ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

Research Report – UCD-ITS-RR-14-25

Understanding Variations in U.S. Plug-In Electric Vehicle Markets

November 2014

Sydney Vergis
Belinda S. Chen

Institute of Transportation Studies ◦ University of California, Davis
1605 Tilia Street ◦ Davis, California 95616
PHONE (530) 752-6548 ◦ FAX (530) 752-6572
www.its.ucdavis.edu

Understanding variations in U.S. plug-in electric vehicle markets

Author(s):

Sydney Vergis, AICP
UC Davis Institute of Transportation Studies
1605 Tilia St., Suite 100, UC Davis West Village
Davis, CA 95616
(916) 322-1034
svergis@ucdavis.edu

Belinda Chen
California Air Resources Board
1001 I Street
Sacramento, CA
95812
belinda.chen@arb.ca.gov

ABSTRACT

Plug-in electric vehicles (PEVs) offer the potential for several energy and environmental benefits including reduced emissions of greenhouse gases and integration with use of domestically produced clean and renewable electricity. Efforts to promote PEVs have thus been increasing in the United States, both nationally and at the state level. However, market penetration rates of PEVs between states have been highly variable. The objective of this study is to better understand the full range of social, economic, and/or policy factors that are influencing statewide PEV sales rates for the purpose of beginning to build a quantitative understanding of market relationships and help decision-makers create more informed policy. We collected a variety of data on these factors for all 50 states. Our regression model found that the number of publicly available charging stations, environmentalism, gasoline and electricity prices, education level, vehicle miles traveled per capita, HOV lane access, and the presence of purchase incentives to be significantly correlated with PEV market shares in U.S. states in 2013. Results suggest that a combination of social, economic, and policy factors are needed to support early PEV markets. While singular variables may not be enough to drive statewide PEV markets; policy approaches that combine options, such as HOV lane access and charging infrastructure investments, may have positive feedbacks on market shares. Prior to developing PEV-related policy, future research should include developing this analysis further into a time-series based study that differentiates between PEV vehicle types.

INTRODUCTION

Beginning in late 2010, plug-in electric vehicles (PEVs) re-emerged in the United States light-duty vehicle market and supporting development of these markets is of growing interest to policymakers and academic researchers. Unlike conventional hybrid electric vehicles (HEVs) which can be fueled only with gasoline, PEVs can operate partially or wholly using grid electricity. There are two types of PEVs. Plug-in hybrids (PHEVs) have both an engine and a battery that can be charged from off-board, grid electricity sources. Various architectures exist for PHEVs but in general they can operate at higher speeds, over longer distances in full electric mode than HEVs; and vehicle range is less limited by the battery capacity given the availability of the gasoline engine. Fully functional battery electric vehicles (BEVs) rely solely on their batteries that must be charged from off-board electricity sources. BEV offerings vary in battery sizes and hence vehicle range, with the majority of models concentrated between 75-100 miles per charge and one model rated as high as 265 miles.

Alternative fuel vehicles such as PEVs have long been promoted by public policy for their potential environmental, economic, and energy security benefits. While the U.S. federal government has set national targets, some states have also adopted a statewide PEV sales mandate. California's Zero Emission Vehicle (ZEV) Regulation is a sales mandate, which requires an increasing share of new vehicle sales to be transitional ZEV (i.e. PHEVs) or ZEV, such as BEVs or hydrogen fuel cell vehicles, for a combined market share of about 15 percent in

2025. Based on current market offerings, to date this sales mandate has been fulfilled almost exclusively by PEVs. California's ZEV regulation has been adopted by nine other states, as permitted by the federal Clean Air Act, to meet air quality and climate change targets.

Across states, approaches to ZEV policy vary dramatically. Some states such as California recognize that to support a new ZEV market, a system that combines a "carrots and sticks" approach, is needed. For example, while California has adopted the ZEV regulation (a "stick"), it also has adopted legislation aimed at promoting the purchase of PEVs, as well as several comprehensive plans to identify specific strategies and actions ("carrots") that state agencies will take to support the goals of the ZEV Mandate. California's Alternative and Renewable Fuel and Vehicle Technology Program, authorized by Assembly Bill 118 (2007) and AB 8 (2013) authorizes up to $100 million to improve light-, medium-, and heavy-duty vehicle and fueling technologies, and to support the installation of alternative fuel charging infrastructure, including electric vehicle charging stations. Further, the Governor's Office has also adopted the 2013 ZEV Action Plan, which identifies specific strategies and actions that State agencies will take to accelerate the market for ZEVs and help achieve the directive of reaching 1.5 million PEVs in California by the year 2025.

