Factors Affecting Vehicle Use in Multiple-Vehicle Households

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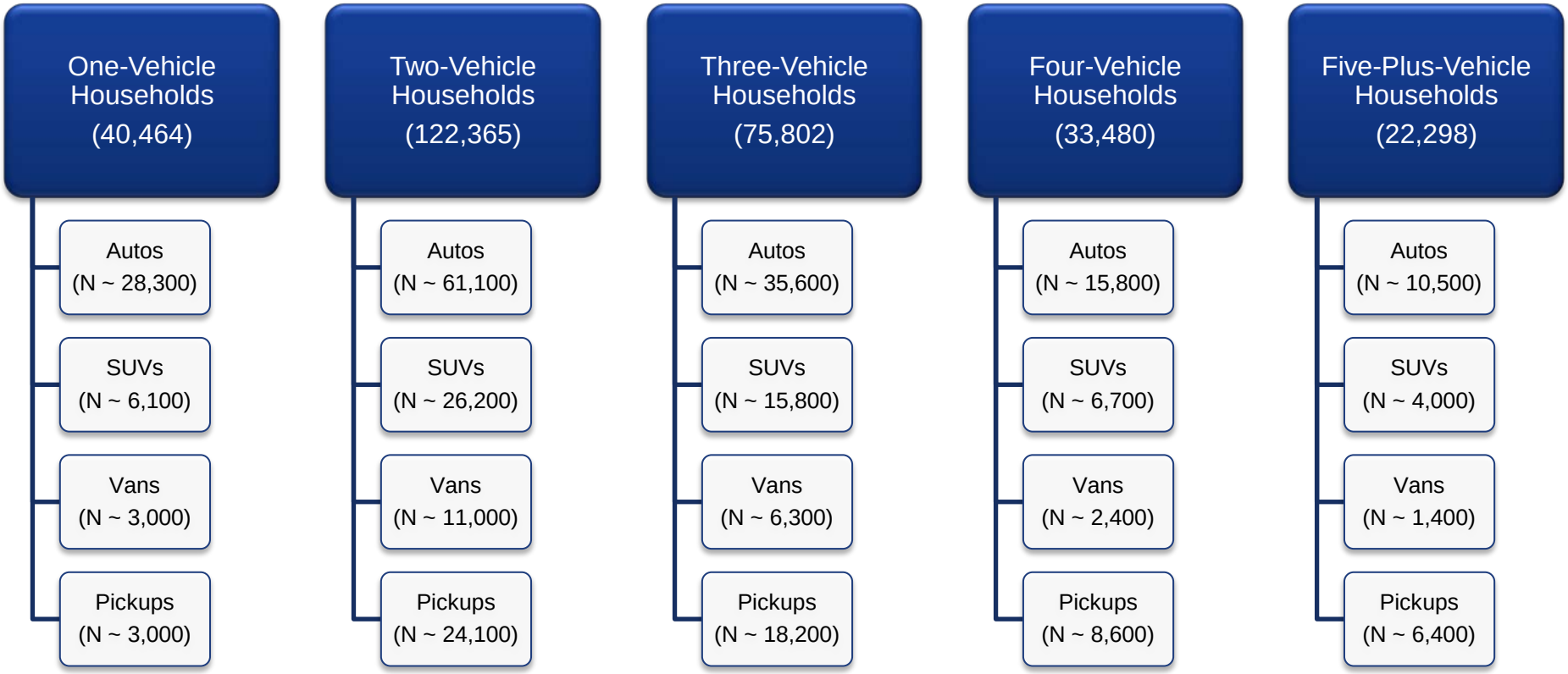
Road Map

- Prevalence of multiple-vehicle households
- “Contributions” to total fleet, vehicle use
- Why and how behavior differs from that of single-vehicle households
- Overview of our analysis
- Useful features of NHTS data
- Econometric complications and fixes
- Highlights of estimation results
- Where we’re headed

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%

Why Do Multiple-Vehicle Households Behave Differently?

