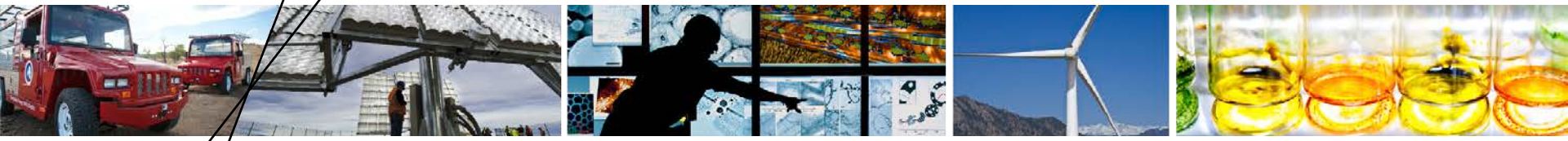
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

The Effect of State Incentives on Plug-in Electric Vehicle Purchases



Easwaran Narassimhan

Caley Johnson

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Motivations and Methods

- Current transportation policy literature lacks a macroeconomic analysis of the relationship between policy incentives and plug-in electric vehicle purchases.

- Used the Alternative Fuels Data Center laws and incentives database to assess the effectiveness of various state policy incentives put in place to encourage plug-in electric vehicle purchases.

- Used other data sets to see the effect that charger density and demographic characteristics have on plug-in electric vehicle purchases.

- Would potentially like to feed some of the estimates into vehicle sales projection models such as SERA, ADOPT, etc.

State Level Incentives

Tax Credit	Purchase Rebate	Sales Tax Waiver	HOV Exemption	Parking Exemption	Excise Tax Exemption	Registration Fee Reduction	Charging Rate Incentive	Charger Incentive
Colorado	California (state, local)	New Jersey*	Arizona*	Arizona*	Arizona*	DC	Arizona	Arizona
Georgia*	Illinois*	Washington	California	Hawaii	Washington, D.C.	Illinois*	California	California (local)
Louisiana	Hawaii		Florida	Nevada	Virginia		Georgia	Colorado
Maryland	Pennsylvania		Georgia				Hawaii (pilot)	Georgia
South Carolina	Texas		Hawaii				Indiana	Indiana (local)
Utah			Maryland				Kentucky (local)	Louisiana
West Virginia			Nevada				Maryland	Maryland
			New Jersey (Local)				Michigan	Michigan (local)
			New York (Local)				Minnesota (local)	Oklahoma
			North Carolina				Nevada (local)	Oregon
			Tennessee				Virginia (local)	West Virginia
			Utah					Austin, Texas
			Virginia					

* Incentives for BEV's only

source: afdc.energy.gov

Potential Factors That May Explain PHEV/BEV Purchases

State Level Incentives*

- **Income Tax Credit** = Income tax credit in thousands of dollars or as a percentage of MSRP of the vehicle, by model and state from 2008 to 2014 in the 1st quarter.

- **Purchase Rebate** = Purchase rebate in thousands of dollars or as a percentage of MSRP of the vehicle, by model and state from 2008 to 2014 in the 1st quarter.

- **Sales Tax Waiver** = Sales tax waiver in thousands of dollars or as a percentage of MSRP of the vehicle, by model and state from 2008 to 2014 in the 1st quarter.

- **HOV Exemption** = A "1" is given if HOV access is granted by model in every state; "0" is otherwise given.

- **Parking Exemption** = A "1" is given for parking fee waivers granted by model in every state; a "0" is otherwise given.

Infrastructure

- **EV Stations per Capita 16+ Years Old** = Number of EV charging stations per thousand driving eligible population by state, from 2008 to 2014 in the 1st quarter.

Economics

- **Adjusted Gasoline Price** = Average tax inclusive price of regular gasoline (in dollars) in a state from 2008 to 2014 in the 1st quarter. Adjusted for 2014 price levels with CPI US index.

*** Incentives included in the analysis based on relative importance**

Potential Factors that May Explain PHEV/BEV Purchases (cont.)

Demographics

- **Adjusted Median Household Income** = Median household income (in thousands of dollars), by state, from year 2008 to 2014 in the 1st quarter. Adjusted for 2014 price levels with CPI U.S. index.

- **Residential Energy Consumed per Capita** = Residential energy consumed per capita (in million btu), by state, calculated for every state from 2008 to 2014 in the 1st quarter. This includes gas, oil, and electric, and serves as an environmental consciousness proxy.

- **Median Age** = Median age of the population (in years), by state, from year 2008 to 2014 in the 1st quarter.

- **Percentage of College Graduates or Higher** = Percentage of population with college degree or higher, by state, from year 2008 to 2014 in the 1st quarter.

