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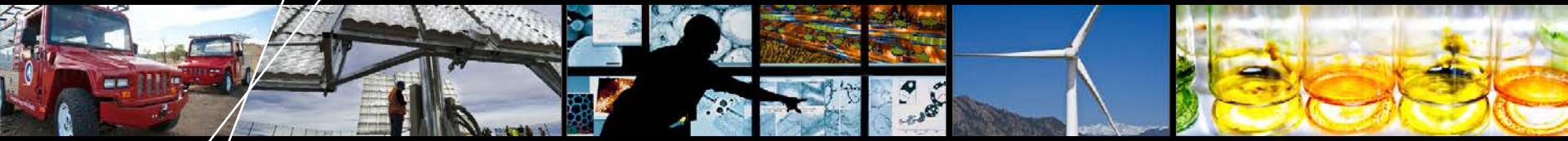
Impact of Direct Financial Incentives in the Emerging Battery Electric Vehicle Market: A Preliminary Analysis



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February 2015

NREL/PR-6A20-63263

Overview

Question

- How have incentives changed purchasing for battery electric vehicles in the United States?

Method

- Regression analysis at the state level to isolate incentive effects from other factors

Contribution

- National data set
- Econometric methods

Limitations

- Emerging market composed of early adopters
- Limited policy variation during study period
- External validity.

Project Scope

Vehicle adoptions

- Battery electric vehicles (BEVs)
  - Vehicles propelled by electric motor only
  - Require charging infrastructure in the form of home or public electric vehicle supply equipment (EVSE)
- Specific vehicles.

Vehicle	U.S. Release Date	Vehicles Registered Through 2013	Percent of Registered BEVs Through 2013
Nissan Leaf	December 2010	38,841	56
Tesla Model S	June 2012	19,275	28

Source: R.L. Polk data

Project Scope

Incentives offered at the state level

- Direct financial incentives
  - Rebates
  - Tax credits
  - Tax exemptions
- High occupancy vehicle (HOV) lane access.

Project Scope

Examples of Incentive Types

State	Incentive Type	Value	Dates	Description
Washington	Tax exemption	$2,000	2009 – present	Sales and use tax exemption on purchase of electric vehicle.
California	Rebate	$2,500	March 2010 – present	Electric vehicles are eligible for a maximum $2,500 rebate through the California Clean Vehicle Rebate Program.
Maryland	Tax credit	$2,000	October 2010 – June 2014	Electric vehicles are eligible for a tax credit based on vehicle battery capacity.
North Carolina	HOV access	–	May 2011 – present	Electric vehicles may travel in HOV lanes regardless of the number of passengers in the vehicle.

Source: Alternative Fuels Data Center (AFDC)

Key Conclusions

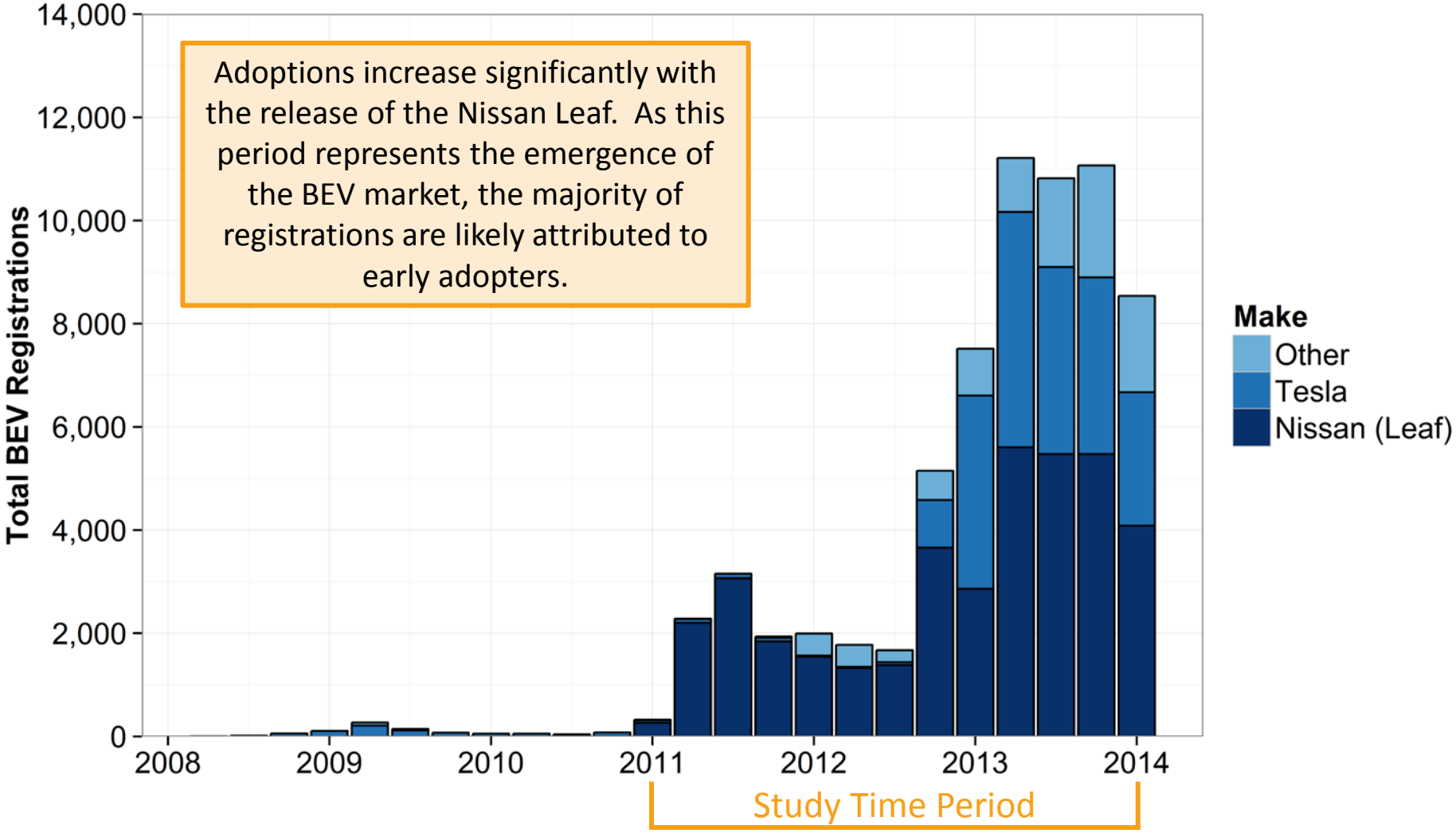
- **Results of regression analysis**
  - Data indicate that both incentives and prevalence of charging infrastructure are correlated with the amount of BEV registrations
  - Analysis shows that tax credits have a positive and statistically significant impact on BEV adoption
  - No statistically significant impact of rebates and HOV lane access was found, however the authors hypothesize that this is due to lack of variation in those incentives within the sample set
- **Implications of results**
  - Tax credit incentives promoted registrations of 700 to 3,500 BEVs since 2011
  - Estimated annual abatement equivalent of 500 to 2,700 tons of carbon dioxide.

Context

- **Hybrid vehicle incentive studies**
  - Gallagher and Muehlegger (2011)
    - Study state incentives for hybrid vehicles in the U.S. from 2000-2006
    - Find a 5% increase in per-capita sales per $1,000 state-level tax incentive, no significant impact of HOV access outside of Virginia
  - Additional studies (e.g., Chandra et al. 2010)
    - Suggest that state and federal incentives promote vehicle adoption (6 to 26 percent of hybrid sales attributed to incentives)
- **Existing BEV studies**
  - Utilize survey-based methodologies (e.g., Tal et al. 2013, DeShazo et al. 2014)
  - Focus on characteristics of buyers (e.g., demographics, vehicle use, purchasing behavior).

