Giving green to get green?
Incentives and consumer adoption of hybrid vehicle technology

Gallagher and Muehlegger (2011)

Presented by:

Banguning Asgha

Washington State University

Introduction

- Hybrid-electric engines combine a gasoline engine and electric motor to improve fuel efficiency
- Hybrid vehicles consume less gasoline and emit less pollution per mile than non-hybrid vehicles
- The adoption of hybrid-vehicle technology plays an important role in both energy and environmental policy debates

Hybrid vehicle incentives

- Beginning in 2000, federal, state, and local governments in the US experimented with a broad set of consumer incentives to stimulate hybrid vehicle adoption
- From 2000 to 2005, the federal government offered a $2000 tax deduction for the purchase of any hybrid vehicle
- Under the Energy Policy Act of 2005, the deduction was converted into a tax credit in January 2006
- The tax credit is more generous than the previous tax deduction and varies by model, depending on the emissions and fuel economy
- Toyota Prius ($3150), Accord Hybrids and the Saturn VUE Green Line ($650)

State incentives (2000-2006)

Table 1
State incentives for hybrid vehicles, 2000–2006.

Single-occupancy HOV lane access	Income tax credit	Sales tax exemption	Vehicle emissions test exemption	State gov. purchasing requirement	Registration or excise tax exemption	Parking fee reduction or exemptions (cities)
AZ (pilot)	CO	CT[+]	CO[+]	MN	DC	Albuquerque, NM
CA[+]	MD*	DC	MD	NM	IL[+]	Austin, TX
CO (on hold)	NY[+,*]	ME*	WA	NY	NM	Baltimore, MD
FL	OR	NM[+]		WI	PA	Ferndale, MI
GA (on hold)	PA					Huntington, NY
NJ	SC					Los Angeles, CA
NY (pilot)	UT*					New Haven, CT
UT	WV*					Salt Lake City, UT
VA						San Antonio, TX
						San Jose, CA
						Santa Monica, CA
						Vail, CO
						Westchester, NY

Note: [+]denotes incentive targeted at high fuel-economy hybrid vehicles (e.g. Prius, Insight, Civic), and *denotes expired program. Data sources: State Tax Commissions, http://go.ucsusa.org/hybridcenter/incentives.cfm; http://www.hybridcars.com; http://whybuyhybrid.

State tax incentives

Table 2
State tax incentives.

State	Duration	Models covered	Generosity range
Income tax credits			
Colorado	2001–present	All, but VUE, GS450h, and Camry*	$2265–$6542
Maryland	2001–2004	Civic, Prius, Insight	$1000
New York	2000–2006	All	$2000
Oregon	2003–present	All	$750–$1500
Pennsylvania	2006–present	Civic, Prius, Insight, Escape	$500
South Carolina	2006–present	All	$130–$630
Utah	2001–2005	Civic	$1537–$1720
West Virginia	2003–2006	All	$2411–$3750
Sales tax waivers			
Connecticut	2004–present	Civic, Prius, Insight	$1217–$1409
District of Columbia	2005–present	All	$1226–$3294
Maine	2000–2005	Civic, Prius, Insight	$300–$500
New Mexico	2004–present	Civic, Prius, Insight	$608–$704

Colorado income tax credits for the VUE, GS450h, and Camry begin post-2006.Generosity for Sales Tax Waivers in CT, DC, and NM are estimated based on vehicle MSRP.

Research questions

1. Is consumer behavior affected by state incentives?
2. Do consumers respond differently to distinct types of tax incentives?
3. Do consumers respond to rising gasoline prices and, if so, how does the effect of rising gasoline prices compare to that of state incentives?

Contributions to literature

1. Unlike the previous papers that focus on either federal incentives or provincial incentives that vary by generosity but not form, this study examines US state incentives that vary both in generosity and form
2. This study informs the long empirical literature on how consumers incorporate future energy costs into durable goods purchase decisions.
3. This paper relates to the growing literature examining the structure of tax incentives by estimating quarterly coefficients on income tax credits.

