percent of ICEs and 2 percent of PEVS).

These differences naturally raise questions about barriers to PEV adoption among low-income and minority ethnic populations. By comparing outcomes in the ICE, hybrid, and PEV markets across income and ethnic groups, we are able to test whether price discrimination and barriers to market access are higher in PEV markets for low-income and minority ethnic groups. We find that, overall, they are not, although there are mixed results for the used PEV market. In general, non-white, low-income populations face higher prices in the used PEV market, relative to a baseline, than they do in the new PEV market. While some people travel farther to buy used PEVs than they do to buy used ICE vehicles, there is not a pattern that would indicate systematic discrimination (e.g. Hispanics travel farther to buy used PHEVs but less far to buy used BEVs). While we admit that our empirical approach cannot control for all potential vehicle composition effects, we view our results as being most consistent with a market that provides access to all ethnicities and income groups.

Introduction

Policy makers consider alternative fuel vehicles an important policy lever to reduce urban air pollution, lower carbon emissions and reduce overall petroleum consumption. Federal, state and local governments offer incentives to encourage consumer adoption of these vehicles. But adoption of these vehicles by African-American, Hispanic and low-income consumers has lagged adoption by Asian, White and high-income consumers. The incentives for alternative vehicles purchases have accrued disproportionately towards high-income households (Borenstein and Davis, 2015).

The need to understand purchase patterns for alternative fuel vehicles is especially important in light of the bold targets set for increasing electric vehicle penetration or phasing out internal combustion engines (ICEs) entirely. In the past year, countries announcing plans to ban ICEs sales include France and UK (by 2040), Norway (by 2025), India (by 2030), and China (timetable not set). Germany has announced plans to put 1 million electric vehicles on road by 2020.[1] Closer to home, Governor Brown issued an Executive Order B-16-12 that calls for 1.5 million zero-emission vehicles statewide by 2025 as part of a goal to reduce transportation emissions in cars and trucks by 50 percent by 2030.

Using a unique and rich dataset of recent electric vehicle (EV) purchases 2011 to 2015, we examine the proliferation of EVs in California, during a period of time in which the market has matured to include new technologies, a robust secondary market, and a suite of policies that promote switching away from gasoline-powered cars. Understanding who is buying these EVs and to what extent these policies are benefiting low-income households is central to the sustainability of alternative vehicle policies.

We analyze the data to answer two questions. First, we examine the characteristics of ZEV buyers and whether patterns of adoption vary across demographic groups or incomes. Although conventional wisdom suggests that adoption is more common among high income households and less common amongst minority groups, our data provides information about the demographic characteristics of the buyers. Thus, we can empirically confirm the extent to which adoption during this period was concentrated amongst particular demographic groups.

The transaction data for California largely confirm the conventional wisdom. High income buyers are more likely to purchase EVs than low-income buyers; non-Hispanic white and Asian buyers are also more likely to purchase EVs than other minorities. These effects are particularly pronounced in the new car market. Low-income buyers and minority buyers are less likely to purchase EVs, and when they purchase EVs are more likely to buy used vehicles. This suggests that high income buyers captured a disproportionately large share of EV incentives during this period.

[1] http://money.cnn.com/2017/09/11/autos/countries-banning-diesel-gas-cars/index.html
https://www.theguardian.com/world/2017/sep/11/china-to-ban-production-of-petrol-and-diesel-cars-in-thenear-future

Based on our findings, we then examine the data for evidence that market barriers impede adoption of alternative fuel vehicles amongst particular demographic groups. The success of targeting incentives towards lower income and minority buyers depends on whether these buyers will switch from traditional vehicles powered by internal combustion engines (ICEs) towards alternative fuel vehicles, or whether impediments might limit substitution. In this paper, we examine two possible barriers during the car buying process that might impede the adoption of alternative fuel vehicles amongst low income and minority car buyers.

The first market impediment we investigate relates to price discrimination across demographic groups or income brackets. The decision to purchase a vehicle depends on the price a potential buyer is able to negotiate. Car dealerships price-discriminate between customers – if a particular consumer has a strong preference for a particular vehicle, the car dealership may be able to negotiate a higher price than if a consumer is indifferent between different vehicles. Even if alternative fuel vehicles are available, low income or minority buyers might pay different prices as a result of the negotiation with dealerships.

The second impediment we consider relates to the availability of alternative fuel vehicles. If few low income or minority buyers purchase alternative fuel vehicles, car dealerships near low income or minority communities might be unwilling to carry a large stock. As a result, a potential car buyer might be less inclined to choose an alternative fuel vehicle as opposed to a vehicle powered by an internal combustion engine (ICE). Although we do not observe the stock of vehicles at each dealership, we can observe how far the buyer of an EV had to travel to purchase an EV from a dealer. Put differently, an individual who wants to purchase an alternative fuel vehicle might have to travel to a dealership far from their home, if dealerships in their community do not carry a wide selection of alternative fuel vehicles.