Other states too, are recognizing the role that public policy plays in supporting the PEV market. In 2013 the governors of California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont signed a memorandum of understanding (MOU) and committed to developing coordinated actions to promote PEV sales within their states. As a result the Multi-State ZEV Action Plan was developed (2014) and provides additional detail and specificity to the commitments in the MOU including: helping to ensure the availability of vehicles in the market, providing consumer incentives, committing to government fleet purchases of PEVs, encouraging private fleet purchase, promoting infrastructure planning and investment, including encouraging workplace charging, developing EV charging signage, and removing barriers for the retail sales of electricity and hydrogen.

In addition to the variation in state policy approaches to ZEV markets, states vary widely in terms of other factors. For example, Hawaii is ranked third in terms of statewide PEV adoption rates, and yet offers no financial incentives for vehicle purchase. However, Hawaii also has the highest average gasoline prices ($4.37 per gallon) and residential electricity prices (37.11¢ per kWh) in the nation. In contrast, Colorado is ranked eighth in terms of statewide PEV adoption rates and offers an income tax credit up to $6,000 for the purchase of an alternative fuel vehicle, or a converted conventional vehicle to an alternative fuel source. Gasoline and residential electricity prices in Colorado are approximately average as compared to the rest of the country. Neither Hawaii nor Colorado has adopted a sales mandate. However, five of the ten states that do have an adopted sales mandate, are represented in the top ten PEV market share states (see TABLE 1).

TABLE 1 Top ten states for PEV market share

Top ten PEV market share states	Sales mandate?
1. California	✓
2. Washington	
3. Hawaii	
4. Oregon	✓
5. Georgia	
6. Vermont	✓
7. Connecticut	✓
8. Colorado	
9. Michigan	
10. Massachusetts	✓

A primary policy question and the objective of this research is to try to explain this variation and better understand whether there are factors that can be attributable to higher (or lower) market shares. This paper focuses on understanding overall PEV market share variation at the state-level to help determine the factors correlated to greater adoption of PEVs and in turn begin to build a body of literature that can help inform policymakers of how best to support development of these markets. Understanding the variation in market shares of the specific PEV technologies or regional variation within a particular state is reserved for future research. This analysis is not intended to project future sales growth; rather it is intended to help understand the variation in sales between states, during a single year.

LITERATURE REVIEW

Existing literature has identified a number of variables that may be contributing to alternative fuel vehicle markets, with a particular focus on the market for HEVs. For the purposes of informing this study, existing literature was used as a basis to identify potentially influential factors on PEV sales. Those factors include: financial incentives for vehicle purchase [e.g. (*1; 2*)], non-monetary incentives such as PEV access to high-occupancy vehicle lanes [e.g. (*3; 4*)], charging infrastructure [e.g. (*5*)], fuel and electricity prices [e.g. (*1; 2; 6*)], as well as consumer and state-specific characteristics such as average income per capita [e.g. (*7*)], average education levels [e.g. (*8*)], and population density [e.g. (*9*)].

The way in which different variables might be interacting with each other, across various geographic contexts is an area of evolving study. One recent analysis of PEV sales across 30 countries found that financial incentives, the number of charging stations, and the presence of a local EV production facility were significantly correlated with sales (*10*). Similar analysis has also been conducted looking at statewide HEV markets. Diamond (2009) looked at the relationship between socioeconomic and policy factors to explain the variation in HEV adoption across U.S. states. This study found that purchase incentives, gasoline prices, and vehicle miles traveled were correlated with HEV adoption. Our study collected data on the market variables that existing literature has identified as important to electric vehicle sales and applied similar statistical methods to those used in Sierzchula et al. (2014) to perform a comprehensive and empirical 50-state comparison of the PEV market, with the goal of contributing to a growing body of literature that will assist state governments in developing policy that supports development of the PEV market.