Data

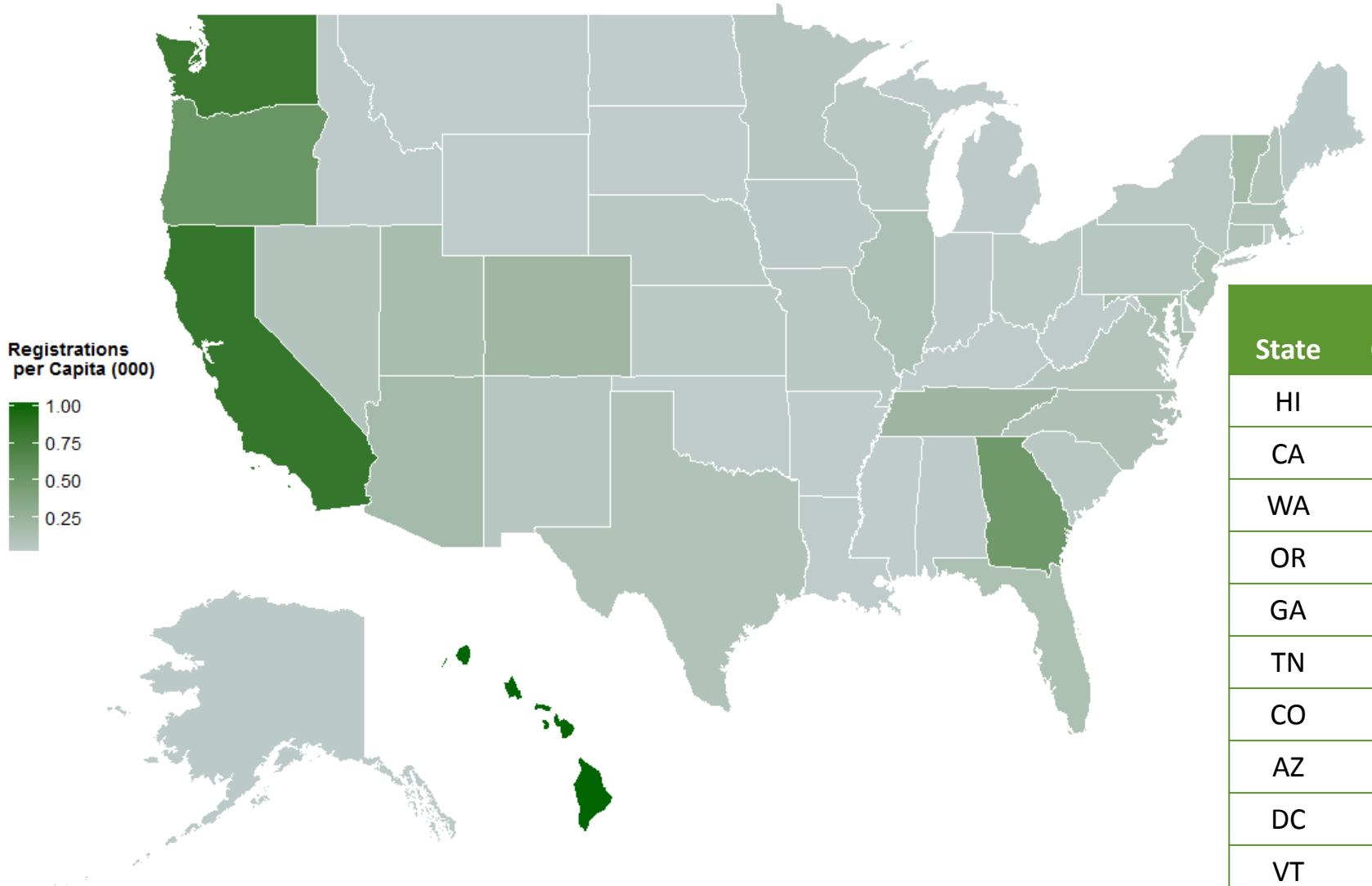
National BEV Registrations by Registration Date



Source: R.L. Polk data

Data

State-level Personal BEV Registrations per Capita

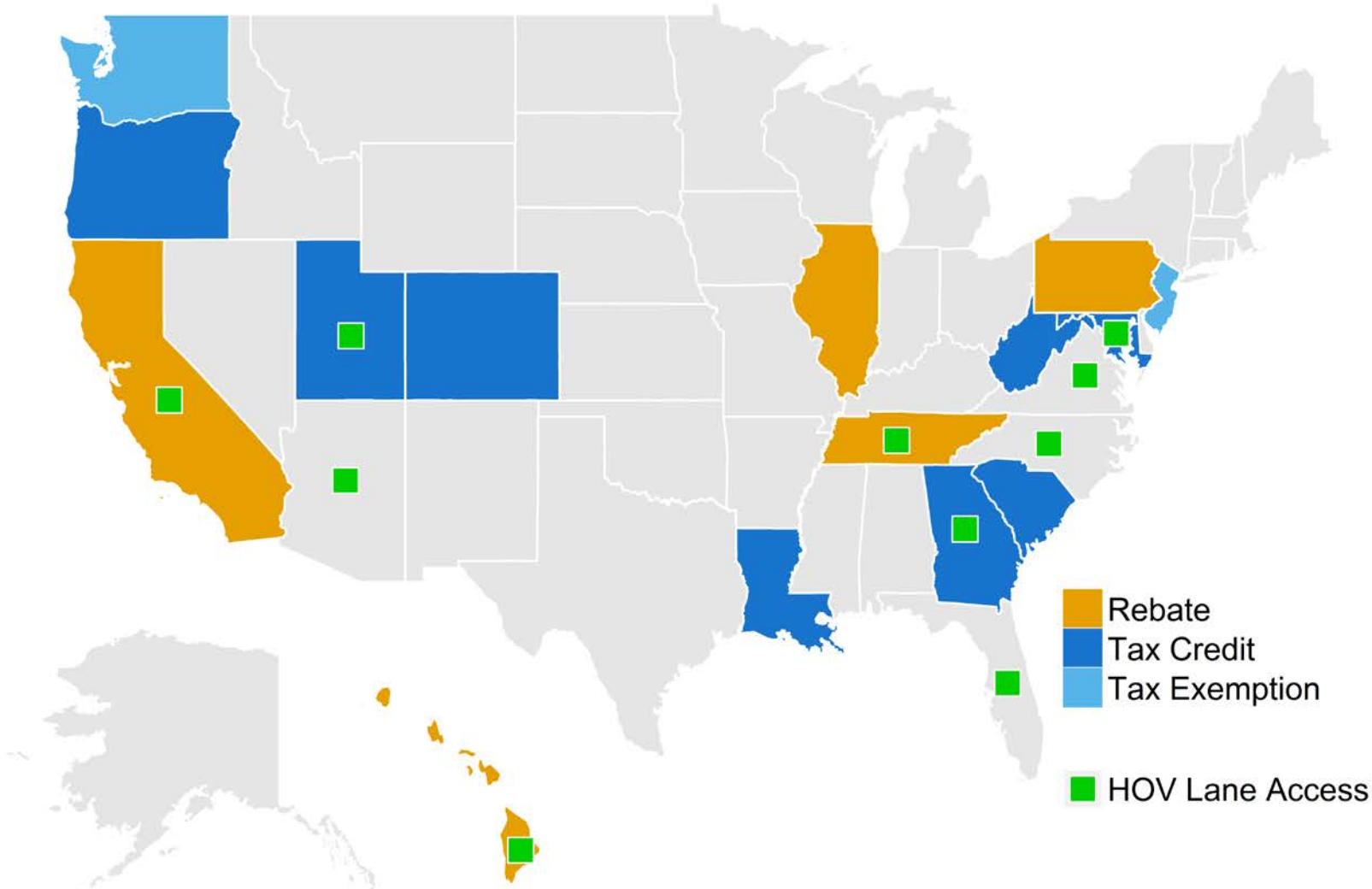


State	BEV per Capita (000)
HI	1.026
CA	0.846
WA	0.815
OR	0.539
GA	0.505
TN	0.224
CO	0.218
AZ	0.182
DC	0.181
VT	0.177

Note: Data through March 2014. Sources: R.L. Polk data; U.S. Census data.