Data

- Quarterly, state-level hybrid vehicle sales data for the eleven models introduced from 2000-2006
- Data on hybrid sales comes from JD Power and Associates' proprietary Power Information Network
- Real-time transaction-level data from approximately 6000 dealers
- Fleet, corporate, and government sales were excluded
- Annual fuel savings (in $/year) calculation:

$$FuelSavings_{imt} = \left(\frac{1}{MPG_{nh}} - \frac{1}{MPG_m}\right) * Gasprice_{it} * MeanVMT_{it}$$

Where:
MPGm is the EPA combined fuel economy rating of hybrid model m,
MPGnh is the mean EPA combined fuel economy rating for all non-hybrid vehicles within the same class,
Gaspriceit is the average tax-inclusive gasoline price in state i at time t,
MeanVMTit is annual vehicle miles traveled per capita in state i

Summary Statistics

Table 3
Summary statistics.

Variable	*N*	Mean	Std. Dev.	Min	Max
Sales data					
Vehicle sales	4781	121.1	386.0	1.0	8871.0
Vehicle sales per thousand pop.	4781	0.017	0.025	0.000	0.243
Incentive data					
HOV_lane access	4781	0.055	0.228	0.0	1.0
Federal tax incentive	4300	1073	797	560	3150
State income tax credit	465	2011	1026	130	4713
State sales tax incentive	173	1037	640	300	2722
Total tax incentive	4331	1270	1015	300	6435
Annual fuel savings ($/year)	4630	424.96	131.77	32.03	1009.29
State-level data					
Per-capita income	1228	32.13	5.68	21.01	56.33
Percent of adults graduating high school	1228	0.86	0.04	0.77	0.93
Percent of adults graduating college	1228	0.27	0.06	0.15	0.49
Percent female	1228	0.51	0.01	0.48	0.53
Mean age	1228	36.46	1.45	30.64	39.55
Retail gasoline price, tax inclusive	1228	180.13	47.26	99.43	310.27
Vehicle miles traveled, per capita (0 0 0)	1172	10.43	1.94	6.79	18.34
Sierra club members	1228	13,917	23,222	535	153,619
Sierra club membership, per thousand pop	1228	2.18	1.25	0.38	5.37
Armed forced participation, per capita	1228	0.0094	0.0074	0.0025	0.0383

For tax incentive variables, fuel savings, and vehicle sales, *N* is the number of non-zero observations and the summary statistics are conditional on a non-zero value. For demographics and gasoline prices, *N* reports the number of state∗quarter observations.