While we do observe some (modest) differences in the prices paid and distance traveled by different demographic groups, we do not find strong evidence consistent with either of these impediments to hybrid vehicle adoption. In the new PEV market in particular, there is little evidence of minority ethnic groups paying higher prices or traveling longer distances to buy their alternative fuel cars. In the used car market, the results are more mixed. Low-income non-whites tend to pay more relative to baseline for used PHEVs and BEVs than in the new car market. But, collectively our analysis suggests the low rate of adoption amongst particular demographic groups and income brackets might be the result of greater price sensitivity or demographic-specific preferences unrelated to negotiation or the availability of EVs.

Background and Previous Literature

Our work relates to two existing literatures: the first studying incentives and new vehicle adoption and a second examining the question of ``environmental justice,'' the distributional impacts of environmental policies on different demographic groups. An established literature examines the effect of government incentives and fuel prices on hybrid vehicle adoption. Gallagher and Muehlegger (2011) examine the effects of federal, state and local incentives and fuel prices on consumer hybrid adoption and find that the state sales tax waivers are most strongly associated with hybrid vehicle adoption and that fuel prices are positively correlated with adoption of high fuel economy hybrids. Similarly, Berensteanu and Li (2011) and Chandra et al. (2010) find significant effects from gasoline prices and tax incentives on consumer hybrid purchase decisions. Sallee (2011) estimates the incidence of tax incentives for sales of the Toyota Prius. He finds that consumers captured a majority of the subsidies, despite the fact that Toyota faced capacity constraints because of excess demand for the Prius during his period of analysis. But, unique to this literature, our transaction-level data provides information about the characteristics of hybrid vehicle buyers and hence, allows us to better understand which demographic groups are most likely to purchase alternative fuel vehicles in the early years of adoption. In contrast, the existing literature has typically used aggregate data, greatly complicating any detailed analysis of the demographics of buyers.

The environmental justice literature documents empirically the distributional impacts of market-based policy instruments like pollution cap-and-trade regulations. Concerns about environmental justice are the primary motivations for many of the programs that encourage EV adoption, including the recent Enhanced Fleet Modernization Program pilots in California. The literature documents disadvantaged groups are more likely to live proximate to pollution point sources and benefit from policies designed to reduce pollution. Bae et al. (2007) documents that low-income and minority families are disproportionately located closer to freeways and are more exposed to air pollution hot spots and Bento et al. (2015) studies the effect of the 1990 Clean Air Act Amendments (CAAA) on home values and finds air quality and home values increased most at locations close to pollution monitors. Since, lower-income families are more likely to own homes in these locations, the paper concludes that the air quality benefits from the CAAA accrue to the low-income homeowners. Families in the lowest quintile of the income distribution received on average annual benefits from the program of 0.3% of their income which is double that of the highest quintile families (using housing prices are a measure of welfare).

A related literature examines whether the emissions reduction benefits of market policies disproportionately accrue to advantaged demographic groups. Ringquist (2011) examines the Clean Air Act Amendment's sulfur dioxide allowance trading program and finds emissions reductions positively correlated with local population educational attainment. In contrast, Fowlie et al. (2012) uses quasi-experimental evidence to estimate the effect of RECLAIM on NOx emissions in southern California. The authors find an average decrease in NOx emissions of 20% relative to a counterfactual in which the RECLAIM facilities remained under direct government "command-and-control," but the emissions reductions associated with the RECLAIM program were not strongly correlated with local demographic characteristics.

Data and Results

To study patterns of adoption by different demographic groups, we use data on approximately 400,000 vehicle purchases in California from a third-party data vendor. Our data contain all new and used California sales of zero-emission vehicles ("ZEVs") as classified by the California Air Resources Board from 2011 through December 2015. In total, approximately 200,000 ZEVs were sold during this period, including approximate 38,000 Chevy Volts, 35,000 Nissan Leafs and 27,000 Tesla Model S. In addition, we have a similarly sized, representative random sample of the sales of select "comparable" vehicles. The select "comparable" vehicles consist of the passenger vehicles most similar to ZEV models, and include both hybrid electric vehicles ("HEVs") and ICE models such as the Toyota Prius, Honda Civic, Honda Accord and the Ford Focus.

For each transaction, the data reports the price paid by the consumer, the location of dealership, the zip code of the buyer and buyer demographic characteristics (e.g., race, gender, income, age) for each transaction and other information about the transaction (e.g., whether the vehicle was leased, odometer reading). Using the population-weighted centroids of the zip code of the buyers and dealerships, we use Bing maps to calculate the shortest driving distance the centroid pairs. We use this as a measure of the distance between a buyer's home and the dealership at which he or she purchased the vehicle. n doing so, we make the implicit assumption that the geographic distance imposes increasing transportation and search costs. Thus, greater distance reflects a greater potential barrier to EV adoption.

We focus on the purchase decisions by California consumers over 2011-2015. The limited sample period offers several attractive features for examining our primary questions of interest. This is a period of time in which BEVs and PHEVs were just beginning to take off, and thus, might provide a more suitable guide for other nascent transportation technologies. Moreover, this was a period of time during which California vehicle incentives, while generous, were largely the same for all private buyers. Thus, the patterns of adoption might better reflect adoption patterns undistorted by targeted incentives to particular demographic groups.