DATA AND RESULTS

Data Collection

Data were collected for all 50 U.S. states from a variety of data sources including state and federal publications. The dependent variable in this analysis is PEV market share (“market share”), which refers to new registrations of PEVs as a percentage of vehicle registrations for all new light-duty vehicles in a given state for the year 2013. Market share is used rather than absolute sales numbers to control for the inherent variability in market sizes across states. The independent variables that are analyzed include: the presence of purchase or tax credit incentives for individuals purchasing a PEV ("purchase incentive"), the number of charging stations per 100,000 residents ("charging infrastructure"), the environmental ethic of each state as determined by Wingfield and Marcus (2007) ("environmentalism"), average gasoline prices ("gasoline"), the presence or absence of a PEV manufacturing industry ("manufacturing"), median household income ("median income"), the percentage of adults 25 years old and older with a bachelor's degree or higher ("education"), the number of vehicles per capita ("vehicles per capita"), average household electricity prices ("electricity prices"), average population per square mile ("density"), average vehicle miles traveled per capita ("VMT per capita"), a variable indicating the presence or absence of a government PEV sales mandate ("sales mandate"), and a variable indicating the presence or absence of a government incentive that allows single-occupancy PEVs to use HOV lanes ("HOV lane").

TABLE 2 shows the variables used in this study, along with a corresponding description of those variables.

TABLE 2 Studied variables for each state

Variable	Description	Units	Source
Market share (Dependent variable)	Market share of PEVs as a percentage of all new light-duty vehicles sold in 2013	Percentage (%)	National automotive statistics
Charging Infrastructure	The number of publically available charging stations per 100,000 residents	Number of stations/100,000 residents	Alternative Fueling Station Locator; U.S. Census
Environmentalism	Score that ranks environmentalism based on carbon footprint, air quality, water quality, hazardous waste management, policy initiatives, and energy consumption	Number score	Wingfield and Marcus
Gasoline price	Average price of regular gasoline in 2013	Dollars ($)/gallon gasoline	U.S. Energy Information Administration-Gasoline and Diesel Fuel Update
Manufacturing	Dummy variable indicating an EV battery manufacturing industry as indicated by receiving ARRA funding	1= Company within the State received ARRA funding 0= No companies within the State received ARRA funding	American Recovery and Reinvestment Act (ARRA) of 2009
Median income	Median household income	Dollars ($)	U.S. Census
Education	Percent of adults 25 years old and older with a Bachelors' degree	Percentage (%)	U.S. Census
Vehicles per capita	The number of vehicles per capita	Vehicles/capita	Federal Highway Administration
Electricity price	Average household electricity prices per kWh	¢/kWh	U.S. Energy Information Administration-Electric Power Monthly
Population density	Population per square mile	Population/square mile	U.S. Census
VMT per capita	Average vehicles miles traveled annually, per capita	VMT/capita	Federal Highway Administration

Variable	Description	Units	Source
Sales mandate	Dummy variable indicating adoption of a statewide sales mandate for PEVs	1= Presence of a government PEV adoption mandate 0= No PEV adoption mandate	Air Resources Board
HOV lane	Dummy variable indicating the presence of a statewide high occupancy vehicle lane incentive for the purchase of a PEV	1= Presence of HOV lane incentive 0= No HOV lane incentive	Vehicle manufacturers and State publications
Purchase incentive	Dummy variable indicating the presence or absence of a purchase subsidy, income tax, or sales tax credit incentives adopted for PEV purchase.	1= Presence of purchase incentive 0=No purchase incentive	Vehicle manufacturers and State publications

Several variables warrant further explanation and discussion. State environmentalism was measured using scores developed by Wingfield and Marcus (2007). States received scores based on several factors including: carbon dioxide emissions per capita, and the presence of policies related to energy efficiency, water quality, hazardous waste management and air quality. A higher score indicates a higher level of environmentalism.

Purchase incentives incorporated into this analysis include purchase or lease rebates, and state sales and income tax credit incentives. While types and amounts of purchase incentives vary state-to-state, the variable used in this analysis reflects the presence or absence of a purchase incentive in the State. Incentives offered by local jurisdictions and electricity providers, incentives for the installation or purchase of home charging equipment as well as ongoing incentives such as annual reductions in PEV vehicle registration fees were not included as part of this study. Rather, the incentives captured in this analysis are accounting only for financial incentives made directly available for vehicle purchase, and that are offered statewide. For a more detailed analysis of how differences in the amount and type of incentive offered affected variations in statewide PEV sales in 2013, see Jin et al (2014). Further, although a federal tax credit is available to PEV consumers, that tax credit is available to residents in all states, and therefore was excluded from this analysis. It may be that inclusion of these other incentives may shed further light on the relationship between consumer subsidies and incentives and PEV sales in the U.S. states and is worthy of future research.