Domestic hybrid sales

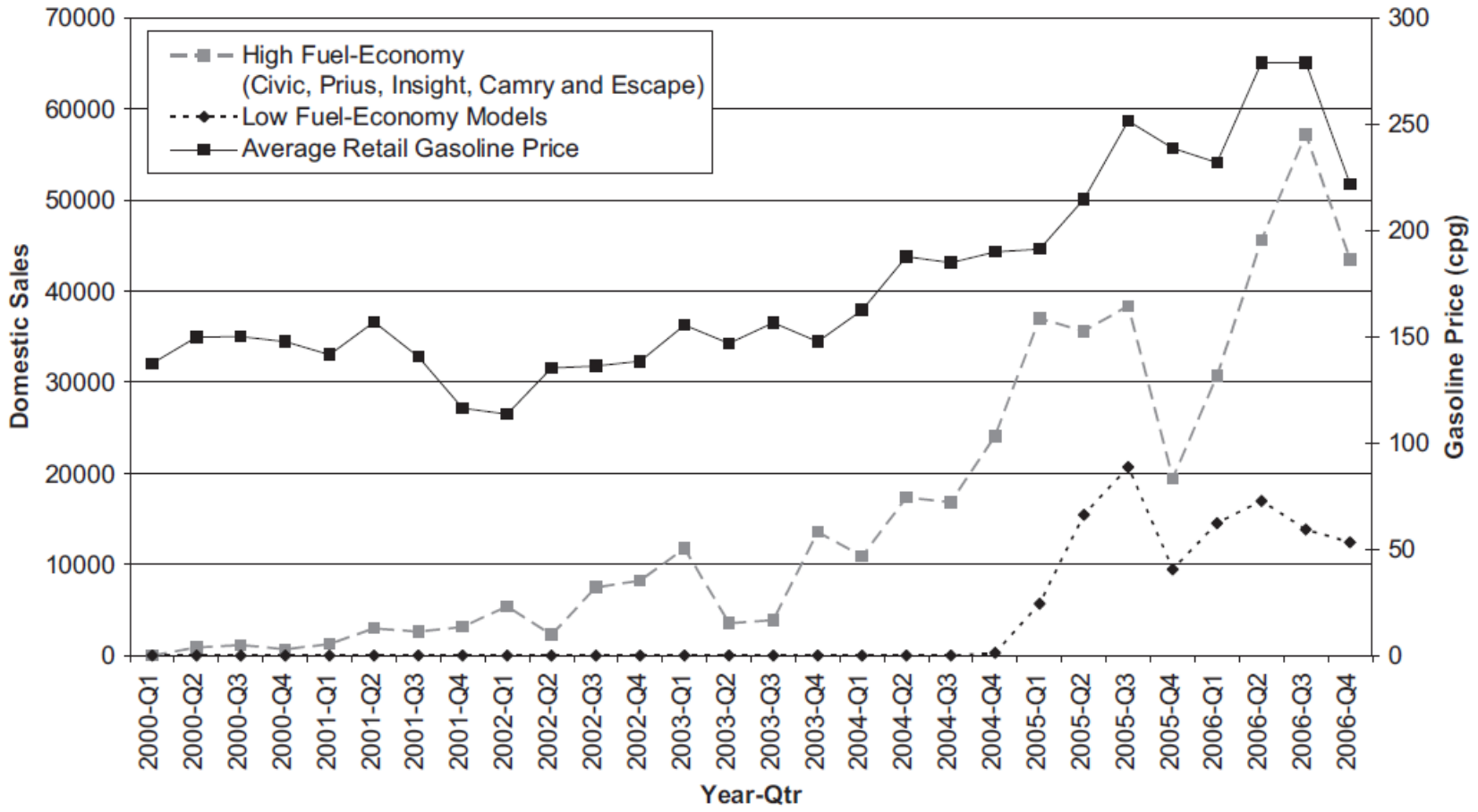

Fig. 1. Domestic hybrid sales. *Note*: National Vehicle Sales are reported on the primary axis. Average US retail gasoline price is reported on the secondary axis.

Methodology

- Focus specifically on the more valuable state tax incentives and single-occupancy access to HOV lanes
- Omit local incentive programs such as parking fee waivers, state vehicle registration fee waivers, and emissions testing
- Indexing state, model, and time as i, m, and t, respectively, the relationship between hybrid sales, incentives, and gasoline can be estimated as:

$$Log(Sales\ Per\ Capita_{imt}) = \alpha_{im} + \beta Fuel\ Savings_{imt} + \lambda\ Incentives_{imt} + \theta Demographics_{it} + \eta_{mt} + \varepsilon_{imt}$$