ZEV Purchases by Demographic Group

We begin by verifying the popular assumption that initial adoption of alternative fuel vehicles has been concentrated amongst high income individuals and particular demographic groups. As Borenstein and Davis (2015) notes, incentives for hybrid vehicles largely accrued to high income households. We begin by examining whether the conventional wisdom for hybrid vehicle adoptions carries over to California EV adoption.

In Figures 1 and 2, we graph the fraction of ICE, HEV and alternative fuel vehicle sales in our data purchased by different demographic groups. In Figure 1, we group buyers into one of four income brackets: less than $50k, $50k - $100k, $100k - $150k and more than $150k. This first two pie charts graph the fraction of comparable ICEs and HEVs purchased by each income bracket. For ICE and HEVs, buyers with incomes below $100k account for 72% and 63% of purchases respectively. These income brackets include for the majority of Californians, hence, it is unsurprising that they also account for the majority of ICE and HEV purchases. In contrast, the majority of alternative fuel vehicles are purchased by buyers with incomes above $100k. The market shares presented in the pie charts confirm the conventional wisdom – high income buyers account for a disproportionately high fraction of alternative fuel vehicle purchases.

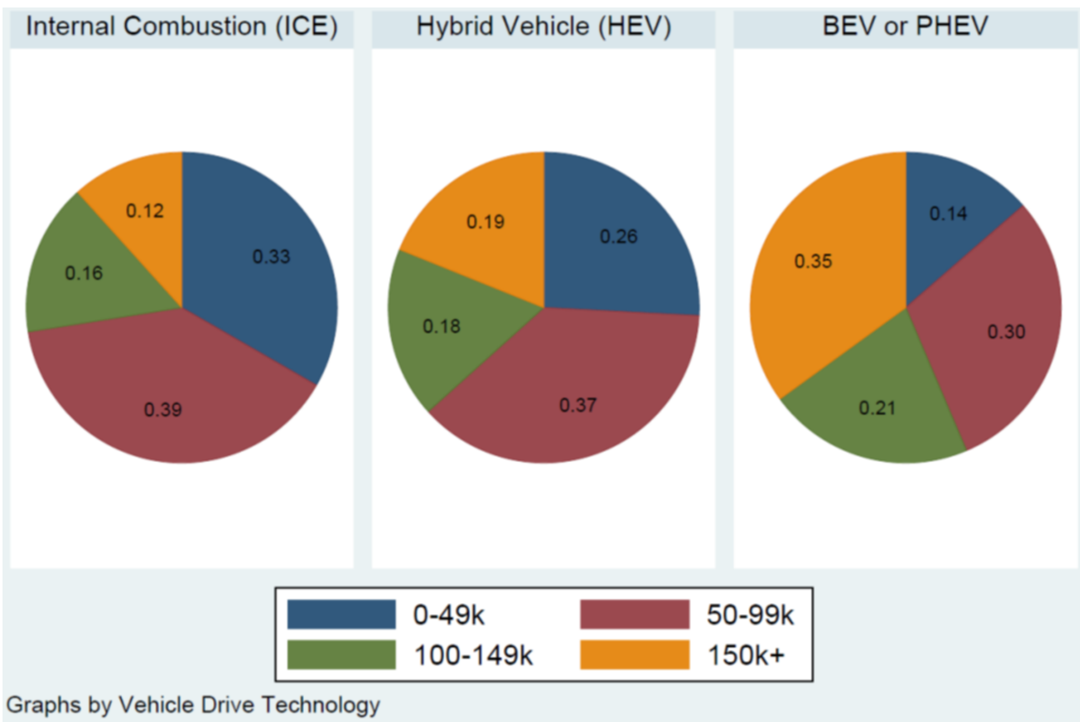

Figure 1. Fraction of Sales by Income Bracket