Additionally, there may be significant within state variation of many of these variables that are currently not incorporated into this research. For example, electricity prices within a state can vary not only by geography but also by utility provider, and rates may vary by time-of-use and/or by consumption. Likewise, population density is not uniform throughout a state and charging infrastructure and HOV lanes may or may not be co-located with these concentrations. Additional research is underway to understand within state regional variation in market shares.

Lastly, it should be noted that not all manufacturers offer their PEVs in all fifty states. The availability and diversity of vehicles for purchase may be significant variables that are currently omitted. Future work will attempt to evaluate the significance of these supply-side factors.

Data observations

A number of observations arise from comparing PEV market shares across states (for some examples see TABLE 3). Of the top three states in the U.S. for PEV market share, two of those states, Washington and Hawaii do not have a PEV sales mandate. Additionally, of these top three states only California and Washington offer some type of purchase incentive while California also offers HOV lane access for qualifying PEVs. States with relatively higher PEV sales are generally on either the East or West coast and are generally those that are considered more environmental than others as measured by the Wingfield and Marcus (2007) scores, for example California and Oregon.

TABLE 3 Top and lowest ranked states for PEV market share

Top Five States (>1%PEV market share)	Lowest Five States (<0.1% PEV market share)
1. California	46. Louisiana
2. Washington	47. Wyoming
3. Hawaii	48. North Dakota
4. Oregon	49. Mississippi
5. Georgia	50. Oklahoma

Model for market share

The regression methods used in this analysis are used to compare and identify the factors that are contributing to variation in PEV market share across U.S. states. Other studies have applied similar methodology when using time series data associated with HEV and vehicle ownerships trends and variation [e.g. (*1*)], when using one year of sales data to explore PEV ownership trends and variation [e.g. (*10*)], and when using one year of sales data (2013) to explore variations in statewide PEV sales based on availability of related incentives (*11*).

After testing for collinearity between the variables shown in TABLE 2, vehicles per capita and median household income were found to be correlated. As such, two main models, one that included vehicles per capita and one that included median household income, were developed that contained combinations of variables that were not collinear with each other. Each model was then run in R, and variables that were insignificant in a given model were removed using a stepwise process. One final reduced model was developed, as both vehicles per capita and median household income reduced the explanatory power of the model. As the PEV market share data was skewed, a logit transformation was performed to normalize the data.

The final reduced model is:

$$Market\ Share\_log_i = \alpha + \beta_1\ Charging\ Infrastructure_i + \beta_2\ Environmentalism_i + \beta_3\ Gasoline\ price_i + \beta_4\ Education_i + \beta_5\ Electricity\ price_i + \beta_6 VMT\ per\ capita_i + \beta_7 HOV\ lane + \beta_8 Purchase\ incentive_i + \varepsilon_i$$

The subscript “i” indicates an observation for each state; ε is the error term. Variables that were tested, but were insignificant and detracted from the explanatory power of the model include:, manufacturing, median income, vehicles per capita, population density, and the presence of a sales mandate.

Results

Variables that are significantly correlated with PEV market shares include: charging infrastructure, environmentalism, gasoline price, education, electricity prices, VMT per capita, HOV lane, and purchase incentive. The model's adjusted R^2 indicates that 82% of the variation in PEV market shares across states is explained by the variables included in the final model. Charging infrastructure, environmentalism, gasoline prices, education levels, HOV lane, and the presence of a purchase incentive are positively correlated with sales, while electricity prices and VMT per capita are negatively correlated.