Data

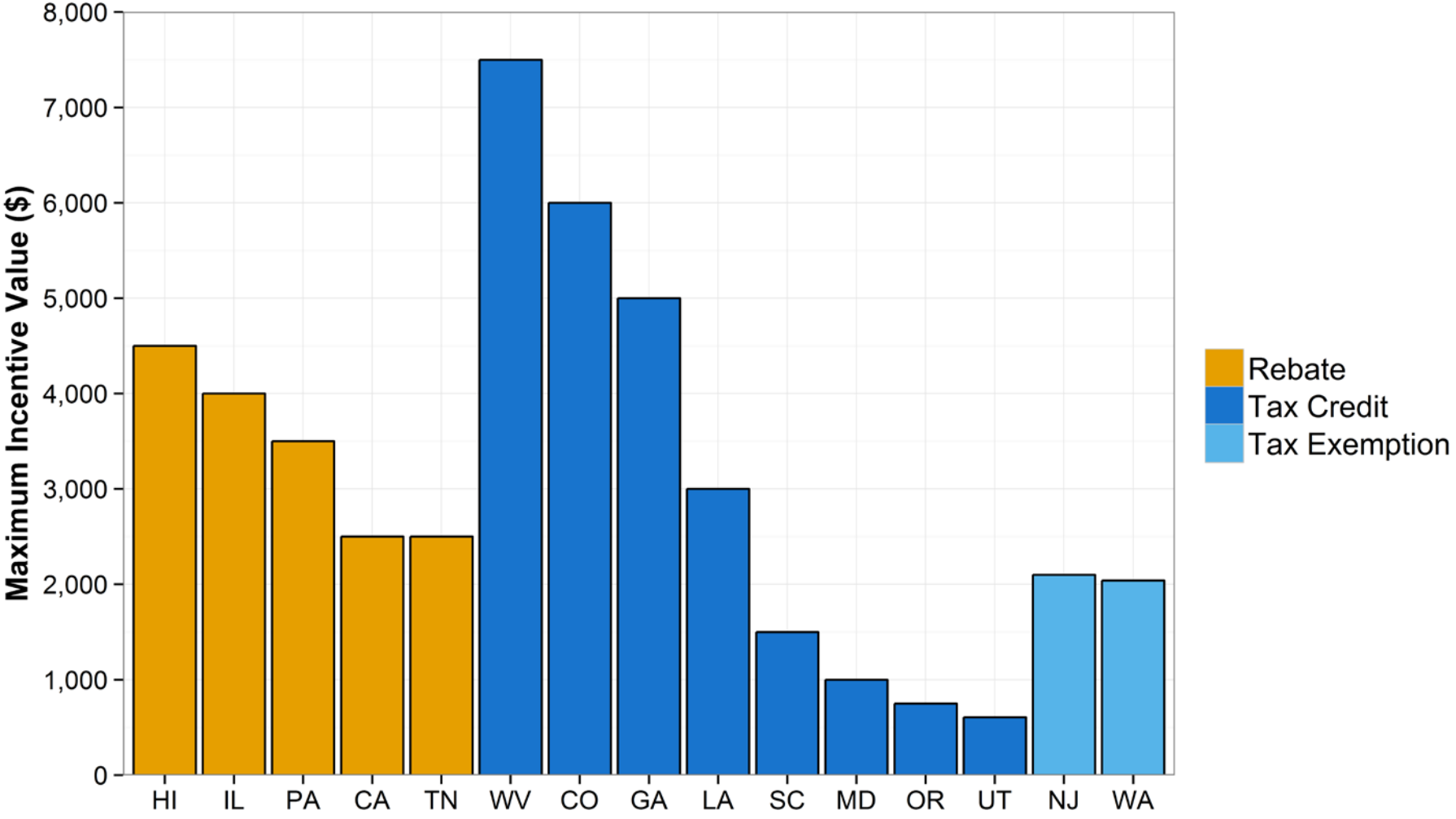
State-level Incentives (2011-2013)



Source: AFDC

Data

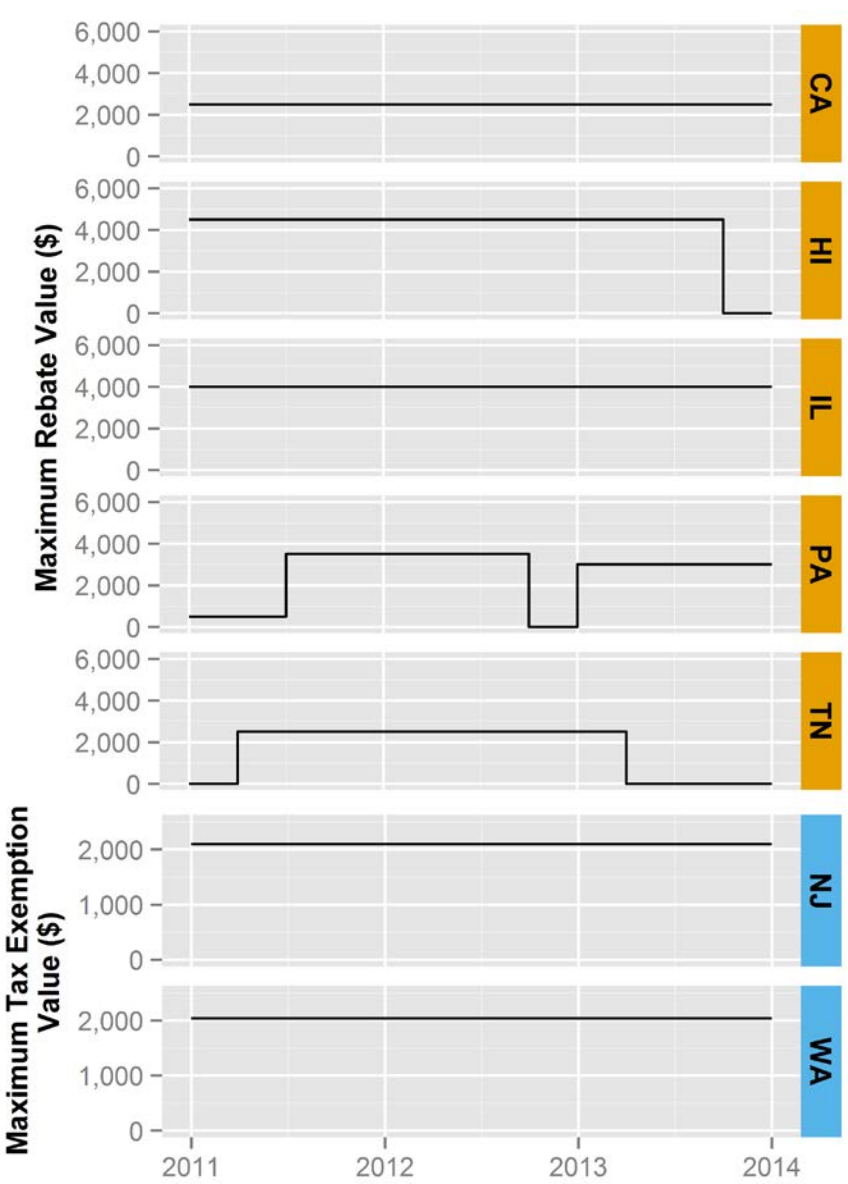
State-level Incentive Values (2011-2013)