Outcome Variable

- **PHEV & BEV Registrations per Capita 16+ Years Old** = Number of (PHEV/BEV) registrations per capita among the driving eligible population, by state, by model, from 2008 to 2014 in the 1st quarter. **We use vehicle registration as our proxy for vehicle purchases.**

Data - Panel Arrangement for the Analysis

State	Vehicle	Time	Vehicle Registrations	Incentives
Alabama	Nissan Leaf	2008_2q	x	x
			x	x
			x	x
		2014_1q	x	x
	Ford Focus	2008_2q	x	x
			x	x
			x	x
		2014_1q	x	x
	Tesla Model S	2008_2q	x	x
			x	x
			x	x
		2014_1q	x	x
California	Nissan Leaf	2008_2q	x	x

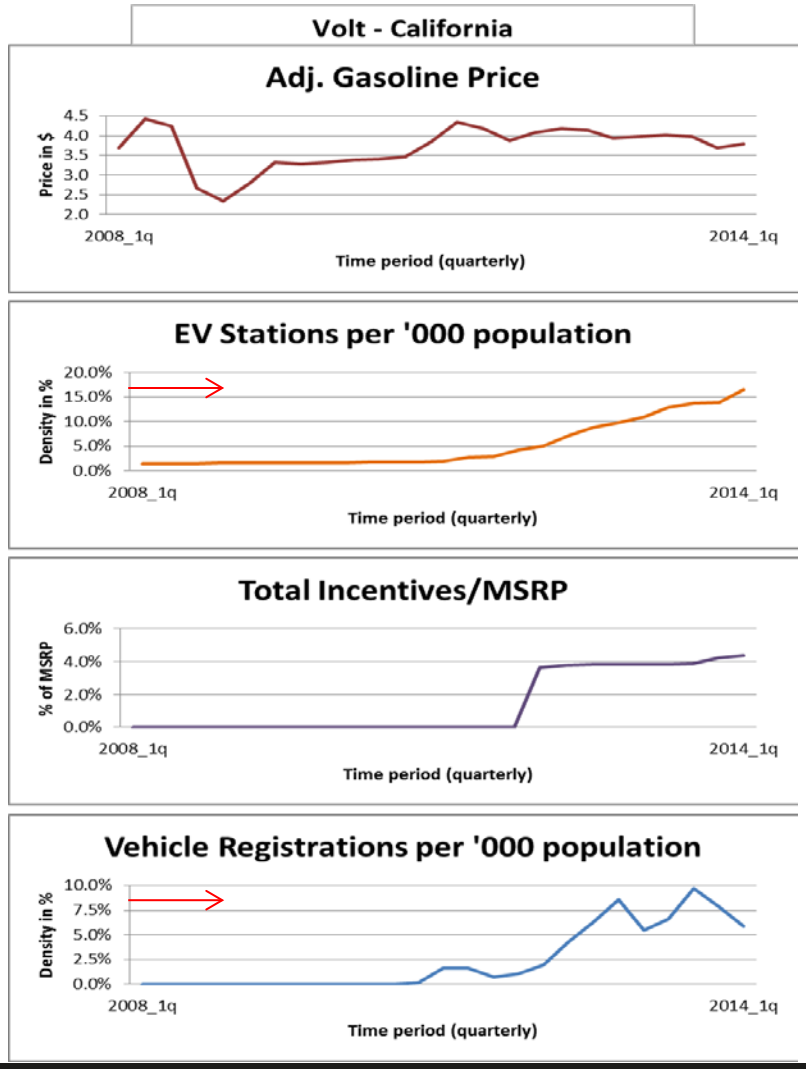
Data - Summary Statistics (PHEV and BEV combined)

Variables	N	Mean	Std. Deviation	Min.	Max.
Registration Data (source: R.L. POLK 2013 data)					
Vehicle Registration	3899	45.90	185.55	1	2961
Vehicle Registration per thousand in population 16+ years of age	3899	0.0065	0.0135	0	0.181
Incentive Data (sources: afdc.energy.gov; state gov. websites)					
State Income Tax Credit ($)	471	2955	2240	**$ 600**	**$ 7500**
State Purchase Rebate ($)	303	2534	983	**$ 200**	**$ 4500**
State Sales Tax Waiver ($)	173	3192	2569	**$ 90**	**$ 7630**
Total Monetary Incentives ($)	947	2864	2015	90	7630
HOV Lane Exemption (1 if HOV exempted, 0 otherwise)	3899	0.296	0.456	0	1
Parking Exemption (1 if parking exempted, 0 otherwise)	3899	0.052	0.222	0	1
Excise Tax Waiver (1 if excise tax waived, 0 otherwise)	3899	0.053	0.224	0	1
Registration Fee Reduction (1 if registration fee waived, 0 otherwise)	3899	0.028	0.166	0	1
Charging Rate Incentive (1 if charging rate discounted, 0 otherwise)	3899	0.216	0.412	0	1
State Infrastructure & Demographics (sources: census.gov/acs; www.api.org; eia.gov; fhwa.dot.gov)					
Public EV installation capacity	1275	106.70	343.76	0	5023
Public EV installation capacity per thousand in population 16+ years age	1275	0.018	0.038	0	0.275
2014 Adjusted Gasoline Price tax inclusive ($)	1275	3.297	0.534	1.763	4.833
2014 Adjusted Median Household Income ($ in thousands)	1275	54.09	8.752	28.85	82.74
Median Age (Years)	1275	37.54	2.354	28.70	44.12
Percentage of Graduates (Bachelor's degree or higher)	1275	28.29	5.797	17.10	55.24
Residential Energy Consumption per Capita (million btu)	1275	70.45	13.69	25	106

Note: "N" represents number of non-zero observations for the variables - Registration data and monetary tax incentives.