TABLE 4 Model results

Variable	Estimated B (std. error)
Constant	-4.437 (.078)
Charging infrastructure	.06 (.016) ***
Environmentalism	.01 (.005) *
Gasoline price	.44 (.02) *
Education	.02 (.0085) *
Electricity prices	-.02 (.008) *
VMT per capita	-.00009 (.00003) **
HOV lane	.013 (.06) *
Purchase incentive	.018 (.007) *
N	50
R^2	0.85
Adjusted R^2	0.825

. p-value < 0.1 * p-value < .05 ** p-value < .01 *** p-value <.001

Significant Variables

Charging infrastructure. Literature related to alternative fuel vehicle markets suggest that charging infrastructure can play an important role in the success of the vehicle market. For example, Yeh (2007) found that refueling stations in partnership with government incentives were likely to increase the adoption of natural gas vehicles and Egbue and Long (2012) note that major challenges to the EV market include provision of sufficient charging infrastructure *(12; 13*). To determine if the number of charging stations in each state was correlated with PEV market sales, the number of publically available charging stations were corrected for population size (100,000) and included in the regression model. The number of charging stations available in each state varies from 10.8 charging stations per 100,000 residents (Hawaii) to none (Alaska). California has the highest PEV market share, but only the 6th highest number of public charging stations per 100,000 residents (4.55).

Even though this model shows a correlation between charging infrastructure and PEV sales (p-value<.001); this statistical relationship should be noted with caution. It is possible that charging infrastructure is not strictly exogenous of PEV market share, as the number of PEVs on the road may influence the number of publically available charging stations installed. Though, as the majority of daily travel for most BEVs may be accomplished through home recharging, which is not included in this metric, and PHEVs are not as dependent on infrastructure to complete trips (but may require mid-trip charging to maximize environmental and economic benefits), the extent to which PEV adoption drives installation of public charging stations or vice versa remains unclear and merits further investigation. Figures 1 and 2 below show the top and bottom five PEV market share states with their corresponding numbers of publically available charging stations per 100,000 population. States are ordered by PEV market share rank order along the x-axis; California has the highest PEV market share, while Oklahoma has the lowest.

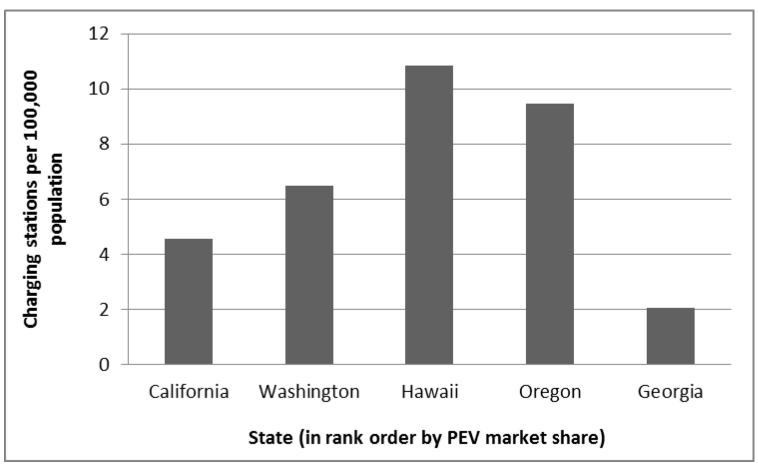

FIGURE 1 Charging stations per 100,000 population among the top five states for PEV market share

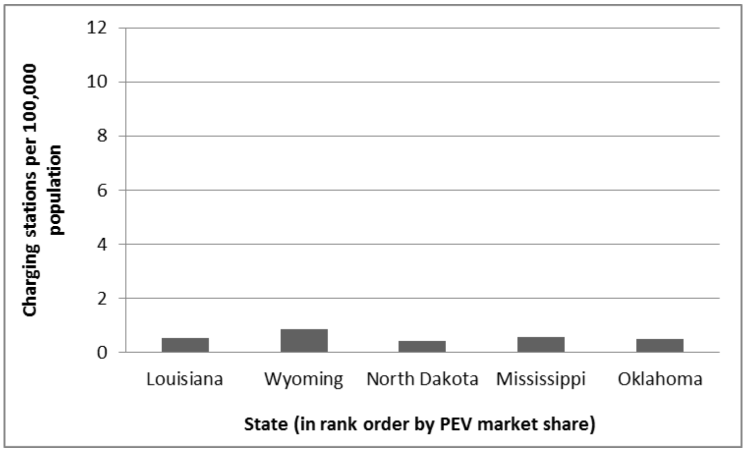

FIGURE 2 Charging stations per 100,000 population among the bottom five states for PEV market share