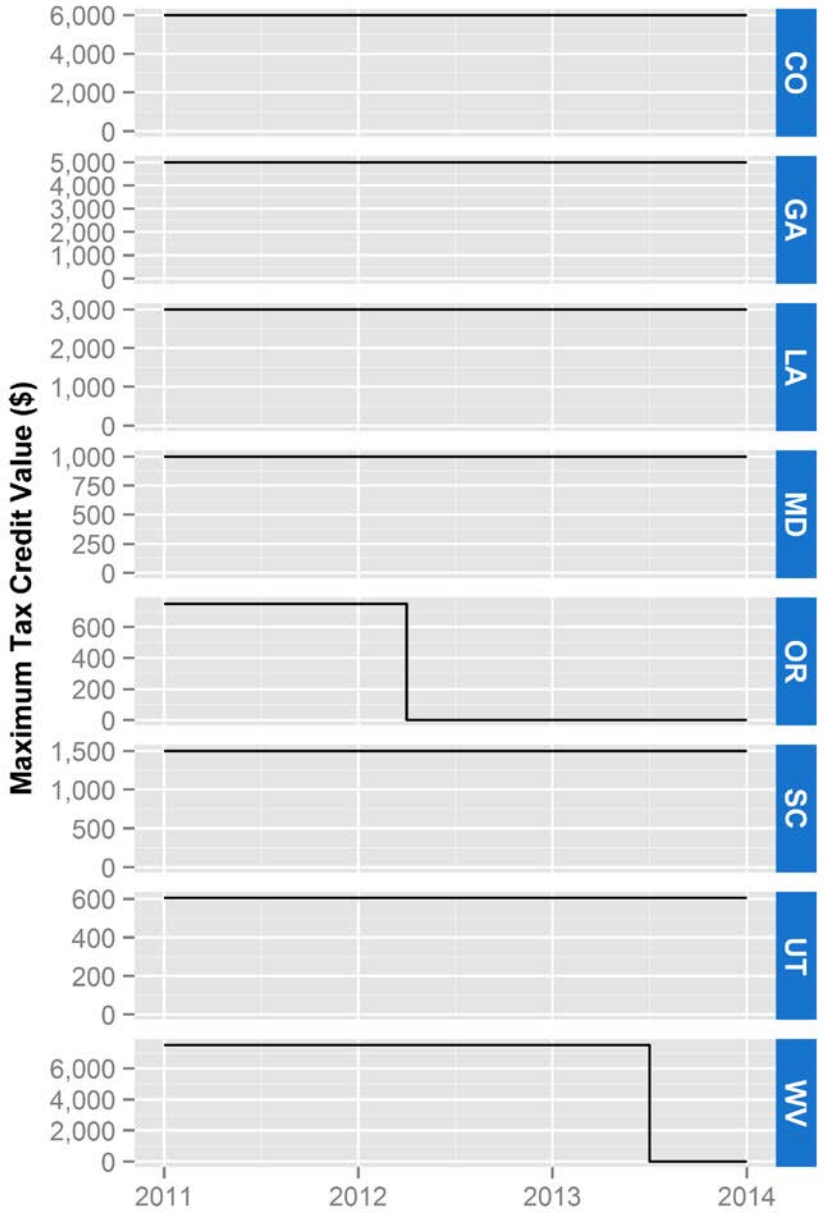


Source: AFDC

Data

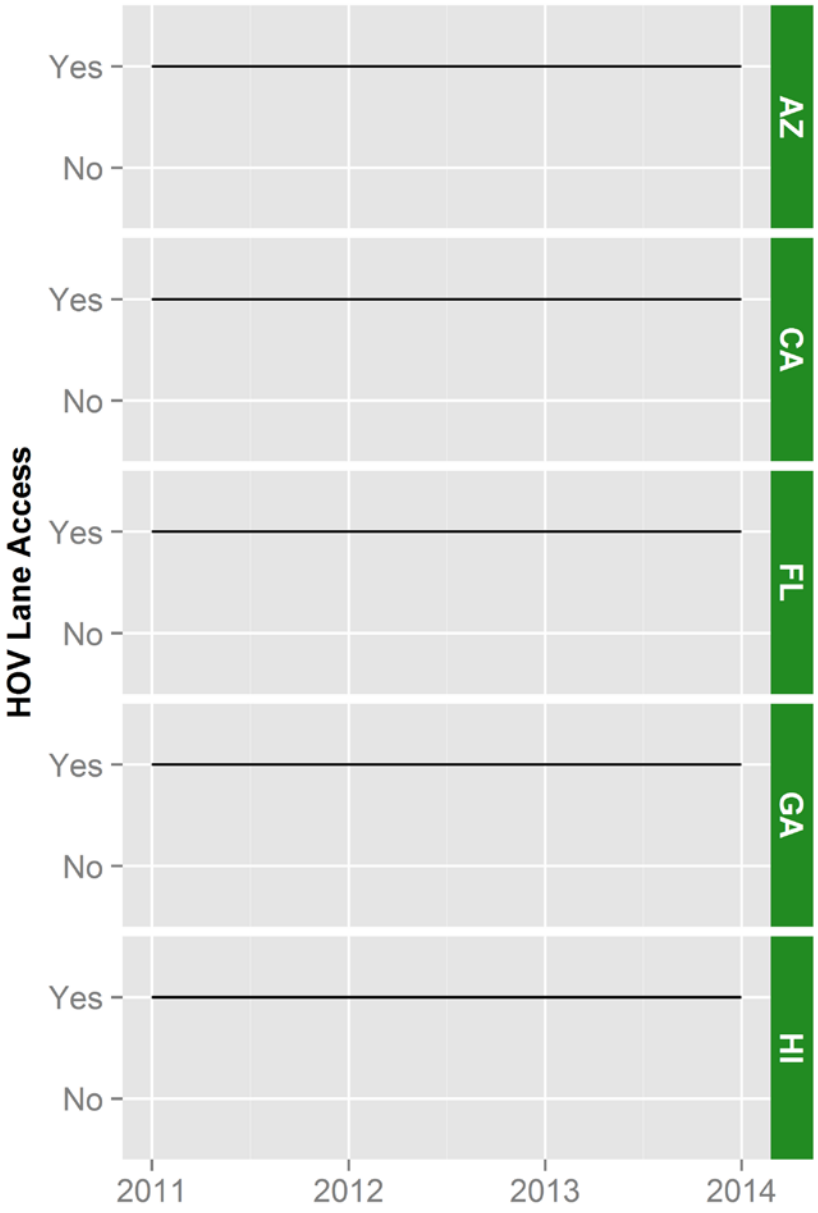
Note: Y-axis scale varies by state.
Source: AFDC

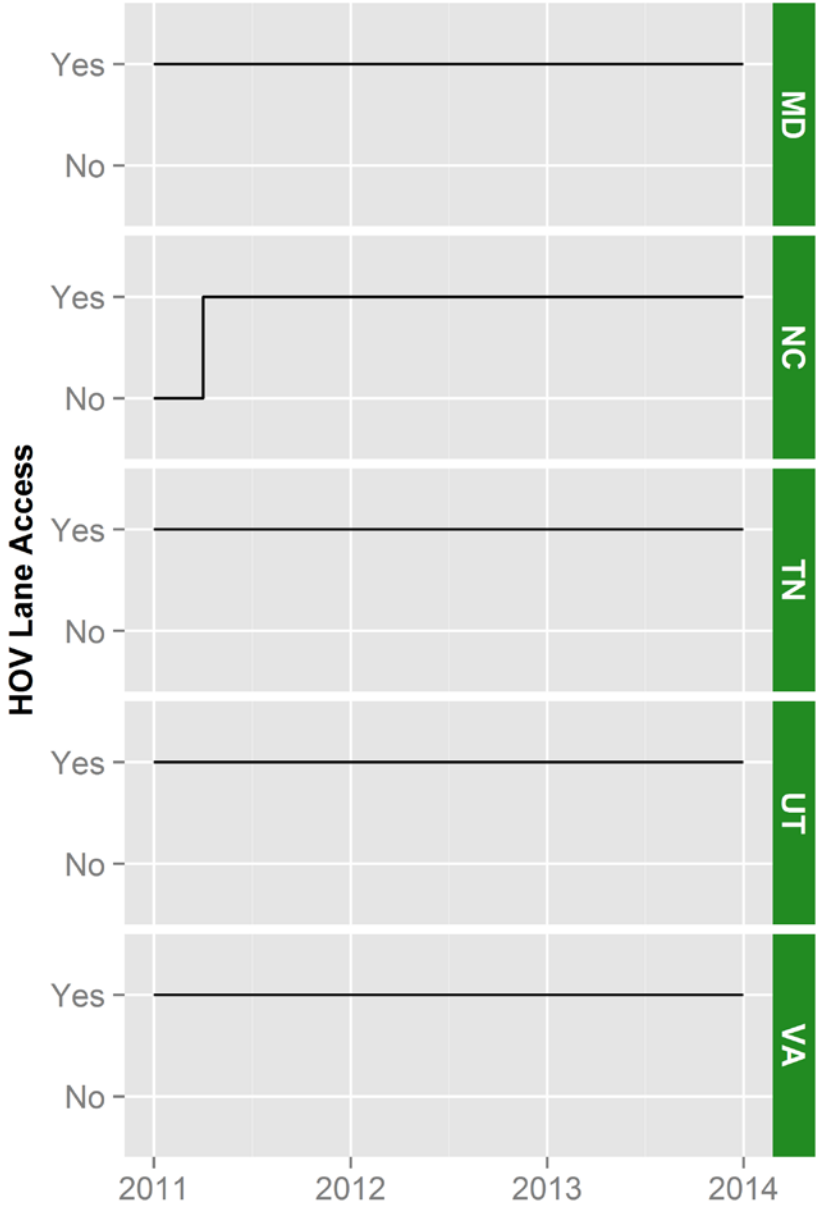




Data

Source: AFDC





Methodology

- **Objective**
  - Assess the impact of state incentives on BEV ownership
- **Approach**
  - Use a regression model to isolate the impact of rebates, tax credits, and HOV lane access on adoption of BEVs
  - Utilize within-state variation to estimate policy effect
    - Lack of within-state variation for tax exemption policies during the study period prevented estimation of their effects
    - Limited variation in other policy mechanisms must be considered when drawing conclusions about estimation results (i.e., assessing external validity)
  - Control for national trends with across-state variation
  - Purge additional within-state variation due to demographics and fuel price changes
  - Estimate average impacts for all BEVs in the data set as well as differential impacts for Tesla and non-Tesla BEVs.

Methodology

Specification

$$\log(PersEV_{imt}) = \alpha_{im} + \beta Incentives_{imt} + \gamma EVSE_{imt} + \delta Demographics_{it} + \lambda Fuel\ Prices_{it} + \theta_{tm} + \varepsilon_{imt}$$

i: state, t: time; m: make

$PersEV$: new personal EV registrations per capita

$Incentives$: Maximum value of direct financial incentives and indicator for HOV lane access

$EVSE$: Stock of public electric vehicle supply equipment (EVSE)