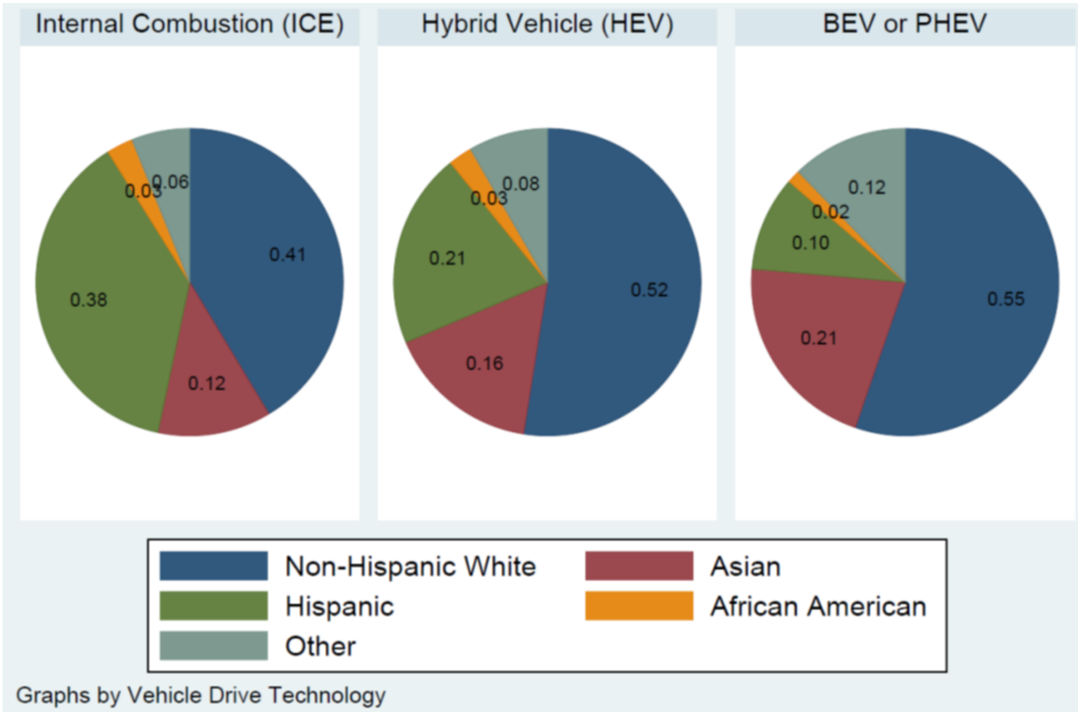

Figure 2. Fraction of Sales by Ethnicity

In a similar fashion, in Figure 2 we split the vehicle purchases by demographic group, and again confirm the conventional wisdom surrounding alternative fuel vehicles. Hispanic and non-Hispanic whites comprise roughly equal fractions of ICE buyers in our data at 38% and 41% respectively. But non-Hispanic whites purchase 55% of the alternative fuel vehicles, compared to 10% of purchases by Hispanics. Asian buyers show similar patterns to non-Hispanic whites, accounting for a relatively high fraction of alternative technology vehicle purchases relative to their share of traditional vehicle purchases.

We also break down the sales of BEV and PHEVs to examine the market shares of sales of new and used EVs, by income bracket and demographic group in Figures 3 and 4.

Figures 3 plots the fraction of all California BEV and PHEV sales over the 2011-2015 period, broken out by whether the vehicle is new or used and by income. Several patterns emerge from the figure. The first is that the vast majority of BEV and PHEV sales in California during the period are new vehicles. This comes as no surprise – penetration of BEV and PHEV vehicles increased substantially during this period. Roughly two-thirds of the used EV vehicle sales in our study period occurred during 2015. In this year, used vehicle sales comprised roughly 15 percent of all vehicles sales.

