Demand for High Fuel Economy Vehicles

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CAFÉ Standards

- Federal fuel economy standards are set to increase dramatically and become binding on manufacturers.
- To begin with we need to know household demand for fuel efficiency.
- “Rebound effect” or the elasticity of miles driven with respect to fuel efficiency (or fuel cost).

NHTS data

- Large representative national sample including inventory of household vehicles and miles driven by each vehicle.
- Previously used for similar modeling (e.g. Bento et. al., 2009 used 2001 NHTS data)
- 2009 data include month of purchase and include about 8000 hybrids (most common are Prius, Civic and Camry)

Data Problems

- NHTS only records vehicle make, year, and model, but that is not sufficient to assign vehicle attributes.

Table 3: Vehicle Specifications for 2009 Civic Hybrids – Ward's Automotive Data

Make & Series	Body Style	Drive Type	Length (ins.)	Width (ins.)	Weight (lbs.)	Horsepower		Trans Std.	MPG City/Hwy	Retail Price
						Hp	@RPM			
Hybrid	4-dr. sedan	FWD	177.3	69.0	2,875	110	6000	CVT	40/45	$24,320
Civic DX	4-dr. sedan	FWD	177.3	69.0	2,630	140	6300	M5	26/34	$16,175
Civic LX	4-dr. sedan	FWD	177.3	69.0	2,687	140	6300	M5	26/34	$18,125
Civic EX	4-dr. sedan	FWD	177.3	69.0	2,747	140	6300	M5	26/34	$19,975

Multiple Imputations

- Previous work typically assigns average values over the possible vehicles. This introduces measurement error and biases inference
- Multiple Imputations randomly chooses a vehicle and assigns it to household, and then repeats this multiple times. Provides consistent inference.

$$\hat{\theta} = \sum_{j=1}^{m} \tilde{\theta}_j / m \qquad \hat{\Sigma} = U + \left(1 + m^{-1}\right) B,$$

where $$B = \sum_{j=1}^{m} \left(\tilde{\theta}_j - \hat{\theta}\right)\left(\tilde{\theta}_j - \hat{\theta}\right)' / (m-1)$$

$$U = \sum_{j=1}^{m} \tilde{\Omega}_j / m.$$

$$\left(\theta - \theta^0\right)' \hat{\Sigma}^{-1} \left(\theta - \theta^0\right) / K$$ is asymptotically distributed $F_{K,\nu}$

$\nu = (m - 1)(1 + r_m^{-1})^2$ and $r_m = (1 + m^{-1})$ Trace$(BU^{-1})/K$

Multiple Imputations Results

- Standard errors calculated ignoring imputation error are downward biased by about 60%
- Multiple Imputation standard errors are large relative to maximum likelihood, but can be easily computed in STATA.