- Minimum potential bias have been discussed

Results

Table 4
Hybrid incentives. Dependent variable: log per-capita sales.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
State tax incentive ($000)	0.0485* (0.0292)			0.0486* (0.0291)	0.0431 (0.0282)	0.0435 (0.0282)
State tax incentive/MSRP		1.186* (0.678)				
State tax incentive dummy			0.201*** (0.0681)			
HOV access dummy	−0.0692 (0.0595)	−0.0690 (0.0594)	−0.0622 (0.0587)		−0.0821 (0.0596)	−0.0798 (0.0603)
UT HOV access				−0.107*** (0.0375)		
CA HOV access				−0.0691 (0.157)		
VA HOV access				0.651*** (0.228)		
VA HOV access*post-7/1/06				−0.250*** (0.0730)		
FL HOV access				−0.175** (0.0864)		
NJ HOV access				0.0110 (0.0729)		
Annual fuel savings ($/year)	0.00132** (0.000580)	0.00133** (0.000580)	0.00146** (0.000576)	0.00132** (0.000581)		
Log (retail gasoline price)					0.706** (0.309)	
Log (retail gasoline price)*low FE hybrid						0.0263 (0.805)
Log (retail gasoline price)*high FE hybrid						0.855** (0.333)
Log (per-capita income)	2.016*** (0.725)	2.021*** (0.726)	2.017*** (0.723)	2.015*** (0.727)	2.109*** (0.666)	2.109*** (0.666)
Log (mean age)	−16.88*** (5.147)	−16.95*** (5.144)	−16.77*** (5.150)	−17.16*** (5.140)	−15.35*** (5.141)	−15.16*** (5.161)
Log (percent female)	0.256 (19.64)	0.108 (19.68)	2.140 (19.43)	−0.343 (19.69)	−0.892 (18.51)	−0.986 (18.47)
Log (percent HS graduate)	1.090 (1.003)	1.080 (1.003)	0.969 (1.003)	1.069 (0.993)	1.074 (0.984)	1.084 (0.982)
Log (percent college graduate)	−0.158 (0.256)	−0.156 (0.256)	−0.140 (0.251)	−0.151 (0.256)	−0.157 (0.254)	−0.156 (0.254)
Observations	4630	4630	4630	4630	4781	4781
R^2	0.935	0.935	0.935	0.935	0.933	0.933

Standard errors, in parentheses, are clustered by state*model. All specifications include state*model and time*model fixed effects. *, **, and ***denote significance at 10%, 5%, and 1%, respectively.

Results

- The coefficient on the value of state tax incentives is positive and significant. Offering a tax incentive of $1000 is associated with a 5% increase in hybrid sales.
- Increasing a tax incentive by 1% of a vehicle's MSRP is associated with a 1.2% increase in sales
- Offering a tax incentive of mean value is associated a 22% increase in sales
- Virginia is the only state for which the coefficient on HOV access is significant and of the expected sign. Vehicle owners in Virginia used carpool lanes to travel to and from Washington DC extensively
- Strong evidence that hybrid adoption is positively correlated with higher gasoline prices
  - ✓ A $100 increase in annual fuel savings is associated with a 13% increase in sale
  - ✓ A 10% increase in gasoline price leads to an 8.6% increase in per-capita sales of high fuel-economy hybrid vehicles (significant).
  - ✓ Point estimate for the cross-price elasticity of low fuel-economy hybrids is not statistically significan
- Demographic variables: per-capita income is significantly correlated with hybrid sales, while the mean age are negatively correlated with hybrid sales

Sales tax waivers vs income tax credits

Table 5
Tax incentives, by type. Dependent variable: log per-capita sales.

Variables	Specification		
	(1)	(2)	(3)
Annual fuel savings ($/year)	0.00145** (0.000584)	0.00146** (0.000584)	0.00152*** (0.000579)
HOV access dummy	−0.0606 (0.0588)	−0.0603 (0.0587)	−0.0600 (0.0583)
State income tax credit ($000)	0.0239 (0.0246)		
State sales tax waiver ($000)	0.374*** (0.141)		
State income tax credit/MSRP		0.578 (0.532)	
State sales tax waiver/MSRP		8.343*** (3.143)	
State income tax credit dummy			0.138** (0.0649)
State sales tax waiver dummy			0.420** (0.171)
P-value for the null hypothesis equating the sales tax and income tax coefficients	0.014	0.014	0.124
Observations	4630	4630	4630
R^2	0.935	0.935	0.935

All specifications include state∗model and time∗model fixed effects, and the full set of demographic controls. Standard errors, in parentheses, are clustered by state∗model. *, **, and ***denote significance at 10%, 5%, and 1%, respectively.