Environmentalism. Oregon, Vermont, and Washington have the highest environmental score according to the work developed by Wingfield and Marcus (2007). Those states are ranked 4th, 6th, and 2nd respectively, in terms of PEV market shares. Interestingly, Georgia's, environmental score places it in the bottom half of all states, while it is ranked 5th in terms of PEV market shares. Existing literature is varied on the relationship between a state's environmental policies and ethics and EV sales. In a study of PEV variations at the countrywide level, the Yale Environmental Performance Index, used as a proxy for a country's environmentalism, and was not significantly correlated with PEV sales (*10*). However, at the buyer level, several studies have found an individual's environmental ethic to be correlated with HEV purchase [e.g. *(14; 15; 16)*]. It should be noted that there are many indices that have been developed to measure a state's environmental policies and general ethic [see (*17*) for a complete overview]. Whether the relationship between PEV sales and a state's environmentalism is significant for the scoring method we chose to use here, or would hold when applying other state ranking systems or other proxies warrants further study.

Gasoline prices. Average prices of regular gasoline for 2013 were included in this analysis. Literature is varied on the relationship between gasoline prices and purchase of alternative fuel vehicles. For example, Diamond (2009) found that high fuel prices were correlated with HEV adoption, while Sierchula et al (2014) found that fuel price was not significant in explaining variation in PEV market shares across countries. Unlike our study, Diamond (2009) used annual average gasoline prices across different U.S. states, over a five year period. Our current study is limited by the use of only a single year of annual PEV market share data; future work may explore gasoline price volatility or time series data for a better understanding of the influence of gasoline prices on PEV market shares.

Education level. U.S. Census data on the percentage of adults (25 years old and older) with a Bachelor's degree was used as a proxy for education level in this analysis. The significant correlation between education level and PEV sales found in this model is consistent with some literature, which identifies correlations between education level and purchase of a new, cleaner vehicle. One study of early adopters in the U.K. found that these consumers typically were those with high education levels and incomes (*18*). In a survey of potential EV owners, individuals working on or completing a graduate degree were more interested in EVs (*13*). Further, according to a California survey of consumers who received a government PEV purchase rebate, over 80% of those consumers had a Bachelor's degree (*5*), which compares to about 60% of average new car buyers in the U.S. (*19*). The finding from our model regarding the correlation between education level and purchase of cleaner vehicles (p-value<.05) is consistent with existing literature.

Electricity prices. According to this model, average household electricity prices are negatively correlated with PEV market share. This finding is consistent with market reports, which find an inverse relationship between price of electricity and PEV purchase decisions *(20*). Our findings imply that an electricity rate structure that incentivizes charging off-peak (e.g. time-of-use) or during periods with excess renewable electricity generation through lower rates could not only help reduce the total cost of ownership of a PEV and environmental impacts of vehicle usage, but also potentially help incentivize PEV purchase. However, given the limitations of this study, future research should evaluate this relationship in greater detail prior to the development of related policy.

VMT per capita. According to the model, average annual vehicle miles per capita is positively correlated with PEV market share (p-value<.01). This finding is consistent with previous research, which suggested a significant correlation between VMT per capita and relative market shares for HEVs across U.S. states (*1*). This relationship may be indicative of the virtuous cycle that can be created between compact land uses and low-carbon transportation choices; in other words, potentially, the lower the VMT demand, the better suited a PEV for a household's travel demand. Exploring the synergistic relationship between land uses, VMT per capita, and PEV adoption is worthy of further study.

HOV lane access. Twelve states have adopted an HOV lane incentive where PEVs are allowed to access HOV lanes without meeting the occupancy requirements. Those states include: Arizona, California, Florida, Georgia, Hawaii, Maryland, North Carolina, Tennessee, Utah, and Virginia. States where HOV lane access is granted to PEVs in select areas within the state were also included in this model, specifically New Jersey and New York. In this model HOV lane access and PEV market shares are positively correlated (p-value<.05). This is consistent with several existing studies, which found that HOV lane access in Virginia impacted HEV market share (*3; 1; 21*). However, caution should be used if applying our study's finding to the development of a statewide incentive structure in states such as Minnesota, Texas, and Washington that have HOV lanes but do not allow access by single-occupancy PEVs. This relationship may be highly dependent on other factors, such as the number of urban centers within a particular state, the extent of HOV lane miles, and the presence or lack of traffic congestion in both controlled and uncontrolled lanes.