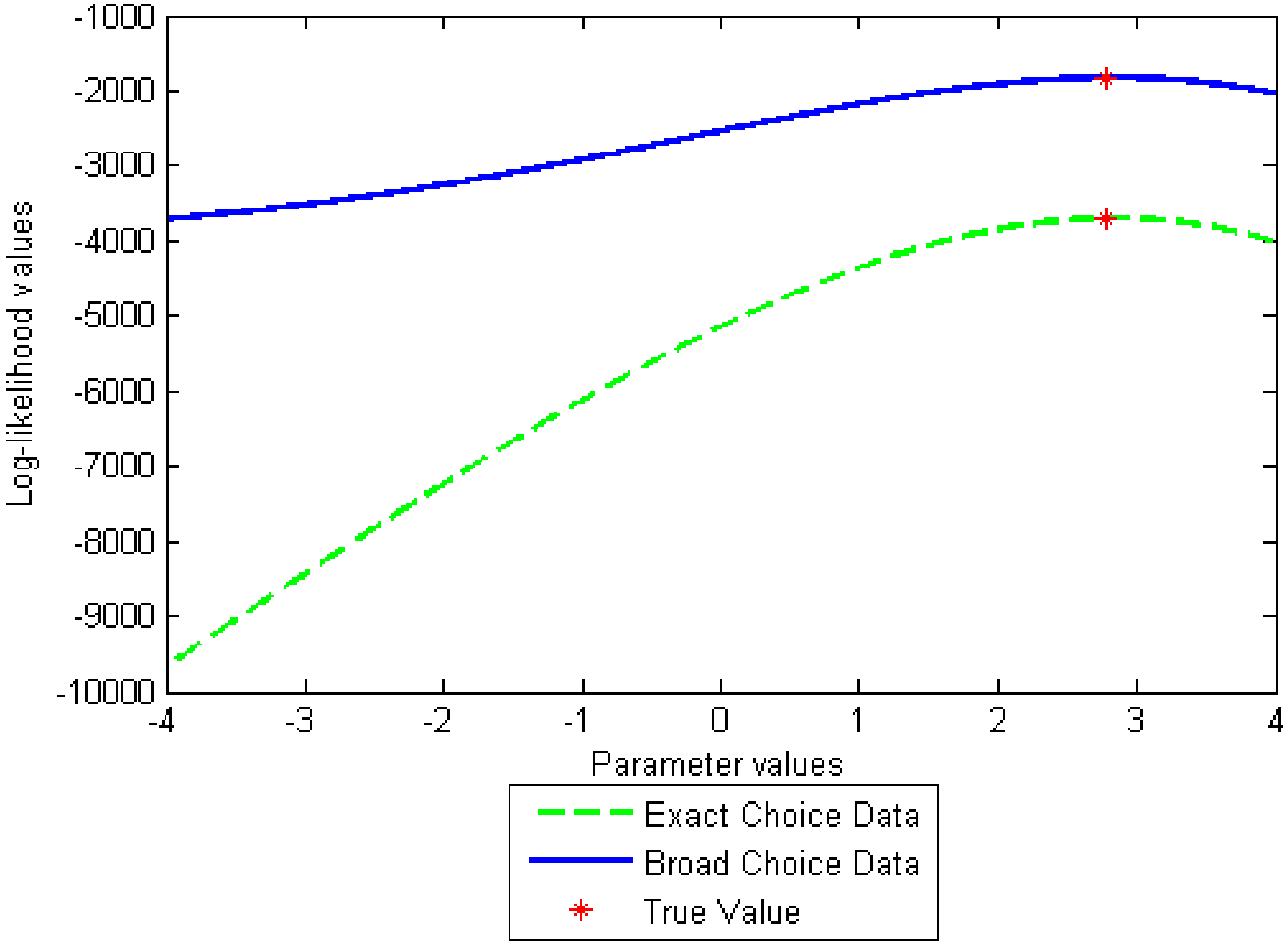
Partial Observability Maximum Likelihood estimation

Efficient alternative to multiple imputations for the case where the household's choice is not fully observed.

We typically only observe that household *i* chooses one from a subset of the alternatives $\left(C_{ik}\right)$. The contribution of observation i to the log likelihood is then given by: $Ln\left(\sum_{j \in C_{ik}} P_{ij}\right)$