Sales tax waivers vs income tax credits

- Conditional on value, a sales tax waiver is associated with more than a ten-fold greater increase in hybrid vehicle sales than a comparable income tax credit.
  - ✓ A one thousand dollar tax waiver (income tax) is associated with a 45% (3%) increase in hybrid vehicle sales
- Relative to vehicle MSRP, a sales tax waiver is associated with a greater increase in hybrid vehicle sales than an income tax credit
- Using dummy variables, a sales tax waiver is associated with a 52% increase in sales, while an income tax credit is associated with a 15% increase in sales
- Several reasons to expect consumers to be more sensitive to a sales tax waiver than an income tax credit is because a sales tax is automatic, immediate, and easy to understand

Why do consumers respond more to sales tax waiver?

Table 6
Tax incentives, by type and quarter of year. Dependent variable: log per-capita sales.

Variables	Specification			
	(1)		(2)	
	Income tax credit ($000)	Sales tax waiver ($000)	Income tax credit/MSRP	Sales tax waiver/MSRP
Second quarter coefficient	0.0355 (0.0293)	0.373*** (0.137)	0.848 (0.641)	8.484*** (3.077)
Third quarter coefficient	0.0327(0.0305)	0.473 (0.305)	0.751 (0.652)	10.58 (6.797)
Fourth quarter coefficient	0.0239 (0.0304)	0.325*** (0.0692)	0.392 (0.677)	7.013*** (1.493)
First quarter coefficient	0.00957 (0.0260)	0.333** (0.155)	0.301 (0.601)	7.450** (3.473)
Observations	4630		4630	
R^2	0.935		0.935	

All specifications include state∗model and time∗model fixed effects, annual fuel savings, a dummy variable for HOV access, and the full set of demographic controls. Standard errors, in parentheses, are clustered by state∗model. *, **, and ***denote significance at 10%, 5%, and 1%, respectively.

Possibilities:

1. If the observed difference is entirely attributable to discounting, we would expect the coefficient on the tax credit should be smallest in the first quarter and greatest in the fourth quarter (closest to claim the credit on their subsequent tax return)
2. If buyers are poorly informed or poorly understand income tax credits at the time of vehicle purchase, we might expect the greatest effect to occur in the second quarter, when consumers are most likely to learn about a tax credit

Estimating implicit discount rates on future fuel savings

Table 7
Implied discount rate robustness tests. Dependent variable: log per-capita sales.

Variables	Within-vehicle class comparison (base case)	Within-vehicle type comparison	Comparison to mean fuel economy for all light vehicles	Within-class comparison using EPA-highway fuel economy for hybrids	Within-class comparison using EPA-city fuel economy for hybrids
	(1)	(2)	(3)	(4)	(5)
Annual fuel savings ($/year)	0.00145**	0.00136***	0.00120***	0.00149**	0.00140**
	(0.000584)	(0.000502)	(0.000436)	(0.000594)	(0.000571)
HOV access dummy	−0.0606	−0.0594	−0.0587	−0.0603	−0.0613
	(0.0588)	(0.0592)	(0.0593)	(0.0589)	(0.0588)
State income tax credit ($000)	0.0239	0.0239	0.0241	0.0239	0.0238
	(0.0246)	(0.0246)	(0.0245)	(0.0246)	(0.0246)
State sales tax waiver ($000)	0.374***	0.376***	0.377***	0.375***	0.374***
	(0.141)	(0.140)	(0.141)	(0.141)	(0.140)
Observations	4630	4630	4630	4630	4630
R^2	0.935	0.935	0.935	0.935	0.935
Implied discount rates					
Five-year vehicle lifespan	14.6%	19.4%	29.5%	13.0%	17.0%
Six-year vehicle lifespan	21.8%	26.3%	35.9%	20.2%	24.0%
Eight-year vehicle lifespan	28.9%	33.0%	41.8%	27.4%	30.9%

All specifications include demographic variables, state∗model fixed effects and time∗model fixed effects. Robust standard errors are clustered at the state∗model level. ***denotes significance at the 1% level. Within-type comparisons compare each hybrid vehicle to the mean non-hybrid light truck or passenger car. Within-class comparisons compare each hybrid vehicle to the mean non-hybrid vehicle in the same vehicle class (e.g. comparing the Toyota Prius to non-hybrid compact passenger cars).