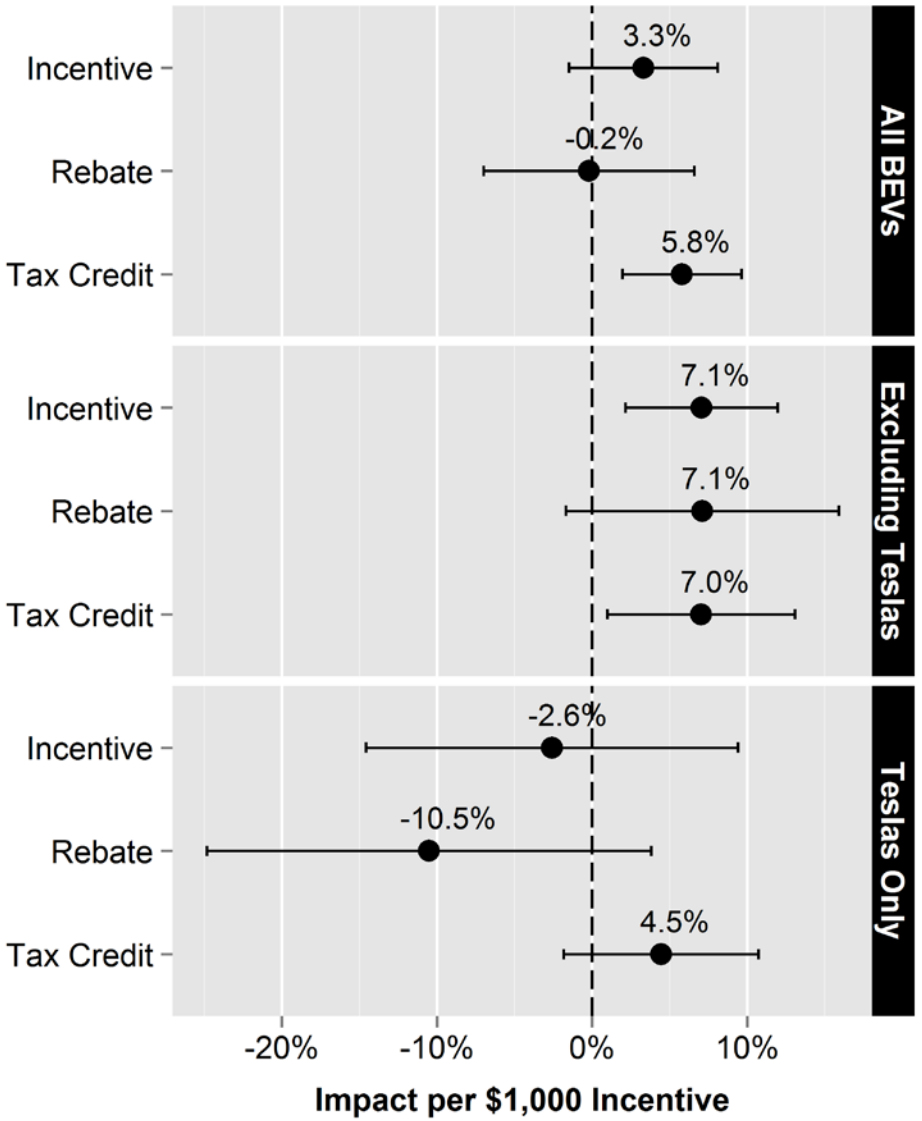
$Demographics$: State-level demographics (full list included in appendix)

$Fuel\ Prices$: State-level gasoline and residential electricity prices.

Address potential endogeneity of charging infrastructure using instrumental variables technique.

Results

- **Incentive impacts for full sample of BEVs are positive, but not statistically significant**
- **A $1,000 increase in tax credit value is associated with a 2% to 10% change in per-capita BEV registrations**
- **Impacts by vehicle make**
  - Non-Tesla vehicles: 2% to 12% impact per $1,000 of incentive
  - Tesla vehicles: Tax credit impacts positive, but not statistically significant
  - Tax exemption impacts could not be estimated due to lack of variation in policies during the study period
- **Results robust to endogeneity correction with chosen instrument**
- **Estimated effect of charging infrastructure is positive, but not significant across specifications**
  - Positive correlation between EVSE and registrations for the subsample of Tesla vehicles.



Note: Error bars indicate 95% confidence interval.

Sample Calculation

	Colorado	
Maximum Incentive Value ($)	6,000	[1]
BEVs Per Capita (000s)	0.211	[2]
Estimated impact (per $1,000 of tax credit)	2% to 10%	
Adjustment to BEVs Per Capita	12% to 60%	[3]
But-for BEVs Per Capita (000s)	0.186 to 0.085	[4]
Population (000s)	5,268	[5]
BEVs Attributed to Incentive	134 to 668	[6]
New BEVs Registered During Incentive Period	1,114	[7]

Notes: [3] = [Impact %] x ([1]/1000); [4] = (1 – [3]) x [2]; [6] = [4] x [5]

CO_2 Equivalent Savings (tons per year)	536 to 2,681	[8]
Vehicle Lifetime CO_2 Equivalent Savings (tons)	3,217 to 16,085	[9]
Abatement Cost per Ton	416 to 2,078	[10]

Notes: [8] Assumes savings of 207 grams of CO_2-equivalent per mile relative to a conventional vehicle with 13,476 annual miles driven (Nguyen et al. 2013; Federal Highway Administration). [9] = [8] x [6-year vehicle lifetime]; [10] = ([1] x [7]) / [9].

BEV Market Implications

	Maximum Incentive Value ($)	BEVs Attributed to Incentive
Tax Credit		
West Virginia	7,500	5 to 26
Colorado	6,000	134 to 668
Georgia	5,000	504 to 2,518
Louisiana	3,000	7 to 34
South Carolina	1,500	7 to 34
Maryland	1,000	17 to 86
Oregon	750	32 to 158
Utah	605	5 to 27
Totals		710 to 3,550

Note: BEVs Attributed to Incentive computed as outlined in item [6] from previous slide.

General Cautions

Preliminary analysis of the BEV market

- Vehicles purchased by early adopters
- State incentives exhibit limited variation over study time period
- Market implications focus on CO_2 impacts only
- Charging infrastructure impact requires additional study as market develops.

Conclusions

- **Econometric analysis reveals positive impact of state-level financial incentives**
- **Impact of HOV lane access and tax exemption incentives inconclusive due to lack of variation during study time period**
- **Evidence that Tesla buyers and buyers of non-Tesla BEVs respond differently to rebates**
  - Response to tax credits not significantly different
- **State-level subsidies produced an estimated 700 to 3,500 new BEV registrations nationwide since 2011**
- **The use of these BEVs resulted in an estimated annual abatement of 500 to 2,700 tons of CO_2.**

Next Steps

- **Revisit impacts as BEV market matures**
- **Utilize variation as old policies expire and new policies emerge**
- **Include analysis of plug-in hybrid electric vehicle (PHEV) market**
- **Analyze localized impacts**
  - Incentives
  - Purchasing behavior
  - Infrastructure availability.

Contact Information

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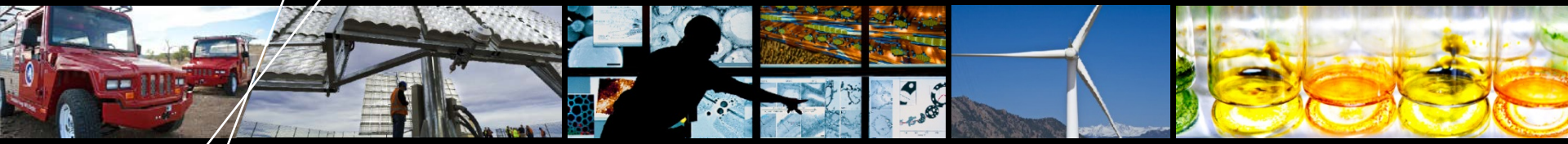