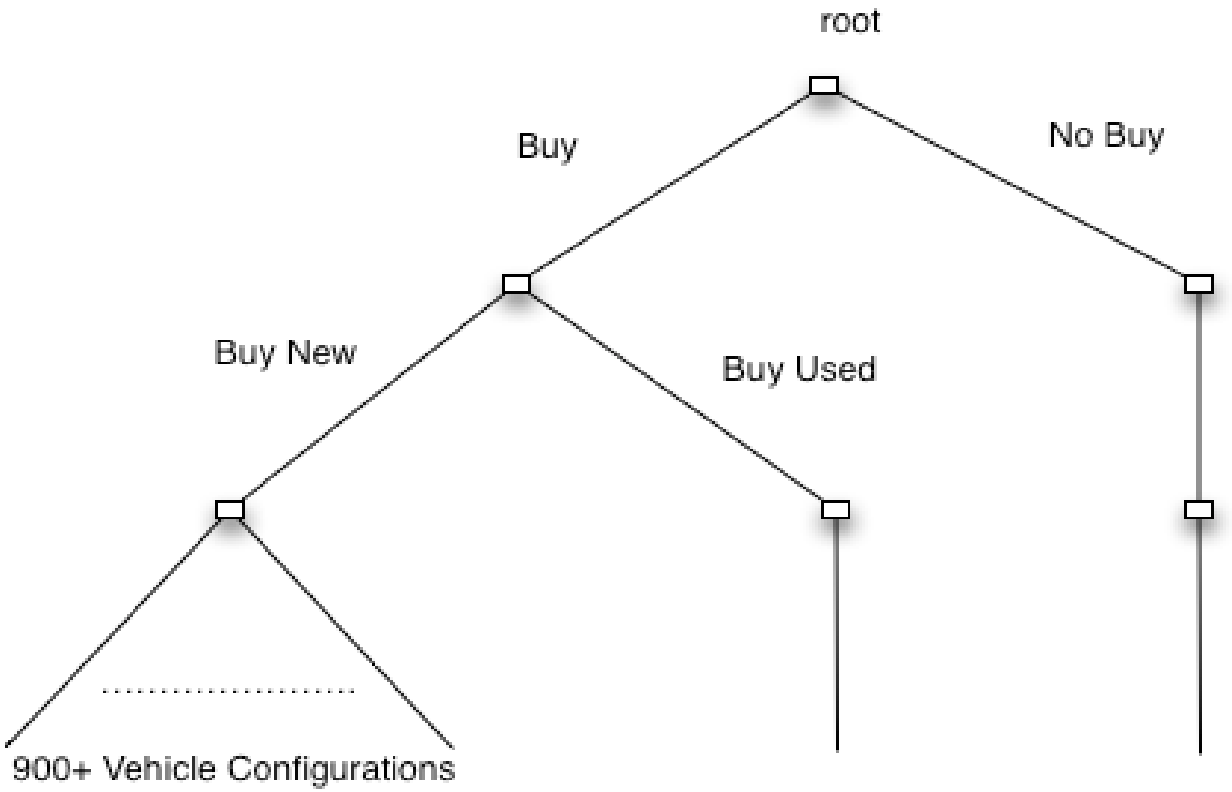
Identification with Partial Observability

- Cannot identify alternative specific constants with partial observability.
- Market share information can be used to identify alternative specific constants (ASC). This requires recovering the ASCs through an auxiliary step using the BLP contraction mapping. A second stage regression is then used to estimate coefficients for variables that only vary across alternatives.


-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
Log-likelihood values
-4
-3
-2
-1
0
1
2
3
4
Parameter values
Exact Choice Data
Broad Choice Data
True Value

Modeling Vehicle Choice

- Model choice of all household vehicles purchased during 2008 model year, including “no buy” option



Data

- All households (more than 100,000) from the 2009 NHTS.
- Detailed description of new 2008 model year vehicles from Volpe Center and DOE (from CAFÉ compliance data)
- Production data and MSRP merged to DOE vehicle descriptions
- Monthly regional gasoline prices from DOE

Vehicle Classification

7 Category Body Type/Size	Frequency	Percent
Standard Small Car	162	17.1
Standard Midsize/Large Car	103	10.9
Prestige Small Car	160	16.9
Prestige M/L Car	94	9.9
Truck	114	12.0
Van	38	4.0
SUV	278	29.3
Total	949	100

Model Attributes

- Demographics: Income, Household size, number of children below 15 years old, rural/urban status, retired status.
- Vehicle attributes: Price, Gallons/100 miles, cost per mile (c/mile) Horsepower/Weight, Curb Weight, Automatic/Manual transmission, Flex/Hybrid, Import (based on manufacturer)

Estimation

- Models estimated using partial observability maximum likelihood with ASCs identified using BLP contraction method.
- Parameters of vehicle attributes recovered using OLS or IV on estimated ASC.
- Not much evidence of price endogeneity using Train and Winston instruments.