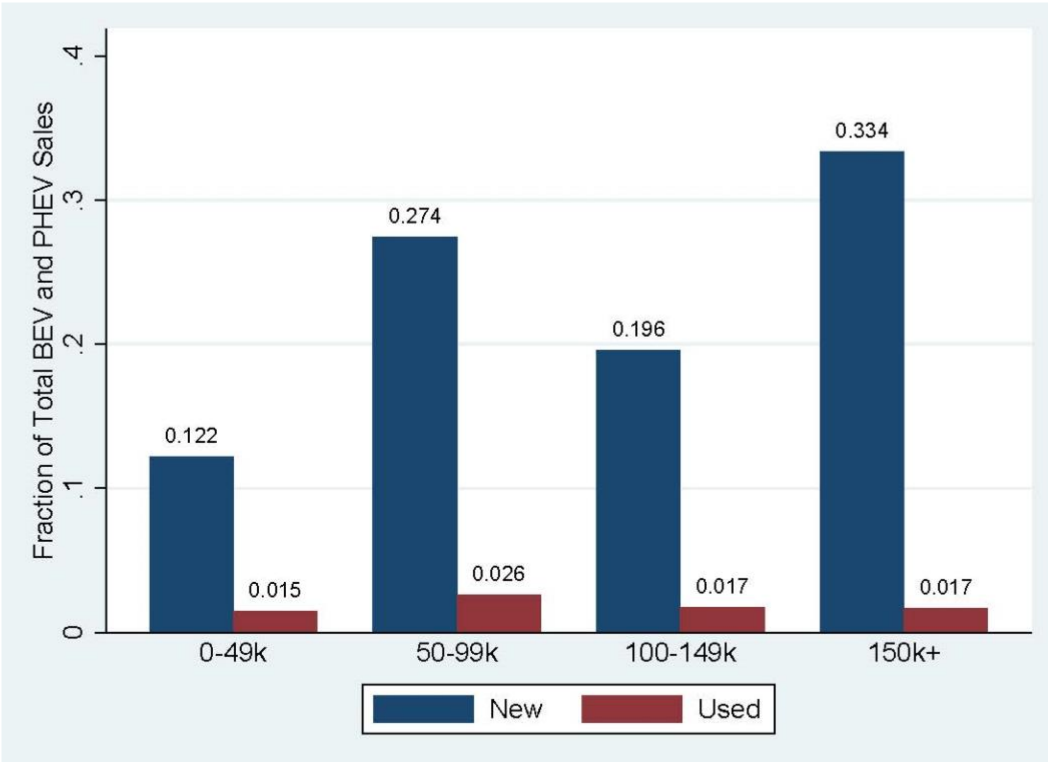

Figure 3. Fraction of New and Used BEV and PHEV sales, by Income

Yet, we still observe patterns in used versus new vehicles purchases by income bracket. High income buyers purchase a much higher proportion of new to used EVs than lower income buyers. Although used EV sales, to the highest and lowest income brackets, each accounted for roughly one and half percent of all EV sales during the sample period, new EV sales to the highest income bracket accounted for 33.4 percent of all EV sales, while new EV sales to the lowest income bracket only accounted for 12.2 percent of all EV sales.

We also examine patterns by demographic group. Unsurprisingly, non-Hispanic whites, the largest demographic group by population, account for the majority of EVs sales in our sample period. But, as with the analysis by income bracket, we find that some demographic groups tend to buy a higher fraction of used EVs than new EVs. Asian buyers and non-Hispanic white buyers purchase roughly 20 and 13 new EVs for every one used EV, respectively. Hispanic and African American buyers tend to be more likely, relatively, to buy used EVs, purchasing seven new EVs for every one used EV.

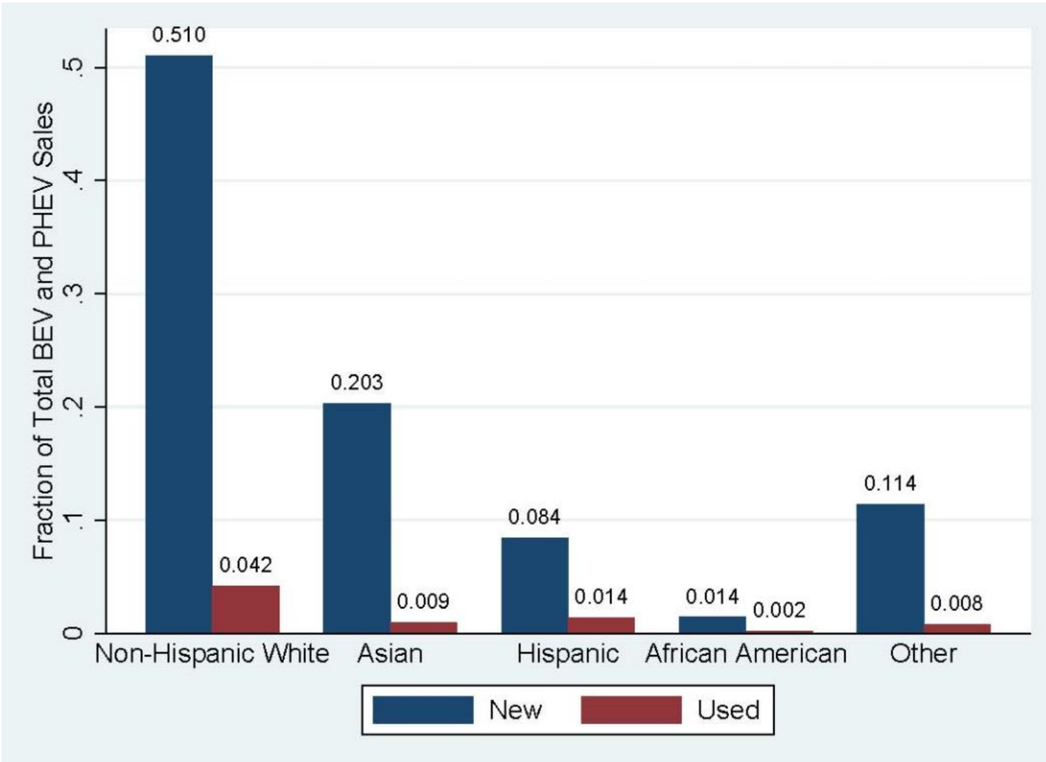

Figure 4. Fraction of New and Used BEV and PHEV sales, by Ethnicity

Barriers to Entry

We now turn to test for evidence of market barriers that might impede adoption of alternative fuel vehicles amongst low-income household or minority groups. For consistency across income and ethnic groups, we focus this analysis on vehicles that are purchased, rather than leased.[2] We test for the presence of two commonly asserted barriers to EV adoption: (1) price discrimination against low-income consumers; and, (2) limited selection of EVs at dealerships proximate to disadvantaged communities. In each case, we rely on regression analysis – by comparing the similar purchases amongst the hundreds of thousands of transactions in our data, we can determine the price paid by buyers or the distance travelled correlates with their demographic characteristics. If the patterns are sufficient strong, we might conclude that there do seem to be systematic differences in access amongst different demographic groups that may impede adoption.