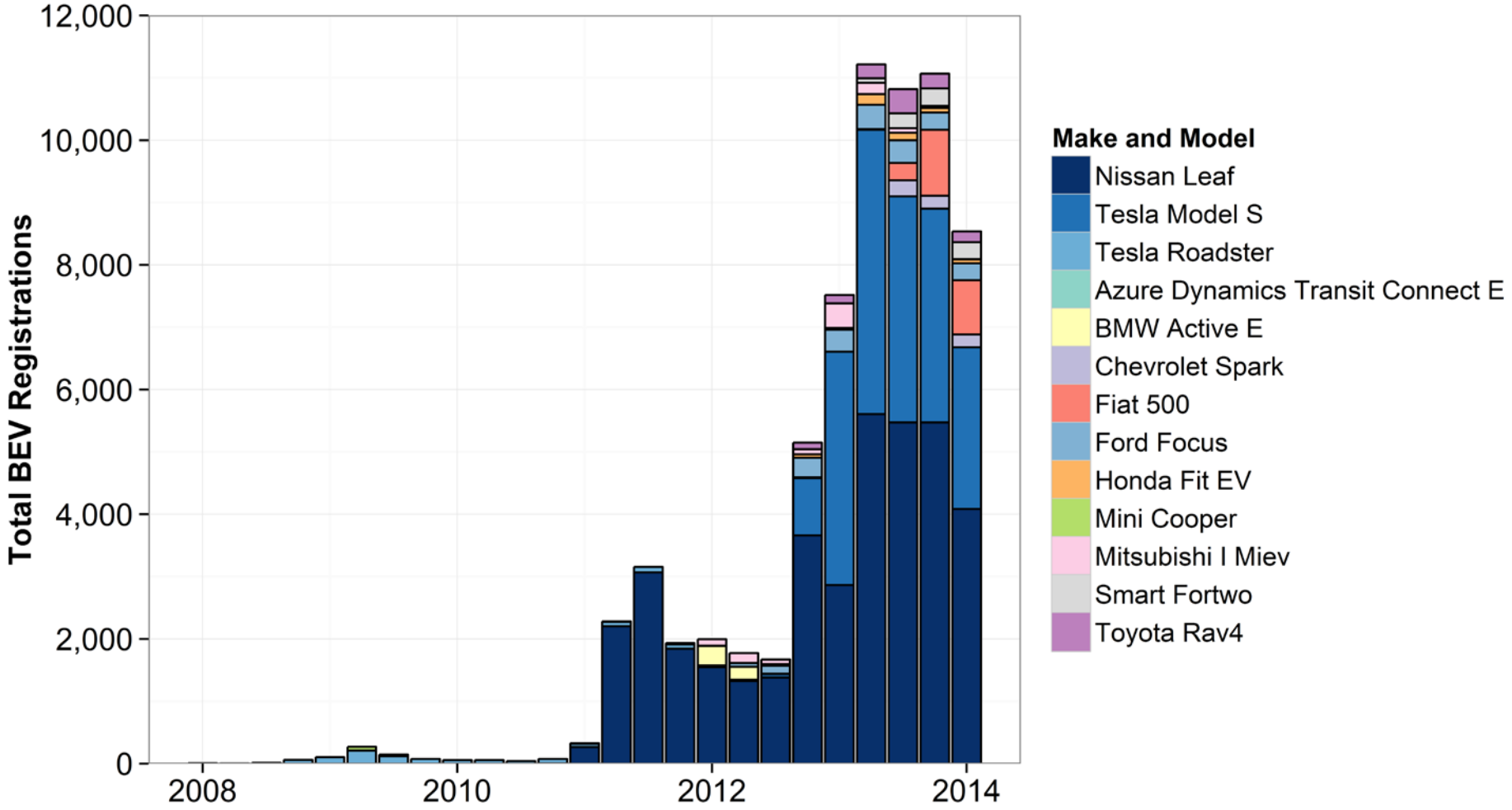
Appendix

Data and Sources

Data	Source
Incentives	U.S. Department of Energy. "Alternative Fuels Data Center." Accessed 2014: http://www.afdc.energy.gov/; state statutes and legislative histories.
Vehicle registrations	R.L. Polk, POLK_VIO_DETAIL_2014, April 2014.
Electric vehicle supply equipment (EVSE)	U.S. Department of Energy. "Alternative Fuels Data Center." Accessed 2014: http://www.afdc.energy.gov/.
Demographics	U.S. Census Bureau. "State & County QuickFacts." Accessed 2014: http://quickfacts.census.gov/; U.S. Department of Commerce, Bureau of Economic Analysis. "Regional Economic Accounts." Accessed 2014: http://www.bea.gov/regional/index.htm/.
Fuel prices	Energy Information Administration. "Average Retail Price of Electricity." Accessed 2014: http://www.eia.gov/electricity/data/browser/; Energy Information Administration. "Gasoline Prices by Formulation, Grade, Sales Type." Accessed 2014: http://www.eia.gov/dnav/pet/pet_pri_allmg_a_EPM0_PTA_dpgal_m.htm; Energy Information Administration. "Monthly U.S. Retail Motor Gasoline and On-Highway Diesel Fuel Prices." Accessed 2014: http://ir.eia.gov/wpsr/psw14.xls.