PHEV Purchases vs. Incentives, Infrastructure, and Gasoline Price

Trend: California, in spite of higher gasoline prices, higher EV station density per thousand population and monetary incentives, purchased the same amount of Chevrolet Volt's per thousand population as Michigan. Are there other factors in the background influencing the trends seen here?



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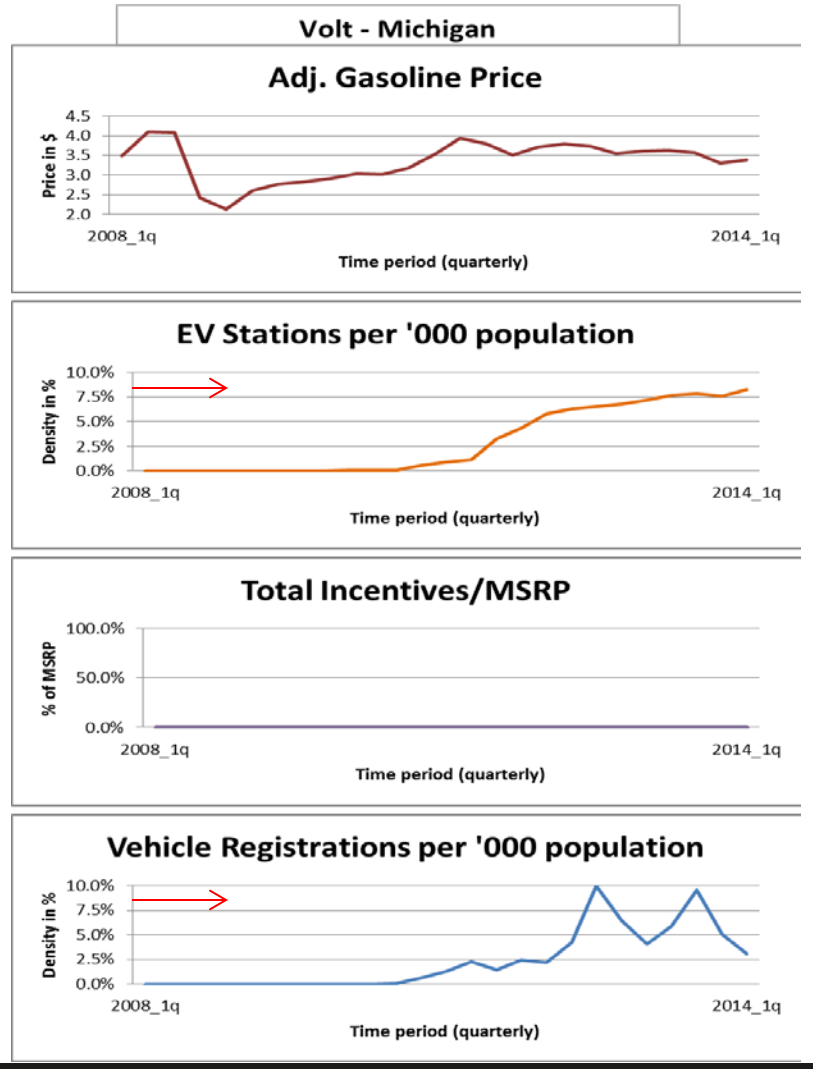
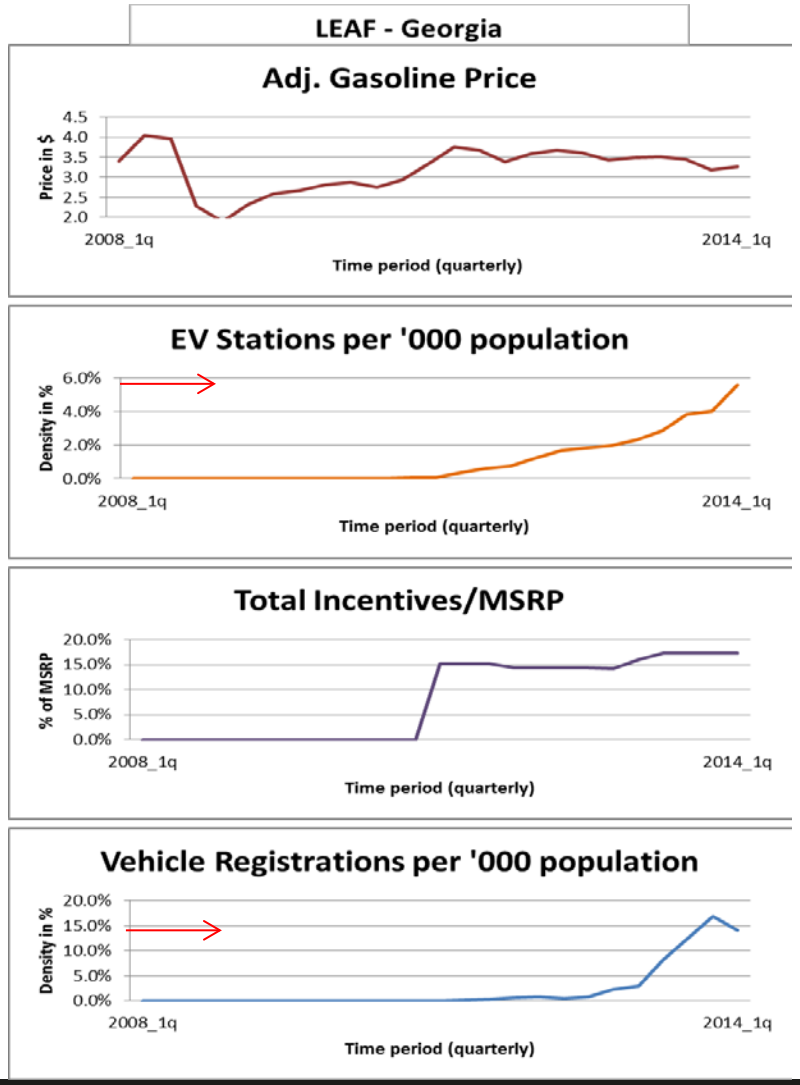