Estimating implicit discount rates on future fuel savings

- The point estimates in column (1) imply that annual fuel savings of $257 generate an equivalent increase in sales to a $1000 sales tax waiver
- The discount rate implied a comparison of hybrid fuel costs and mean fuel costs for light trucks or passenger cars is greater than the discount rate implied by the within-class comparison
- The discount rate implied a comparison of hybrid fuel costs and mean fuel costs for light trucks and passenger cars (column 3) is greater than the discount rate implied by implied a comparison of hybrid fuel costs and mean fuel costs for light trucks or passenger (column 2)
- Columns (4) and (5) calculate the discount rates implied if consumers use the city-ratings and highway-ratings for hybrid vehicles rather than the combined fuel economy rating.
- Little evidence of changing the source of the fuel economy rating for the hybrid vehicles substantively affects our implied discount rates

Sensitivity test

- The sensitivity tests do not substantially affect our point estimates

Table 8
Sensitivity analyses. Dependent variable: log per-capita sales.

Variables	Base results	Restrict sample to states offering a tax incentive	Restrict sample to quarters with positive sales in all states	Drop months with Prius and Civic production constraints	Drop low volume models (insight, VUE, GS450h)
	(1)	(2)	(3)	(4)	(5)
Annual fuel savings ($/year)	0.00132**	0.000794	0.00159***	0.00130**	0.00166**
	(0.000580)	(0.00128)	(0.000560)	(0.000584)	(0.000644)
HOV access dummy	−0.0692	−0.137	−0.0975*	−0.0687	0.0196
	(0.0595)	(0.105)	(0.0577)	(0.0600)	(0.0482)
State tax incentive ($000)	0.0485*	0.0501	0.0498*	0.0474	0.0491
	(0.0292)	(0.0337)	(0.0290)	(0.0289)	(0.0389)
Observations	4630	1056	4319	4514	3594
R^2	0.935	0.939	0.935	0.935	0.912

All specifications include state∗model and time∗model fixed effects, and the full set of demographic controls. Standard errors, in parentheses, are clustered by state∗model. *, **, and ***denote significance at 10%, 5%, and 1%, respectively.

Social Preferences

- We examine whether hybrid vehicle adoption correlates with preferences for environmentalism or energy security:

$$Log(SalesPerCapita_{imt}) = \phi_i + \gamma HighEff_m * proxies_{it} + \beta FuelSavings_{imt} + \lambda Incentives_{imt} + \theta Demographics_{it} + \eta_{mt} + \varepsilon_{imt}$$

- We decompose the state.model fixed effects into a state fixed-effect common for all hybrid vehicles
- As a proxy for environmental preferences, we use state-level per-capita Sierra Club membership
- Results:
- One standard deviation increases in Sierra Club membership per capita and per-capita military participation are associated with 17% and 11% increases in sales of high fuel-economy hybrid vehicles (not significant in low-fuel economy hybrid vehicles)
- Interaction between proxies and dummy variables for the Prius and Insight shows consumers in states with high Sierra Club Membership have an additional preference (idiosyncratic preference) for the Prius relative to other high fuel-economy hybrid vehicles (positive coefficient on Prius, while negative coefficient on Insight).

Conclusion

1. Both the generosity and type of tax incentive affects consumer behavior. The mean sales tax waiver (value $1077) is associated with over three times the increase in sales of the mean income tax credit (value $2011)
2. Inconsistent evidence of consumers respond to single-occupancy HOV access. Only the HOV program offered by Virginia is estimated to be positively correlated with hybrid sales
3. Hybrid vehicle adoption is positively correlated with gasoline prices. Demand for the highest fuel-economy vehicles rises most with gasoline prices.

- Recommendations:
  - ✓ The results encourage policy-makers to carefully consider both the nature of incentives and incentive generosity as well as motivate future research in this area (feebate programs and high fuel-economy vehicles)
  - ✓ The results suggest that state policies can substantially affect hybrid vehicle purchases at the state-level. it is important to consider the larger impacts of state policies on national adoption of hybrid vehicles