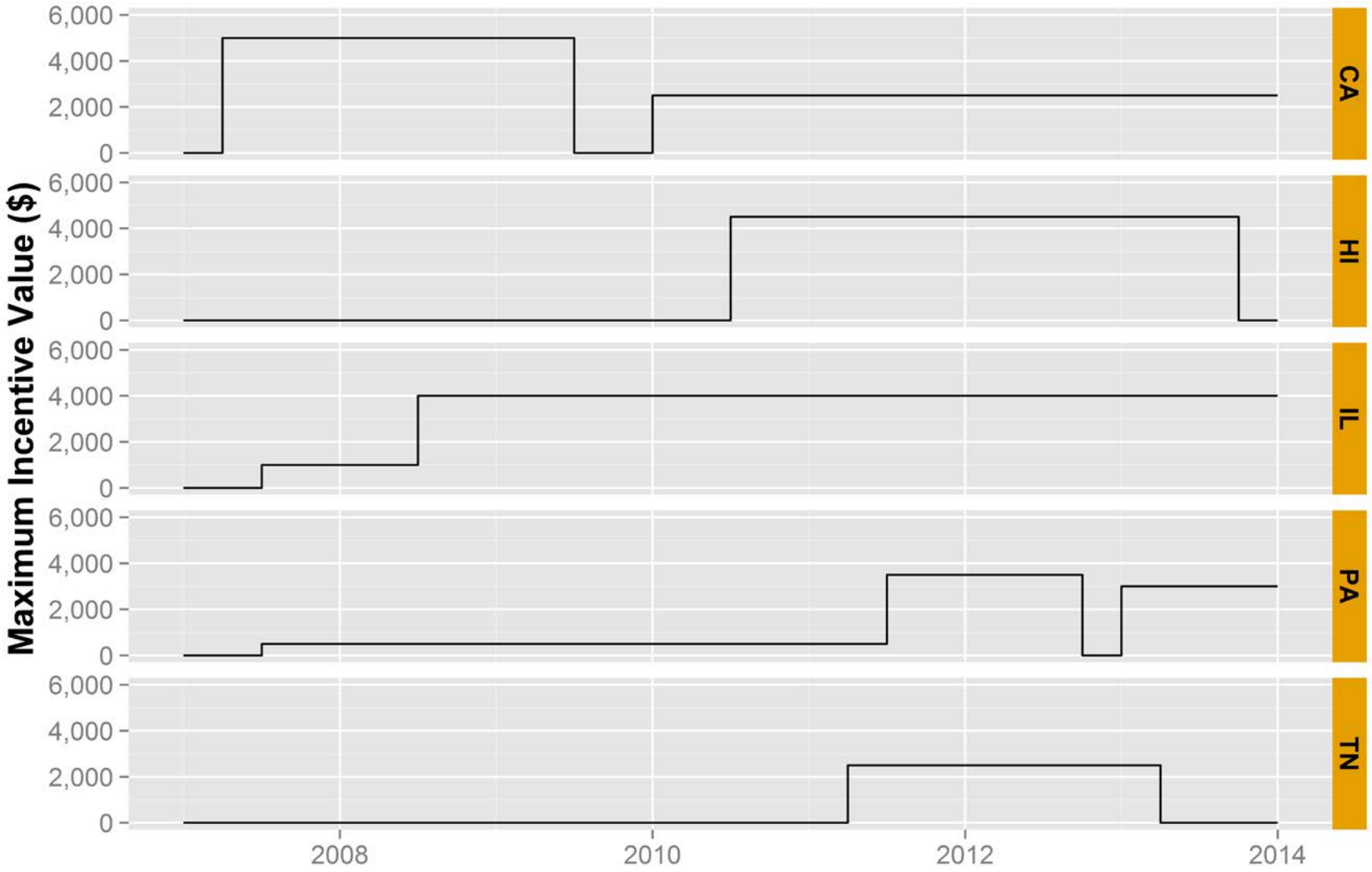
BEV Registrations

National BEV Registrations by Registration Date



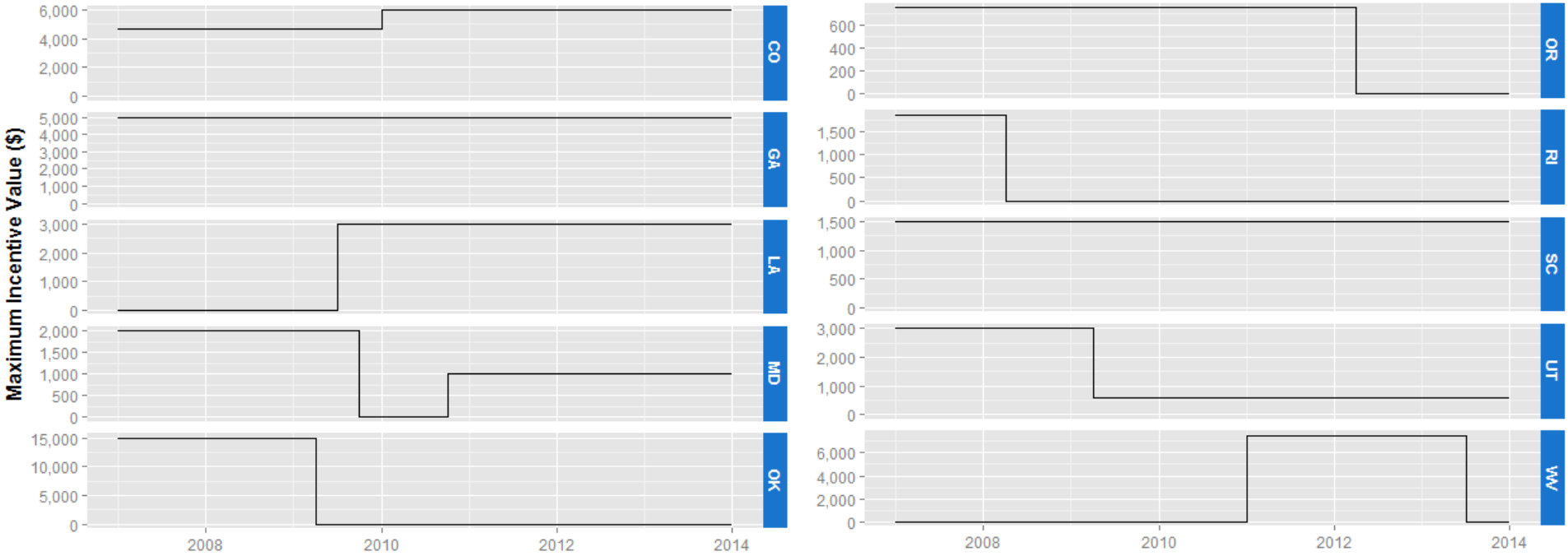
Source: R.L. Polk data

BEV Incentive Policies: Rebates



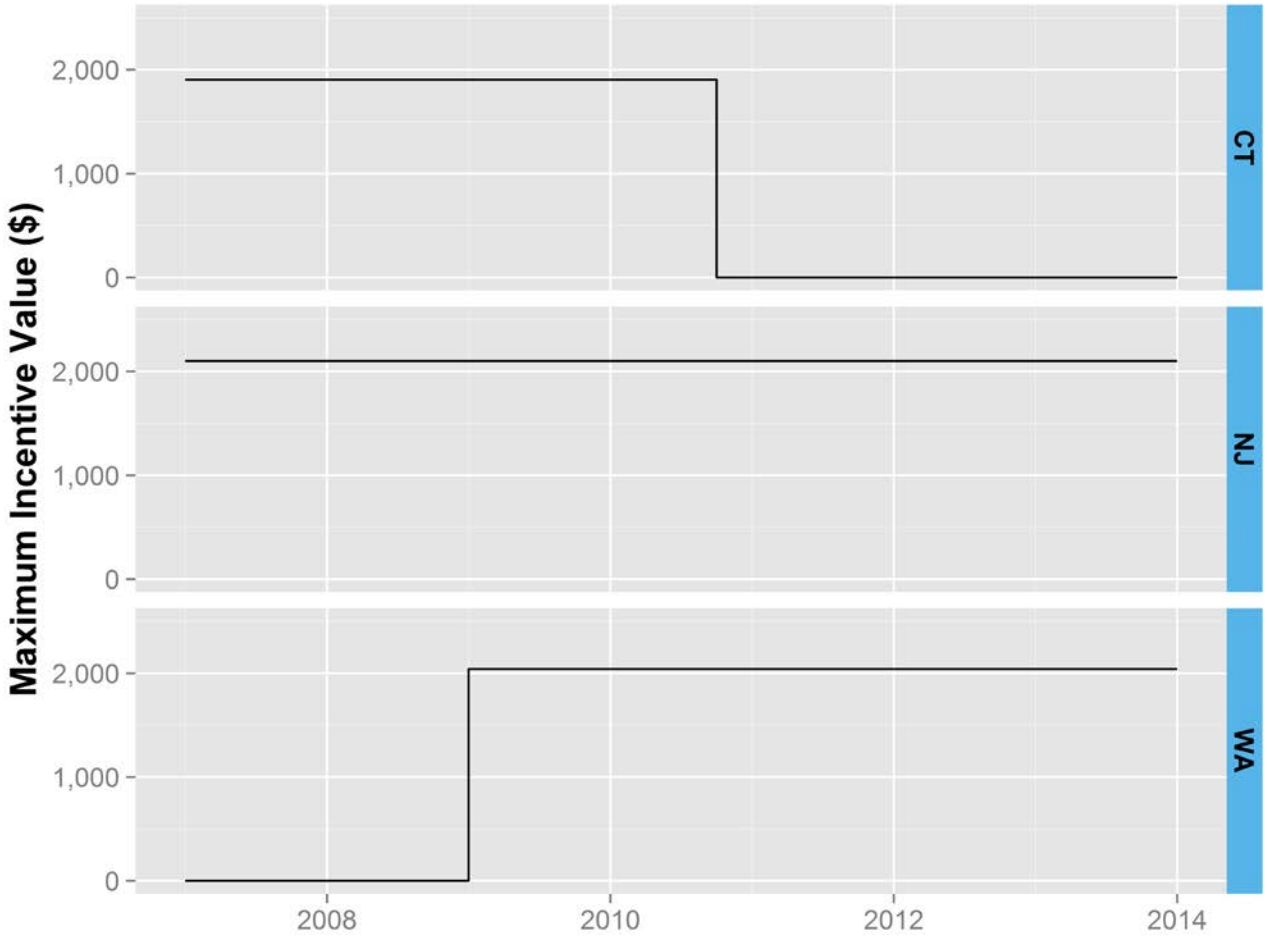
Source: AFDC

BEV Incentive Policies: Tax Credits



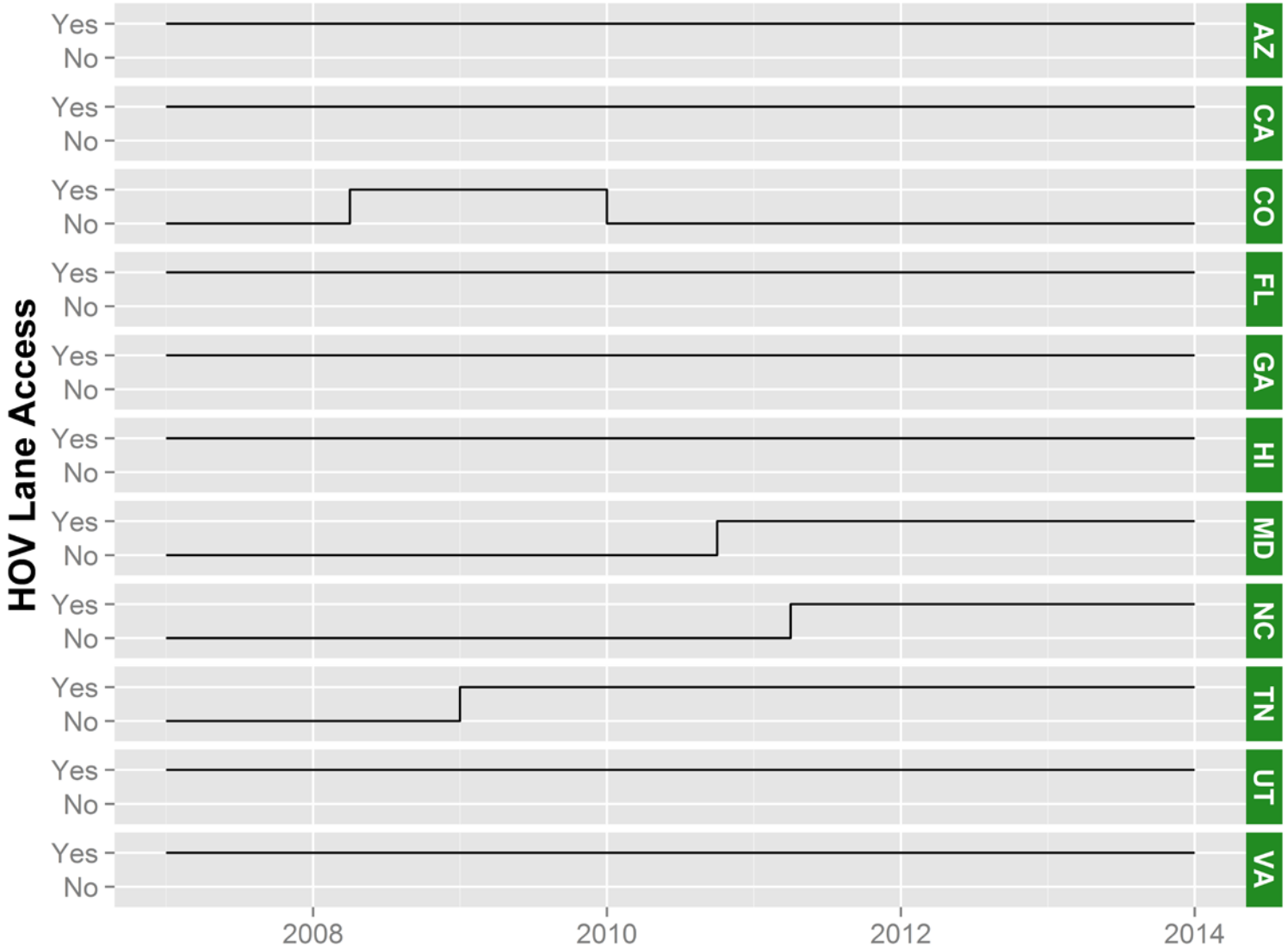
Source: AFDC

BEV Incentive Policies: Tax Exemptions



Source: AFDC

BEV Incentive Policies: HOV



Source: AFDC

Methodology

Endogeneity

- The “chicken and egg” problem: BEV registrations and charging infrastructure are co-determined (i.e., EVSE installations promote BEV adoption and BEV adoption leads to EVSE installation)
- Existence and level of impact remains an open question in the literature
  - Majority of charging takes place at home
  - Public charging infrastructure investment motivated by non-financial benefits (e.g., “green” marketing)
- Control using instrumental variables technique (removes co-determined variation)
- Instrument for EVSE infrastructure
  - Anecdotal evidence suggests potential of public charging station availability for both fleet and public charging
  - BEV adoptions by fleets driven by clean vehicle mandates
  - Fleet BEV registrations used to instrument for public EVSE.