BEV Purchases vs. Incentives, Infrastructure, and Gasoline price (cont.)

Trend: Colorado, in spite of similar gasoline prices, EV station density per thousand population and monetary incentives, purchased fewer Nissan LEAF's per thousand population than Georgia did.



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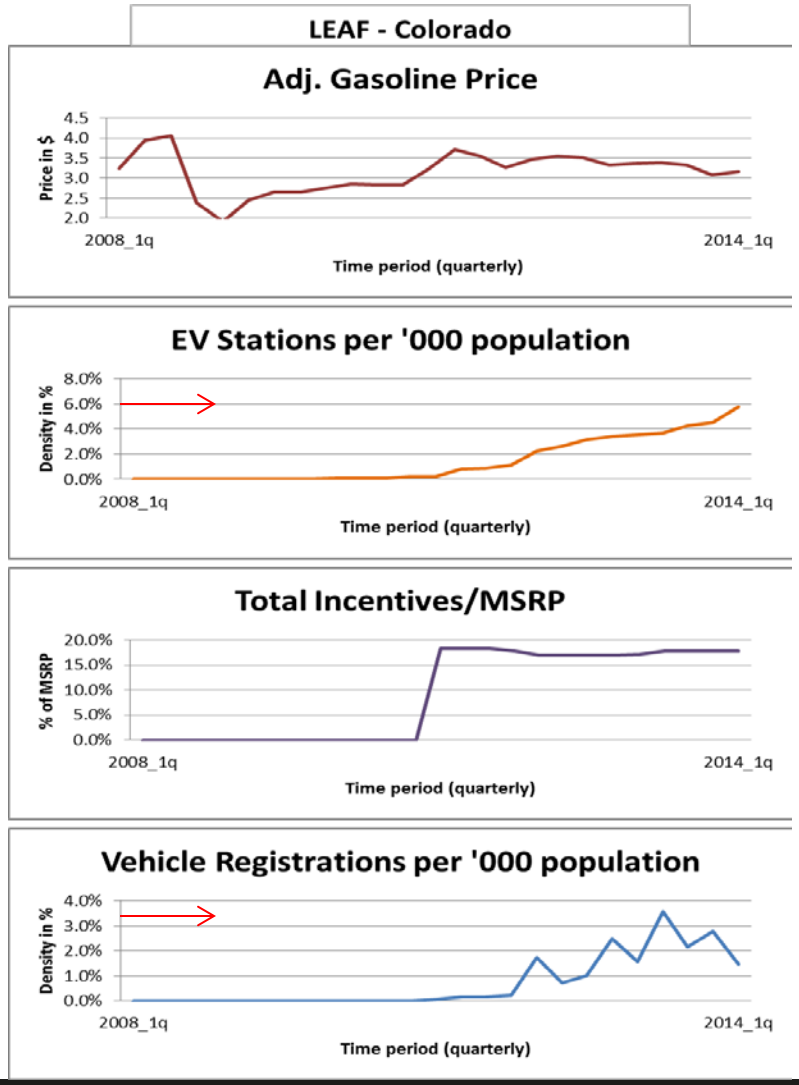