To test the presence of price discrimination, we compare the price premium (or discount) paid by different demographic groups when purchasing alternative-technology vehicles as opposed to comparable vehicles with internal combustion engines. We calculate how much more (or less) a particular demographic group paid relative to the average price paid all vehicles of the

[2] This sample restriction eliminates approximately 150,000 transactions, or roughly 37 percent of our sample.

same make, model, model-year and trim. Price differences may be a result of compositional effects (e.g. non-Hispanic Whites buy different cars than Asians), differences in bargaining power, or discrimination. Since we cannot separately identify these effects empirically, the results must be interpreted with this caveat in mind.

The empirical specification reflected in the price tables below is from equation 4.2:

$$\boldsymbol{P_{imzt}} = \boldsymbol{\alpha_0} + \sum_{k\in\{ethn\}} \boldsymbol{\beta_k} * \boldsymbol{I_{i\in k}} + \sum_{k\in\{ethn\}} \boldsymbol{\gamma_k} * \boldsymbol{I_{i\in k}} * \boldsymbol{Inc_i} + \sum_{k\in\{ethn\}} \sum_{j\in\{type\}} \boldsymbol{\delta_{kj}} * \boldsymbol{I_{i\in k}} * \boldsymbol{I_{j=m}} + \sum_{k\in\{ethn\}} \sum_{j\in\{type\}} \mu_{kj} * I_{i\in k} * I_{j=m} * Inc_i + \theta * X_{imzt} + \varepsilon_{imzt}$$

where *i, m, z* and *t* denote buyer, car type purchased (ICE, HEV, PHEV, BEV), buyer location (zip) and month of sample, respectively. The covariate matrix X_{imzt} includes vehicle age, distance between buyer and dealer zip centroids, summations over the product of vehicle type and income, month-of-sale fixed effects, buyer zip code fixed effects, and car model fixed effects. The "Intercept" row in the tables that follow is comprised of the estimates of α_0 (Base Effect) and β_k's (the incremental average difference in price paid by various ethnicities for an ICE). Income effects by ethnicity are represented by γ_k. Price effects by ethnicity broken down by vehicle type come from δ_{kj}, and ethnicity-type-income effects from the estimates of μ_{kj}.

We present price results separately for new (Table 1) and used (Table 2) cars. The "Base Effect" intercept is the sales price paid for a car by the average Non-Hispanic White buyer. The subsequent coefficients can be thought of as average changes in the transaction price for buyers of different ethnicities (moving across the columns) and incomes (various rows) for different vehicle types (rows). For example, Asians pay roughly \$535 less for an ICE as non-Hispanic Whites and, all else equal, pay \$17 less for every \$10,000 of income. HEVs are on average \$1,680 more expensive than ICEs, but Asians pay an additional \$207.

Our main research question of interest relates to the price of PHEVs and BEVs. Two patterns become relatively clear when examining the market for new cars in Table 1. First, low-income customers do not seem to face higher prices when negotiating a PHEV or BEV. If anything, low-income customers purchase these cars at a slight discount to high-income customers purchasing identical PHEVs and BEVs. There are differences in price paid by demographic group, but they suggest that non-Hispanic whites and Asians, not Hispanics and African Americans, pay a price premium when purchasing PHEVs and BEVs.

Table 1. Transaction Price Differences (Income and Ethnicity by Vehicle Type – New Cars)

	Base Effect	African American	Asian	Hispanic	Other
Intercept	34,022.67	27.14	-534.74	167.64	-594.09
	(1,836.03)***	(195.95)	(92.05)***	(88.02)*	(235.40)**
Income (USD 1000s)	1.71	-2.05	-1.70	-1.57	1.57
	(0.92)*	(1.78)	(0.65)***	(0.86)*	(1.69)
HEV	1,679.57	-872.46	206.58	-169.81	-58.36
	(294.20)***	(493.33)*	(161.79)	(172.88)	(649.63)
HEV × Income	-1.15	6.56	1.55	1.74	1.51
	(1.06)	(3.48)*	(1.00)	(1.84)	(3.86)
PHEV	6,187.27	-4,412.56	67.29	-210.66	-4,406.17
	(373.21)***	(1,451.54)***	(150.84)	(155.79)	(1,001.67)***
PHEV × Income	-0.30	27.15	1.27	0.74	22.33
	(1.14)	(8.88)***	(1.01)	(1.60)	(4.89)***
BEV	5,020.96	-2,951.96	-683.98	-1,035.39	-2,654.37
	(1,617.29)***	(2,897.00)	(424.03)	(434.20)**	(2,016.88)
BEV × Income	1.59	16.76	-1.51	2.98	14.26
	(1.85)	(15.42)	(2.74)	(4.67)	(9.57)
N	133,661	2,238	25,789	26,779	13,243

Table 2. Transaction Price Differences (Income and Ethnicity by Vehicle Type – Used Cars)