Results

	Model								
	(1)			(2)			(3)		
Variables	Coeff.	(Std. Err.)		Coeff.	(Std. Err.)		Coeff.	(Std. Err.)	
Incentive ($000)	0.033	(0.0245)							
Rebate ($000)				-0.002	(0.0346)		-0.003	(0.0345)	
Tax Credit ($000)				0.058	(0.0196)	***	0.060	(0.0199)	***
HOV	0.046	(0.1517)		0.047	(0.1522)		0.083	(0.1464)	
EVSE (100s)	0.021	(0.0127)	*	0.021	(0.0127)	*	0.052	(0.0180)	***
N	822			822			822		
Adjusted R^2	0.8197			0.8196			0.8177		
Fixed Effects									
Year-quarter*Make	Yes			Yes			Yes		
State*Make	Yes			Yes			Yes		
Endogeniety correction	No			No			Yes		
Additonal controls									
Ln (mean age)	-6.462	(9.1256)		-6.848	(9.1982)		-7.053	(9.0986)	
Ln (pct female)	15.977	(12.7495)		16.088	(12.7715)		16.308	(12.8090)	
Ln (population per sq mile)	1.064	(13.6643)		0.760	(13.7264)		-4.457	(13.9108)	
Ln (per capita income)	-17.126	(11.5635)		-17.106	(11.5761)		-20.157	(11.7509)	*
Ln (pct high school grad)	3.162	(5.7456)		2.933	(5.8166)		1.023	(6.0222)	
Ln (pct college grad)	0.723	(1.3986)		0.768	(1.4064)		0.737	(1.3602)	
Ln (residential electricity price)	-1.144	(0.9031)		-1.157	(0.9052)		-1.190	(0.9269)	
Ln (retail gasoline price)	-12.381	(18.7411)		-12.561	(18.6773)		-12.749	(16.0587)	
Instrument							Fleet BEVs		

Notes: Standard errors in parantheses, clustered at the state level: *** significant at 1%; ** significant at 5%; * significant at 10%.

Results

	Model								
	(4)			(5)			(6)		
Variables	Coeff.	(Std. Err.)		Coeff.	(Std. Err.)		Coeff.	(Std. Err.)	
Incentive ($000)	0.071	(0.0250)	***						
Rebate ($000)				0.071	(0.0449)		0.071	(0.0451)	
Tax Credit ($000)				0.070	(0.0309)	**	0.072	(0.0317)	**
HOV	0.492	(0.1905)	***	0.492	(0.1906)	***	0.514	(0.1867)	***
EVSE (100s)	-0.031	(0.0195)		-0.031	(0.0195)		-0.010	(0.0144)	
N	822			822			822		
Adjusted R^2	0.8285			0.8283			0.8272		
Fixed Effects									
Year-quarter*Make	Yes			Yes			Yes		
State*Make	Yes			Yes			Yes		
Endogeniety correction	No			No			Yes		
Additonal controls									
Ln (mean age)	-1.429	(11.1058)		-1.424	(11.2438)		-1.669	(11.3362)	
Ln (pct female)	14.223	(13.8105)		14.222	(13.8451)		14.276	(13.8663)	
Ln (population per sq mile)	-4.023	(17.8630)		-4.018	(18.0053)		-7.470	(18.7657)	
Ln (per capita income)	-1.663	(14.3142)		-1.663	(14.3325)		-3.743	(14.6424)	
Ln (pct high school grad)	4.372	(7.2087)		4.375	(7.3502)		3.285	(7.5509)	
Ln (pct college grad)	1.675	(1.4240)		1.674	(1.4455)		1.658	(1.4183)	
Ln (residential electricity price)	-0.340	(1.0414)		-0.340	(1.0453)		-0.337	(1.0545)	
Ln (retail gasoline price)	-12.533	(23.1886)		-12.524	(23.4426)		-14.304	(21.3161)	
Instrument							Fleet BEVs		

Notes: Standard errors in parantheses, clustered at the state level: *** significant at 1%; ** significant at 5%; * significant at 10%.

Results

	Model								
	(4)			(5)			(6)		
Variables	Coeff.	(Std. Err.)		Coeff.	(Std. Err.)		Coeff.	(Std. Err.)	
Interactions									
Incentive ($000)*Tesla	-0.096	(0.0689)							
Rebate ($000)*Tesla				-0.173	(0.0719)	**	-0.171	(0.0772)	**
Tax Credit ($000)*Tesla				-0.024	(0.0472)		-0.025	(0.0488)	
HOV*Tesla	-0.904	(0.2217)	***	-0.897	(0.2227)	***	-0.948	(0.2336)	***
EVSE (100s)*Tesla	0.113	(0.0322)	***	0.113	(0.0323)	***	0.067	(0.0192)	***
Ln (mean age)*Tesla	-10.423	(14.7909)		-11.217	(14.7677)		-11.217	(15.5346)	
Ln (pct female)*Tesla	8.795	(14.9816)		8.939	(14.9481)		8.355	(15.3915)	
Ln (population per sq mile)*Tesla	9.442	(20.0879)		8.952	(20.1594)		16.792	(22.3854)	
Ln (per capita income)*Tesla	-40.110	(18.5668)	**	-39.882	(18.6539)	**	-35.388	(20.2660)	*
Ln (pct high school grad)*Tesla	-3.599	(8.5275)		-3.887	(8.6630)		-0.618	(9.6744)	
Ln (pct college grad)*Tesla	-3.045	(1.8044)	*	-2.991	(1.8165)	*	-2.961	(1.8982)	
Ln (residential electricity price)*Tesla	-2.057	(1.2331)	*	-2.070	(1.2326)	*	-1.979	(1.2722)	
Ln (retail gasoline price)*Tesla	5.649	(31.6320)		5.914	(32.0702)		5.403	(31.8988)	

Notes: Standard errors in parantheses, clustered at the state level: *** significant at 1%; ** significant at 5%; * significant at 10%.

Market Implications

Panel A

	Maximum incentive value (dollars)	BEVs per capita (000)	New BEVs during incentive period	BEVs attributed to incentives	Annual CO_2-equivalent savings (tons)
	(A)	(B)	(C)	(D)	(E)
Tax credit					
WV	7,500	0.018	25	(5 - 26)	(20 - 102)
CO	6,000	0.211	1,114	(134 - 668)	(536 - 2,681)
GA	5,000	0.504	5,036	(504 - 2,518)	(2,020 - 10,099)
LA	3,000	0.024	112	(7 - 34)	(27 - 135)
SC	1,500	0.047	226	(7 - 34)	(27 - 136)
MD	1,000	0.145	861	(17 - 86)	(69 - 345)
OR	750	0.534	464	(32 - 158)	(126 - 632)
UT	605	0.152	441	(5 - 27)	(21 - 107)
Totals					(2,847 - 14,237)

Panel B

	Vehicle lifetime CO_2 savings (tons)		Abatement cost per ton (dollars)	
	6-year lifetime	10-year lifetime	6-year lifetime	10-year lifetime
	(F)	(G)	(H)	(I)
Tax credit				
WV	(123 - 614)	(205 - 1,023)	(306 - 1,528)	(183 - 917)
CO	(3,217 - 16,085)	(5,362 - 26,808)	(416 - 2,078)	(249 - 1,247)
GA	(12,119 - 60,595)	(20,198 - 100,991)	(416 - 2,078)	(249 - 1,247)
LA	(162 - 809)	(270 - 1,348)	(416 - 2,078)	(249 - 1,247)
SC	(163 - 816)	(272 - 1,360)	(416 - 2,078)	(249 - 1,247)
MD	(414 - 2,072)	(691 - 3,453)	(416 - 2,078)	(249 - 1,247)
OR	(758 - 3,790)	(1,263 - 6,317)	(92 - 459)	(55 - 275)
UT	(128 - 642)	(214 - 1,070)	(416 - 2,078)	(249 - 1,247)
Totals	(17,084 - 85,422)	(28,474 - 142,370)		

Note: Ranges presented assume 2% to 10% incentive impact per $1,000 of incentive. Abatement cost per ton for 6-year and 10-year lifetime scenarios computed as (A*C)/F and (A*C)/G, respectively.

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