MNL Average Own and Cross Elasticities

	SmallCar	MLCar	Prestige SCar	Prestige MLCar	Truck	Van	SUV
SmallCar	-1.16	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
MLCar	0.0025	-1.32	0.0024	0.0025	0.0025	0.0025	0.0025
Prest Scar	0.0004	0.0004	-2.05	0.0004	0.0004	0.0004	0.0004
Prest MLCar	0.0008	0.0008	0.0009	-2.12	0.0008	0.0008	0.0008
Truck	0.0014	0.0014	0.0014	0.0014	-1.28	0.0014	0.0014
Van	0.0018	0.0018	0.0018	0.0018	0.0018	-1.31	0.0018
SUV	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	-1.48

Within-segment elasticities	Ave. Cross elasticities within segment		Distribution of own price elasticities		
			Min	Ave	Max
SmallCar	0.0011		-2.89	-1.16	-0.59
MLCar	0.0022		-2.01	-1.32	-0.90
Prestige Scar	0.0004		-6.10	-2.05	-0.58
Prestige MLCar	0.0010		-6.17	-2.12	-1.28
Truck	0.0014		-1.88	-1.28	-0.84
Van	0.0017		-1.72	-1.31	-0.88
SUV	0.0013		-3.25	-1.48	-0.88

MNL Segment Level Elasticities

	Small Car	MLCar	Prestige Scar	Prestige MLCar	Truck	Van	SUV
SmallCar	-1.19	0.39	0.39	0.39	0.39	0.39	0.39
MLCar	0.68	-1.43	0.68	0.68	0.68	0.68	0.68
Prestige Scar	0.09	0.09	-2.21	0.09	0.09	0.09	0.09
Prestige MLCar	0.07	0.07	0.07	-2.64	0.07	0.07	0.07
Truck	0.19	0.19	0.19	0.19	-2.24	0.19	0.19
Van	0.19	0.19	0.19	0.19	0.19	-2.10	0.19
SUV	0.30	0.30	0.30	0.30	0.30	0.30	-2.05

WTP ($1K) from 2 level NL model

Income Group	Hybrid no College not Japanese	Hybrid no College Japanese	Hybrid College Japanese
<25K	29.2	9.6	1.4
25-75K	55.4	18.2	2.6
75-100K	103.3	33.9	4.9
>100K	229.6	75.4	10.9

Income Group	GalPHmile	Op Cost College	1cPMile No college
<25K	10.3	0.30	36.3
25-75K	19.6	0.56	68.8
75-100K	36.5	1.05	128.3
>100K	81.2	2.33	285.3

Caveats and Problems

- Many uncertainties in matching vehicle prices and attributes
- Price coefficient is very sensitive to changes in model specification
- Data consistency problems (e.g. AWD weights) and inconsistencies across different data sources.

Future Work

- Add data on vehicle attributes and prices for used vehicles purchased during 2008 MY window.
- Use matching and/or control functions to look at rebound effect across all vehicle choices
- Investigate conditioning on other vehicle holdings.