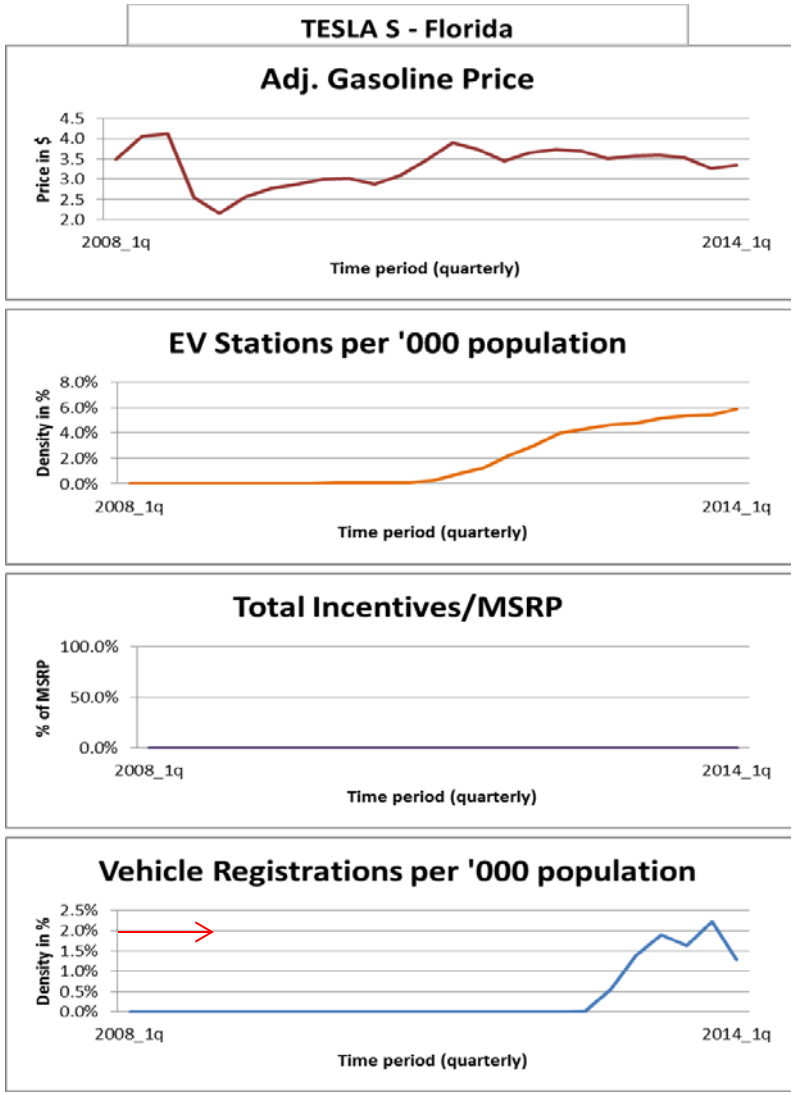


BEV Purchases vs. Incentives, Infrastructure, and Gasoline price (cont.)

Trend: Florida, in spite of offering zero incentives, purchased the same amount of Tesla Model S vehicles per thousand population as Colorado did, which offered tax incentives.



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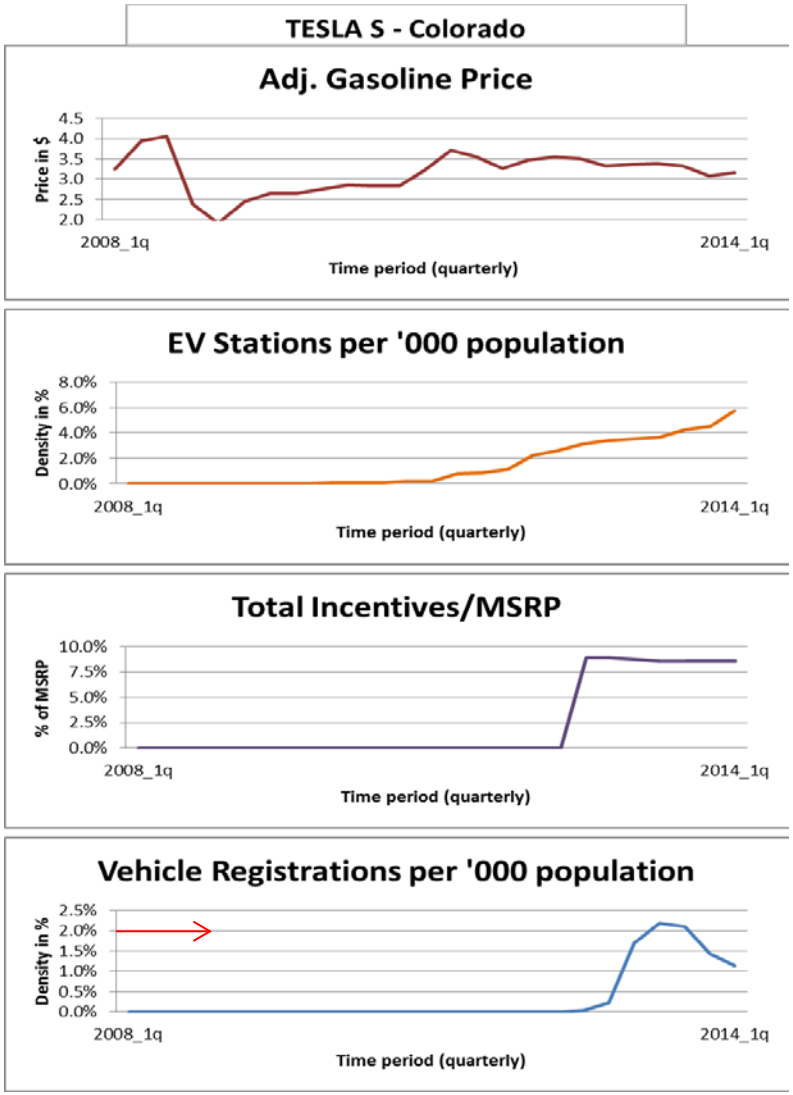