	Base Effect	African American	Asian	Hispanic	Other
Intercept	20,882.52	-333.11	-390.50	305.74	252.61
	(3,029.23)***	(401.17)	(242.35)	(187.53)	(323.32)
Income (USD 1000s)	-0.39	3.42	4.35	-0.04	1.61
	(1.36)	(4.67)	(2.68)	(2.23)	(3.28)
HEV	-473.87	347.10	617.31	-13.17	887.16
	(781.45)	(1,504.58)	(851.56)	(519.95)	(1,116.40)
HEV × Income	1.85	-4.58	-6.26	2.55	-13.08
	(3.02)	(15.27)	(7.04)	(6.84)	(9.80)
PHEV	2,649.49	370.49	-333.45	1,462.53	2,577.80
	(1,248.87)**	(1,877.79)	(1,594.99)	(444.72)***	(1,866.07)
PHEV × Income	4.78	-4.69	-2.04	-22.19	-23.52
	(3.70)	(14.76)	(9.61)	(5.53)***	(12.44)*
BEV	8,343.11	-233.01	-457.64	-368.33	-2,998.73
	(3,025.47)***	(2,596.43)	(912.19)	(766.72)	(1,517.45)**
BEV × Income	6.98	3.48	-1.82	-18.52	13.71
	(5.77)	(19.56)	(7.53)	(7.66)**	(9.79)
N	116,615	3,920	10,341	41,502	7,648

The results are significantly different in the used car market. Whereas in the new car market the price paid for PHEVs and BEVs is increasing in income, the opposite is true for non-whites buying PHEVs and for Asians and Hispanics buying BEVs. In those cases, increases in income are associated with lower prices. The income-unadjusted prices paid for PHEVs by African Americans, Hispanics and other ethnicities are significantly higher ($370 for African Americans and $2,578 for other ethnicities) than those paid by non-Hispanic whites. On the other hand, non-whites pay lower prices on average for BEVs than non-Hispanic whites. These results show that, on average, low-income non-whites face higher prices in the used PEV market (relative to baseline) than they do in the new PEV market.

To further assess barriers related to the availability of alternative fuel vehicles, we perform a similar comparison for distance traveled. Our data afford us the opportunity to calculate the distance traveled from a buyer's home to the dealership at which they purchased their vehicle. If local dealerships in disadvantaged communities do not have sufficient supply of alternative fuel vehicles, we would expect that consumers in these communities who purchase alternative fuel vehicles would have to travel relatively further to make the purchase. In Tables 3 and 4, we present regression results relating distance traveled to income and ethnicity by vehicle type for the new and used market, respectively.

The average distances traveled for new ICEs differ significantly by ethnicity. African Americans and Asians travel more than three miles more than non-Hispanic whites. However, when we look at distance traveled to purchase new PHEVs and BEVs, there is not a statistically significant difference beyond what is observed for ICEs. There appear to be small differences in distance traveled by income for Hispanics buying BEVs (wealthier buyers travel farther) and other ethnicities for PHEVs (less wealthy buyers travel farther). But, on net, these differences are small in absolute magnitude. This suggests that local availability does not explain the gap in adoption for new PEVs.

The patterns of distance traveled to buy used PHEVs and BEVs are somewhat different than to buy new ones. On average, people tend to travel 10.2 miles to buy used cars, which is 1.6 miles farther than they travel to buy new cars. People travel farther still to buy used PHEVs (3.8 miles farther) and BEVs (9.6 miles farther). Relative to this baseline, Asians and Hispanics travel even farther (3.5 and 2.0 miles respectively) for use PHEVs, but Hispanics and other ethnicities travel less distance for used BEVs (2.8 and 9.5 miles respectively). There are mostly no differences in distance traveled as a function of income across ethnicities, but Hispanics travel somewhat farther for PHEVs and BEVs as their incomes increase, and other ethnicities travel somewhat farther for BEVs as incomes increase. Interestingly, there are no measurable differences in distance traveled by African American used PHEV and BEV buyers relative to non-Hispanic whites.

Table 3. Distance to Dealer (Income and Ethnicity by Vehicle Type – New Cars)

	Base Effect	African American	Asian	Hispanic	Other
Intercept	8.6008	3.0580	3.4406	0.8931	2.3518
	(6.0378)	(0.9935)***	(0.5820)***	(0.4265)**	(0.6863)***
Income (USD 1000s)	0.0111	-0.0118	-0.0043	-0.0075	-0.0050
	(0.0031)***	(0.0102)	(0.0041)	(0.0033)**	(0.0056)
HEV	1.6703	-1.1876	0.2529	0.0942	0.4140
	(0.6819)**	(2.0751)	(0.9596)	(0.9287)	(1.3746)
HEV × Income	-0.0017	-0.0117	-0.0053	0.0052	-0.0058
	(0.0044)	(0.0174)	(0.0072)	(0.0073)	(0.0113)
PHEV	4.4764	0.2388	-1.0939	-0.5188	2.4959
	(0.7014)***	(2.5204)	(0.6914)	(0.6739)	(1.6003)
PHEV × Income	-0.0059	-0.0096	0.0040	0.0018	-0.0183
	(0.0038)	(0.0183)	(0.0051)	(0.0055)	(0.0106)*
BEV	7.6789	6.7448	-3.6819	-1.5118	-3.0980
	(1.8982)***	(5.7656)	(2.5910)	(1.3403)	(2.2683)
BEV × Income	-0.0242	-0.0381	-0.0059	0.0173	0.0051
	(0.0073)***	(0.0292)	(0.0080)	(0.0101)*	(0.0121)
N	132,311	2,212	25,593	28,083	12,348