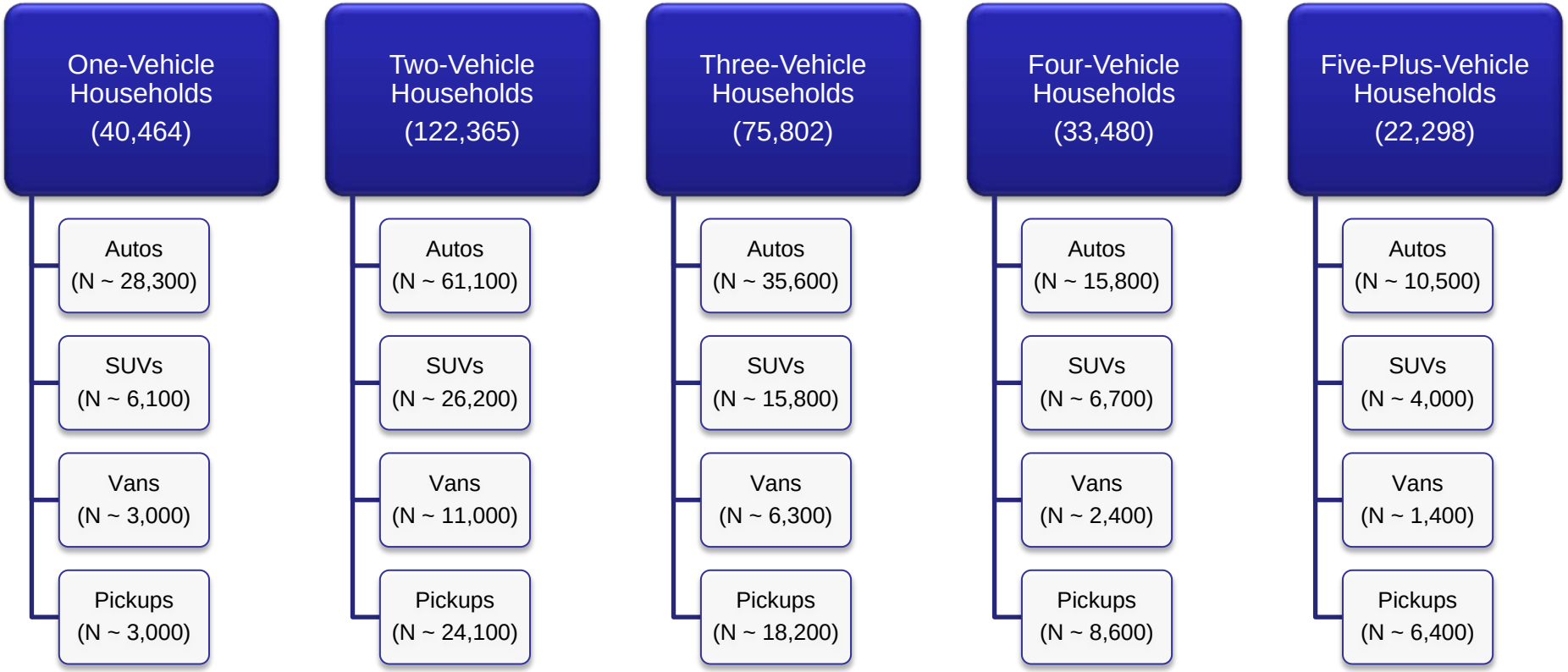
Modeling Choice of New Vehicles in Multi-Vehicle Households

- Model choice of all 2007 MY new vehicles purchased, conditional on holdings of existing vehicles.
- Nested Logit models with small car, large car, SUV, van, and pickup at upper level. Best fit with SUV, van, and pickup nests collapsing to conditional logit.
- Use Lee's generalization of Heckman correction to deal with selection bias in miles equation.

Multiple-Vehicle Households in the 2009 NHTS

Number of Vehicles	Sample Size	Weighted Averages				
		Household Size	# of Drivers	Drivers per Vehicle	Vehicle Age	Percent Rural
1	40,464	1.8	1.2	1.2	8.4	16%
2	122,365	2.8	2.0	1.0	7.8	24%
3	75,802	3.1	2.4	0.8	8.8	33%
4	33,480	3.4	2.8	0.7	9.5	40%
5+	22,298	3.6	3.0	0.6	11.5	48%

Households Vehicles by Number and Type



Role of Multiple-Vehicle Households

Variable	Percent of Total Accounted for by Multiple-Vehicle Households				
	2 Vehicles	3 vehicles	4 vehicles	5+ vehicles	All
U.S. Households	36%	14%	5%	3%	58%
Household Vehicles	39%	23%	11%	10%	83%
Light-Duty Vehicles	35%	21%	10%	8%	74%
Household VMT	42%	23%	11%	7%	83%
Light-Duty VMT	36%	20%	10%	6%	72%
Fuel Consumption	31%	18%	9%	6%	64%
U.S. CO_2 Emissions	9%	5%	3%	2%	19%

NL Model of 2007 New Vehicles for Multi-Vehicle Households (about 2400 households and 200 alternatives)