Methodology - Hypotheses

Hypothesis 1: Increases in monetary incentives like tax credits, purchase rebates, and sales tax waivers increase PHEV/BEV purchases.

Hypothesis 2: Non monetary incentives, such as HOV exemptions and parking exemptions have a positive impact on PHEV/BEV purchases.

Hypothesis 3: Increasing the number of EV charging stations per capita that are available to the driving- eligible population encourages more customers to purchase PHEV/BEV.

Hypothesis 4: Increases in gasoline prices lead to more PHEV/BEV purchases.

Methodology – Regression Equation and Model

$$(\textbf{PHEV \& BEV Registrations } \boldsymbol{per\ '000\ population\ 16+\ years\ age_{svt}})$$

$$= \propto + \beta_1 * (Income\ tax\ credit_{svt}) + \beta_2 * (Purchase\ Rebate_{svt}) + \beta_3 * (Sales\ Tax\ Waiver_{svt})$$

$$+ \beta_4 * (HOV\ Exemption_{svt}) + \beta_5 * (Parking\ Exemption_{svt})$$

$$+ \gamma_1 * (EV\ Stations\ per\ '000\ population\ 16+\ years\ age_{st}) + \gamma_2 * (Adj.\ Gasoline\ Price_{st})$$

$$+ \delta_1 * (Adj.Median\ Household\ Income_{st}) + \delta_2 * (Residential\ Energy\ consumed\ per\ capita_{st})$$

$$+ \delta_3 * (Median\ Age_{st}) + \delta_4 * (Percentage\ College\ Graduates\ or\ higher_{st})$$

$$+ \theta_{vt} + \mu_{sv} + \varepsilon_{svt}\ ;$$

where s = state, v = vehicle model & t = time (quarterly; 2008_1q until 2014_1q).

Regression Model: Random Effects Model

Statistical Tests : Hausman Test, Breusch-Pagan Lagrange Multiplier (LM), Serial Correlation, Intra class correlation test, Normality of residuals, Heteroskedasticity test and dummy variable test.

Methodology - Fixed Effects or Random Effects ?

- **Hausman Test**: This is a test of Null hypothesis that both fixed and random effects are consistent with random effects being more efficient. The results of the test recommends Random effects model for both PHEV and BEV panel data.

- **Breusch-Pagan Lagrange Multiplier (LM):** This test of Null hypothesis for zero variance across "State*Vehicle" entities was rejected, thus showing us that there is significant variation between entities, not just within entities, and recommends a random effects model.

- **Serial Correlation**: This test indicates the presence of first order serial correlation.

- **Heteroskedasticity Test**: This test of Null hypothesis for constant variance within a "State*Vehicle" entity was strongly rejected, suggesting that we need to correct our standard errors upon running the regression.

- **Dummy Fixed Effects** (Vehicle*Time): Testing the parameter after the regression strongly recommended the inclusion of "Vehicle*Time" fixed effects.