Table 4. Distance to Dealer (Income and Ethnicity by Vehicle Type – Used Cars)

	Base Effect	African American	Asian	Hispanic	Other
Intercept	10.2360	0.6974	1.6256	-0.6805	-0.1807
	(3.0218)***	(0.6690)	(0.5373)***	(0.3116)**	(0.7023)
Income (USD 1000s)	0.0108	-0.0124	-0.0002	-0.0053	0.0034
	(0.0025)***	(0.0077)	(0.0047)	(0.0030)*	(0.0070)
HEV	2.7657	-1.8372	-0.4667	-1.3678	0.1564
	(1.0580)***	(1.6165)	(1.2434)	(1.4440)	(2.2692)
HEV × Income	-0.0073	0.0224	0.0044	0.0222	-0.0046
	(0.0068)	(0.0165)	(0.0080)	(0.0178)	(0.0166)
PHEV	3.7684	-1.5839	3.5423	2.0476	-0.6379
	(1.3743)***	(2.5830)	(1.8613)*	(1.0923)*	(2.4137)
PHEV × Income	0.0041	0.0175	-0.0142	0.0181	-0.0104
	(0.0063)	(0.0267)	(0.0125)	(0.0100)*	(0.0161)
BEV	9.5863	0.4320	-0.6465	-2.8416	-9.5035
	(2.3777)***	(2.2655)	(1.2165)	(1.1881)**	(3.0444)***
BEV × Income	-0.0243	-0.0086	-0.0120	0.0381	0.0657
	(0.0074)***	(0.0144)	(0.0076)	(0.0127)***	(0.0202)***
N	112,479	3,803	9,807	40,816	7,218

The results of our work suggest that price discrimination and market access are not limiting adoption amongst these groups. In the new PEV market in particular, there is little evidence of minority ethnic groups paying higher prices or traveling longer distances to buy their alternative fuel cars. In the used car market, the results are more mixed. Low-income non-whites tend to pay more relative to baseline for used PHEVs and BEVs than in the new car market. While it's possible that these effects are compositional, it's also possible that there are more obstacles to market access in the used PEV market.

Discussion and Directions for Future Research

Finally, we offer several directions for future research. Although we find little evidence of discrimination towards minority groups in the new or used PEV market, further research is needed to rule out compositional effects (e.g. that minority used PEV buyers are selecting used PEVs with more expensive features than those chosen by non-Hispanic white buyers). In general, the results of this study support a continued effort to understand and potentially remediate barriers in the California used PEV market.

Second, in this analysis, we focus specifically on the experience of California buyers. Yet the markets for new and used vehicles extend nationally. Vehicles regularly flow between states in response to supply and demand shocks. Hence, interactions between state programs and the spillovers from jurisdictions offering EV subsidies to those not offering EV subsidies may prove important for policy.

Finally, in this report, we focus on the purchase decisions by California consumers over 2012-2015. As discussed above, this offers several attractive features for study. This is a period of time in which BEVs and PHEVs were just beginning to take off, and thus, might provide a more suitable guide for other nascent transportation technologies. Moreover, this was a period of time during which California vehicle incentives, while generous, were largely the same for all private buyers. Thus, the patterns of adoption might better reflect adoption patterns undistorted by targeted incentives to particular demographic groups.

But, further study of the effect of rebate programs is central to program cost-efficacy. Investments through the Low Carbon Transportation funds, including the Clean Vehicle Rebate Program and the Enhanced Fleet Modernization Program are potentially important ways to increase adoption levels, and evaluating the effects of these policies is an important area of future research. Rebate programs are the mainstay of policy efforts to stimulate electrification in the transportation sector, with nearly $400 million having been spent in California since 2010, and a proposal to allocate another $3 billion. California has spent over $400 million on electric vehicle (EV) incentives in the last 5 years.

Towards the very end of the study period, incentives in California begin to be targeted towards low- and middle-income buyers, with the means-testing of the Clean Vehicle Rebate Program and the Enhanced Fleet Modernization Program pilots in the San Joaquin Air Pollution Control District and the South Coast Air Quality Management District.

Although outside the scope of this report, the changes to these programs provide a unique setting in which to examine the effect of these programs and learn about adoption amongst low- and middle-income households. Evaluation of these programs is particularly important in light of the fact that incentives in California (and elsewhere) are increasingly targeted as lower income individuals, and state and national governments (e.g., Norway, France, UK, China, India and elsewhere) have set bold goals to reduce the numbers of internal combustion engines on the road, necessitating adoption of alternative fuel vehicles by mainstream buyers.

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