Purchase incentive. In our data, nine of the 50 states offer a purchase rebate or sales or income tax credit. A variety of private, public, and academic sources have attempted to understand the role of financial incentives in the vehicle market. In public testimony, vehicle manufacturers have stressed the importance of financial incentives in early markets for advanced technology vehicles [e.g. (*22*)]. In conducting a survey of PEV consumers who also applied for the California purchase rebate of up to $2,500, 72% of respondents reported that the State incentive was extremely or very important in making it possible to acquire a PEV (*5*). Literature such as Sierzchula, et al (2004), suggests that purchase incentives are significantly correlated with PEV sales across different countries, and a recent white paper by Jin et al (2014) suggests that the most effective incentives in driving PEV purchases are subsidies, HOV lane access, access to charging infrastructure, and exemptions from emissions testing. However, studies of the HEV market in the U.S. is conflicted; some studies such as Bersteanu and Li (2011) suggest that subsidies are correlated with HEV sales, while others such as Diamond (2009) find no relation with HEV purchase. Further research such as a time series analysis should be undertaken to further analyze the relationship between incentives and sales.

Insignificant variables

Several variables were not significantly correlated with 2013 PEV market shares, including manufacturing, income, density, and the presence of a sales mandate. However, further analysis is needed to understand the relationship between all studied variables and PEV shares. For example, it may be that the sales mandate variable may be a proxy for other variables such as the ability for state policy to develop supportive legislative packages of purchase incentives and charging infrastructure. The sales mandate variable also does not reflect the extent to which such policies have accelerated the development and commercialization of PEVs [see (*23*)]. Other variables, too, may benefit from further refinement, for example the variable median household income may be obscuring important differences in distributions of household incomes in each state; the density variable does not reflect regional population concentrations; and the manufacturing variable may benefit from further refinements that capture a fuller range of economic activities associated with PEV and PEV components manufacturing.

CONCLUSIONS

Based on the model developed in this paper, publically available charging infrastructure, state environmentalism, gasoline price, electricity price, education level, VMT per capita, HOV lane access, and the presence of purchase incentives are significantly correlated with statewide PEV market shares. Results suggest that any singular variable is not enough to drive statewide PEV markets, rather a combination of social, economic, and policy factors are needed. Before applying our results to policy, several study limitations should be considered. Limitations of the data include those related to the types of incentives included in the analysis and the timeframe of the data (2013, only). It is important to note that some variables in this analysis may fluctuate from year to year (e.g. gasoline prices), therefore, the relationship between PEV sales and studied variables may be further understood by taking a longitudinal approach to the data presented in this study. Further, it may also be that differences between PHEVs and BEVs, such as the need for new charging infrastructure facilities may be confounding these results and future studies may find it beneficial to differentiate between the two vehicle types.

NOTES AND ACKNOWLEDGEMENTS

The statements and opinions expressed in this paper are solely the authors' and do not represent the official position of the California Air Resources Board (CARB). The mention of trade names, products, and organizations does not constitute endorsement or recommendation for use. The Air Resources Board is a department of the California Environmental Protection Agency. CARB's mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. CARB oversees all air pollution control efforts in California to attain and maintain health-based air quality standards. The authors declare no competing financial interest.

We would like to thank Alberto Ayala, Annette Hebert, Todd Sax, Erik White, Anna Wong, Joshua Cunningham, and Pat Chen at CARB, Daniel Sperling at UC Davis, and Kenneth Gillingham at Yale University for feedback on this paper. However any errors remain our own.

Works Cited

1. Diamond, D. The impact of government incentives for hybrid-electric vehicles: evidence form US states. In *Energy Policy*, 2009, pp. 972-983.

2. Bersteanu, A. and Li, S. Gasoline prices, government support, and the demand for hybrid vehicles in the United States. In *International Economic Review*, 2011, pp. 161-182.

3. Diamond, D. Impact of High Occupancy Vehicle Lane Incentives for Hybrids in Virginia. In *Journal of Public Transportation*, 2008, pp. 39-58.

4. Tal, G. Evaluating the Impact of High Occupancy Vehicle Lane Access on Plug-In Vehicles Purchasing and Usage in California. s.l. : Institute of Transportation Studies, University of California, Davis, 2014.