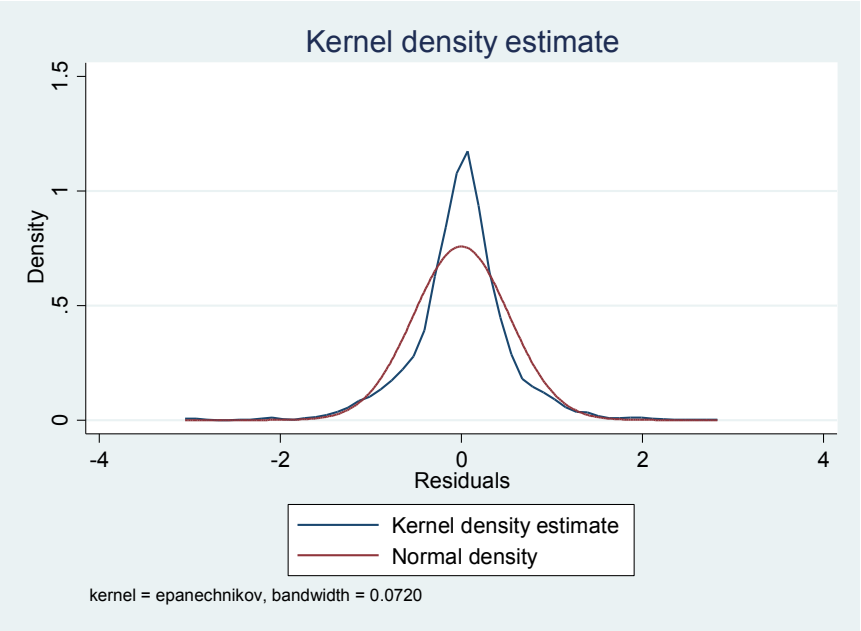
- **Intra Class Correlation Test**: Indicates more than 50% of residuals are explained by random effects.

Random Effects Model – Assumptions

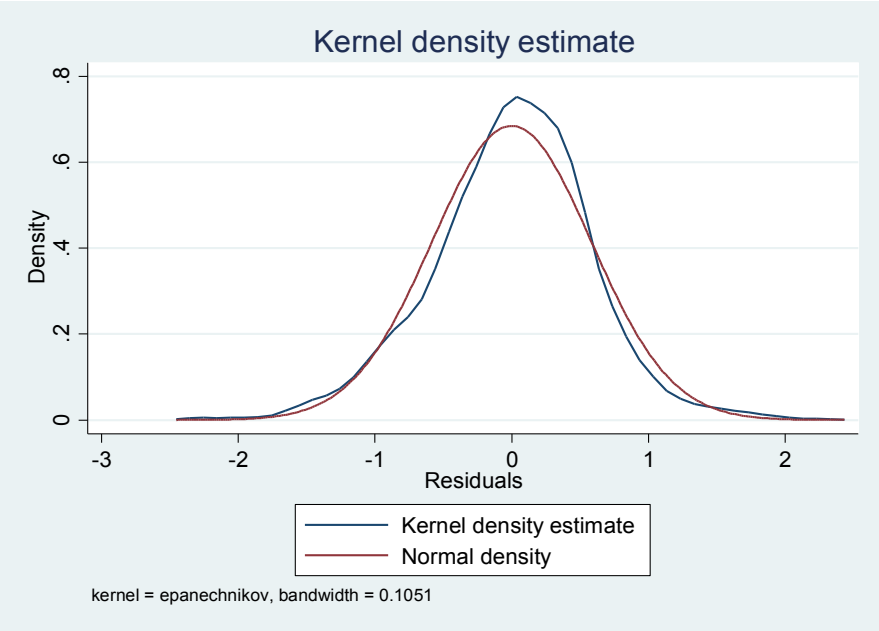
Unobserved Factors are Uncorrelated with X: Unobserved factors that go into the composite error term are not correlated with the explanatory variables of the regression equation.

Normality of Residuals: An important assumption when running a random effects model with a likelihood estimation methodology is the assumption of normality of residuals. Upon running the regression, the following test indicates normality in the residuals.

PHEV



BEV



Results and Conclusions - PHEV

Random Effects Regressions with Robust Standard errors - PHEV

	phev1re b/se	phev2re b/se	phev3re b/se	phev4re b/se
Tot Incentive/MSRP	0.693			
	(0.616)			
Tot Incentive $000		0.013		
		(0.017)		
Inc tax credit/MSRP			0.417	
			(0.549)	
Purchase Rebate/MSRP			1.602	
			(2.056)	
Salestax waiver/MSRP			33.146	
			(87.941)	
Inc tax credit $000				0.009
				(0.016)
Purchase Rebate $000				0.029
				(0.049)
Salestax waiver $000				-0.747
				(1.746)
HOV Exemption	0.317*	0.318*	0.317*	0.312*
	(0.126)	(0.127)	(0.125)	(0.126)
Parking Exemption	-0.318	-0.320	-0.308	-0.315
	(0.212)	(0.213)	(0.207)	(0.210)
EV stations pcap>16	2.030*	2.020*	2.030*	2.124*
	(0.830)	(0.829)	(0.937)	(0.914)
Log(gasoline price)	1.372+	1.375+	1.358+	1.371+
	(0.814)	(0.815)	(0.805)	(0.811)
Log(Median HH Inc)	0.577	0.582	0.537	0.578
	(0.354)	(0.354)	(0.364)	(0.364)
Log(Res energy pcap)	-0.224	-0.228	-0.198	-0.198
	(0.265)	(0.264)	(0.274)	(0.273)
Log(Median age)	2.390***	2.392***	2.404***	2.392***
	(0.643)	(0.642)	(0.641)	(0.641)
Log(% college above)	0.921*	0.911*	0.945*	0.920*
	(0.384)	(0.384)	(0.383)	(0.384)
N	1877.000	1877.000	1877.000	1877.000