Variable	Coefficient	Std. Err.	T-stat
price-fedtax ($1000)	-0.0163	0.0045	-3.6
((price-fedtax)/income) *10	-0.0483	0.0141	-3.4
Passenger volume	0.1275	0.0148	8.6
Passenger volume *SUV	-0.2013	0.0219	-9.2
Passenger volume *Van	-0.0631	0.0326	-1.9
payload*Pickup	1.8656	0.4735	3.9
wheelbase	0.0293	0.0030	9.8
length- wheelbase	0.0211	0.0028	7.5
Horsepower/curbweight	0.0307	0.0090	3.4
curbweight (ton)	0.2867	0.1445	2.0
displacement	0.1932	0.0421	4.6
GPM	-0.0553	0.0055	-10.0
GPM*college	-0.0276	0.0043	-6.4
Asia	0.3805	0.0704	5.4
Europe	0.1906	0.1144	1.7

hybrid	-2.1363	0.2755	-7.8
Prius	1.8231	0.1838	9.9
fedtax available	0.3570	0.2042	1.8
State hybrid incentives	-0.2158	0.1570	-1.4
Hybrid*California	0.8652	0.1764	4.9
Luxury brand	-0.6465	0.1119	-5.8
Luxury brand*High income	0.9505	0.1172	8.1
SUV*kids under 16	0.4729	0.0850	5.6
Van*kids under 16	1.3618	0.1498	9.1
hybrid*college	0.2002	0.1688	1.2
Van*vans in household	-0.2900	0.2465	-1.2
SUV*SUVs in household	-0.0976	0.0851	-1.2
pickup*pickups in household	-0.7210	0.1125	-6.4
US*Number of US vehs.	0.4318	0.0446	9.7
asia*Number of Asian vehs.	0.5750	0.0599	9.6
Europe*Number of European vehs.	0.9751	0.1269	7.7
compact*urban	0.3165	0.1577	2.0

NL Choice model notes

- Caveat: based on a single imputation!
- Conditional logit specification rejected vs. Nested Logit.
- WTP for fuel economy increases with income. WTP are all positive but very large for high income college educated households.
- There are strong portfolio effects. Households do not want to hold more than 1 Van or SUV, or pickup trucks.

NL Choice Model Notes 2

- Need to include “luxury” brand indicator to get reasonable price effects.
- Model shows significant “country of brand” loyalty. Both Asian and European brands favored over US.
- Upper level nest constants show large cars and SUV favored over compacts, but Vans and Pickups are disliked.

Prius Effect

- Although hybrids are disliked, the negative effect almost vanishes for Prius. Probably due to fact that Prius ownership signals "green", and therefore Prius brand is highly valuable.
- Federal tax subsidy has positive effect beyond simply reducing price, and Californians dislike hybrids less than the rest of the US.

Model of (Annual miles/total household miles) (2351 observations excluding outliers)

Variable	Coefficient	Std. Err.	T-stat
GPM / GPM for other vehicles	-0.0367	0.0186	-2.0
Avg. vehyear for other vehs	-0.0032	0.0007	-4.4
price / price for other vehs	0.0154	0.0125	1.2
GPM / income	3.0938	5.4039	0.6
hybrid	0.0130	0.0194	0.7
hybrid*compact	-0.0074	0.0511	-0.1
No. of household vehicles	-0.0823	0.0045	-18.3
No. of household drivers	-0.0241	0.0110	-2.2
Midsize car	0.0157	0.0110	1.4
SUV	0.0238	0.0113	2.1
Van	0.0436	0.0179	2.4
Pickup	0.0131	0.0156	0.8
Vans in household	-0.0157	0.0123	-1.3
SUVs in household	-0.0192	0.0085	-2.3
Pickups in household	0.0060	0.0095	0.6
control function	0.0062	0.0153	0.4

Utilization Model Notes

- No significant rebound effect.
- No “sample selection” bias.
- No direct price effect (from GPM)
- Significant relative price effect – less efficient vehicles relative to other vehicles in household are driven less.
- No effects (except for kids and retired) in single vehicle household models.