5. California Center for Sustainable Energy. EV Dashboard. 2014.

6. Dijk, M., Orsato, R. and Kemp, R.The emergence of an electric mobility trajectory.In *Energy Policy*, 2013, pp. 135-145.

7. Hidue, M., Parsons, G., Kempton, W., Gardner, M. Willingness to pay for electric vehicles and thier attributes. In *Resource and Energy Economics*, 2011, pp. 686-705.

8. Lane, B., Potter, S. The adoption of cleaner vehicles in the UK: exploring the consumer attitude-action gap. In *Journal of Cleaner Production*, 2007, pp. 1085-1092.

9. IEA. Technology Roadmap Electric and Plug-in Hybrid Electric Vehicles. Paris : IEA, 2011.

10. Sierzchula, W., Bakker, S., Maat, S., van Wee, B.The influence of financial incentives and other socio-economic factors on electric vehicle adoption. In *Energy Policy*, 2014, pp. 183-194.

11. Jin, L., Searle, S. and Lutsey, N. Evaluation of State-level U.S. Electric Vehicle Incentives. s.l. : ICCT, 2014. White Paper.

12. Yeh, S. An empirical analysis on the adoption of alternative fuel vehicles: the case of natural gas vehicles. In *Energy Policy*, 2007, pp. 5865-5875.

13. Egbue, O. and Long, S. Barriers to widespread adoption of electric vehicles: an analysis of consumer attitudes and perceptions. In *Energy Policy*, 2012, pp. 717-729.

14. Diamond, D. Public policies for hybrid electric vehicles- The impact of government incentives on consumer adoption. Fairfax, VA : School of Public Policy, George Mason University, 2008. PhD dissertation.

15. Kahn, M. Do greens drive hybrids or hummers? Environmental ideology as a determinannt of consumer choice. In *Journal of Environmental Economics and Management*, 2007, pp. 129-145.

16. Hidrue, M.K., Parsons, G.R., Kempton, W., Gardner, M.P. Willingness to pay for electric vehicles and their attributes.In *Resource and Energy Economics*, 2011, pp. 686-705.

17. Konisky, D.M. and Woods, N.D. Measuring State Environmental Policy. In *Review of Policy Research*, 2012, pp. 544-569.

18. Lane, B. Car buyer research report: Consumer attitudes to low carbon and fuel-efficient passernger cars. s.l. : Ecolane Transport Consultancy, 2005.

19. Strategic Vision. The Psychology of the PEV Customer: Or how to sell more PEVs in the future. 2013.

20. Vannieuwkuyk, M. 2012 US BEV Market Study- BEV Challenge. s.l. : J.D. Power, 2012.

21. Gallagher, K. and Muehlegger, E. Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. In *Journal of Environmental Economics and Management*, 2011, pp. 1-15.

22. Global Automakers. Clean Vehicle Rebate Project FY 2014-15 Funding Plan- Electronic Filing. June 20, 2014. http://www.globalautomakers.org/sites/default/files/document/attachments/AllianceandGlobalLetter-CVRP-AQIP_20-Jun-2014.pdf.

23. Vergis, S. and Mehta, V. Technology Innovation and Policy: A Case Study of the California ZEV Mandate. [book auth.] M. Nilsson. *Paving the Road to Sustainable Transport: Governance and Innovation in Low-carbon Vehicles.* Oxford : Routledge, 2012.

24. California Air Resources Board. Staff Report: Initial Statement of Reasons for Rulemaking. 2013 Minor Modifications to the Zero Emission Vehicle Regulation. s.l. : ARB, 2013. http://www.arb.ca.gov/regact/2013/zev2013/zev2013isor.pdf.

25. Wingfield, B. and Marcus, M. America's Greenest State. s.l. : Forbes.com, 2007.

26. U.S. Energy Information Administration. Gasoline and Diesel Fule Update. 2014.

27. U.S. Department of Energy . The Recovery Act: Transforming America's Transportation Sector- Batteries and Electric Vehicles. July, 2012.

28. U.S. Census. State and County QuickFacts. accessed 2014.

29. U.S. Department of Transportation: Federal Highway Administration. Highway Fiannce Data Collection. Annual Automobile Vehicle Miles of Travel. 2013.

30. U.S. Energy Information Administration. Electric Power Monthly. 2013.

31. UC Davis. Zero Emission Map: About. s.l. : UC Davis, 2014.