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001 Rsq (overall) = 0.75

Ceteris Paribus Effects

- **Monetary Incentives:** No effect on PHEV purchases.
- **HOV Exemption:** PHEV purchases are 31% higher if a state has an HOV exemption.
- **EV Charging Infrastructure:** A 10-unit increase in EV station density leads to 2.1 % higher PHEV purchases.
- **Gasoline Price**: A 1% increase in gasoline prices leads to a 1.37 % increase in PHEV purchases.
- **Median Age**: A 1% increase in median age leads to a 2.4% boost in PHEV purchases.
- **Graduates**: A 1% increase in graduates leads to a 0.9% boost in PHEV purchases.

Results and Conclusions - BEV

Random Effects Regressions with Robust Standard errors - BEV

	bev1re b/se	bev2re b/se	bev3re b/se	bev4re b/se
Tot Incentive/MSRP	3.149**			
	(1.110)			
Tot Incentive $000		0.056**		
		(0.019)		
Inc tax credit/MSRP			1.850	
			(1.297)	
Purchase Rebate/MSRP			5.558***	
			(1.653)	
Salestax waiver/MSRP			3.460	
			(3.388)	
Inc tax credit $000				0.041*
				(0.020)
Purchase Rebate $000				0.094*
				(0.044)
Salestax waiver $000				0.049
				(0.046)
HOV Exemption	-0.113	-0.108	-0.099	-0.097
	(0.114)	(0.114)	(0.115)	(0.114)
Parking Exemption	0.240	0.217	0.253	0.224
	(0.206)	(0.209)	(0.204)	(0.209)
EV stations pcap>16	2.341*	2.202*	2.571**	2.371**
	(0.913)	(0.950)	(0.897)	(0.919)
Log(gasoline price)	2.954**	2.974**	2.776**	2.824**
	(0.900)	(0.911)	(0.875)	(0.881)
Log(Median HH Inc)	1.079**	1.121**	0.988*	1.087**
	(0.407)	(0.413)	(0.429)	(0.421)
Log(Res energy pcap)	-0.890**	-0.930**	-0.770*	-0.856*
	(0.332)	(0.340)	(0.340)	(0.338)
Log(Median age)	-0.839	-0.895	-0.820	-0.861
	(0.618)	(0.620)	(0.613)	(0.618)
Log(% college above)	0.300	0.250	0.361	0.280
	(0.368)	(0.376)	(0.374)	(0.376)
N	2022.000	2022.000	2022.000	2022.000

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001 Rsq (overall) = 0.67

Ceteris Paribus Effects

- **Income Tax Credit**: A $1,000 increase in tax credits leads to a 4.1 % increase in BEV purchases.
- **Purchase Rebate:** A $1,000 increase in rebates leads to a 9.4% increase in BEV purchases.
- **EV Charging Infrastructure**: A 10-unit increase in EV station density leads to a 2.4 % increase in BEV vehicle purchases.
- **Gasoline Price**: A 1% increase in gasoline prices leads to a 2.8 % increase in BEV purchases.
- **Median Income**: A 1% increase in median income leads to a 1.1% increase in BEV purchases.
- **Residential energy:** A 1% decrease in consumption leads to a 0.9% increase in BEV purchases.

Policy Implications

- **PHEV**: In the presence of federal monetary incentives, it appear that state monetary incentives don't increase PHEV purchases, regardless of whether the state monetary incentive is offered as a tax credit, purchase rebate, or sales tax waiver.

- **PHEV**: Non-monetary incentives, like HOV exemptions, seem to encourage people to purchase PHEVs.

- **BEV**: Monetary incentives appear to significantly increase BEV purchases. This is expected, as purchase price for BEVs are still significantly higher than their gasoline-equivalent models, and require both federal and state monetary incentives in order to encourage more BEV purchases.

- **EV Charging Infrastructure**: From the regression results, it is also clear that EV charging infrastructure has a significant impact on both PHEV and BEV purchases. The results indicate that adding more EV charging stations would reduce range anxiety and thus increase PHEV/BEV purchases.

Future work

- Quantify rebates given for home EV charger installations and discounts given on residential electricity rates for EV charging. Include charger installation rebate and charging rate discounts as explanatory variables in the regression model.

- Further reduction of omitted variable bias by adding more variables that may explain vehicle purchases. Robustness checks for the regression model.

- Collect data on airport parking exemption for plug in electric vehicles in various cities and incorporate that in to the parking exemption variable.

- Separate analysis excluding high-end BEV's such as Tesla.

- Separate analysis excluding states like Alaska and California that might be skewing the results.

- Make corrections to start dates (if any) of various monetary and non-monetary incentives in the incentives and laws database. Re-do the analysis with the corrected data.