- Mix of vehicle types and sizes allows closer matching of vehicle attributes to size and composition of group traveling, purpose and duration of trip, etc.
  - Seating capacity, passenger comfort, occupant protection
  - Luggage-carrying, cargo, and towing capacity
  - Reliability, safety, performance
- Differences in fuel economy provide flexibility in responding to variation in fuel prices
- More vehicles per driver accommodates “competitive scheduling” of household members’ activities and travel

Objectives of Analysis

- Model household and vehicle characteristics affecting ownership and use of individual vehicles
  - Household characteristics: size, income, drivers, location
  - Vehicle attributes: type, age, fuel economy
- Test for differences in factors affecting vehicle use
  - Between single- and multiple-vehicle households
  - Among two-, three-, and four or more-vehicle households
- Utilize information provided by wide variation in vehicle use, including non-use of many vehicles on survey day
- Account for simultaneity among vehicle use, type, and fuel economy in vehicle purchase decisions
- Control for influence of survey-related factors
  - Wide variation in fuel prices over survey period
  - Travel differences between weekdays, weekends

Useful Features of 2009 NHTS Data

- Wide variation in fuel prices throughout survey facilitates isolating effects of fuel prices and fuel economy
- Vehicle type and make/model identifiers provide controls for vehicle attributes
- Vehicle age and ownership duration variables support analysis of factors affecting purchase decisions
- Household location useful in identifying effects of intra-urban and regional differences in travel behavior
- “Flags” help to assess reliability of estimated variables
- Large sample size enables precise estimation of many effects on vehicle use

Estimation Procedure

Create dataset

Merge data from NHTS household, trip, and vehicle files to create a single record for each individual vehicle

Split by household type: one-, two-, three-, four-plus-vehicle households

Designate each vehicle in turn as “primary” in regression

Each vehicle’s survey-day usage appears once as the dependent variable of an observation

Characteristics of other (alternative) household vehicles appear as explanatory variables in that observation

Employ alternative measures of vehicle use

Estimated annual use (BESTMILE)

Daily VMT (sum of survey-day trip distances)

Experiment with alternative MPG measures

EIADMPG is partly constructed from BESTMILE, so simultaneity is “definitional”

EPATMPG is notoriously poor predictor of on-road MPG for *individual* drivers

Alternative approaches to control for vehicle type

Dummy variables assume “fixed effects”: only constant term differs by vehicle type

Stratification allows effects of all explanatory variables to differ by vehicle type

Basic Model Specification

Determinants of Vehicle Use	Alternative Measures of Determinant
Operating cost	Fuel economy (miles per gallon)
	Fuel price ($ per gallon)
	Fuel cost per mile ($ per gallon / miles per gallon)
Vehicle attributes	Vehicle type
	Vehicle age
Household characteristics	Income
	Household size, composition, licensed drivers
	Location (urban, suburban, rural), region
Substitutability of other vehicles	Vehicle type
	Operating cost
	Utilization
Control measures	Day of survey (weekday, weekend)
	Month/season of year

Complications and Fixes

Zero-VMT vehicles:
almost one-third of vehicles not driven on survey day

- Discard zero-VMT vehicles and estimate using OLS
- Use Heckman sample selection model

BESTMILE:
estimation procedures may result in varying reliability

- Use only vehicles with BESTMILE estimated from odometer
- Use all vehicles, check to see how results differ

Endogeneity:
fuel economy may depend on expected vehicle use

- Use Hausman Test for endogeneity of fuel economy
- Use instrumental variable estimation procedures to reduce resulting bias, inconsistency in parameter estimates
  - "Instrument" MPG with household income, fuel prices, etc.
  - Estimate vehicle use and MPG equations jointly using 2SLS
- Particular problem with EIADMPG: construction of variable employs BESTMILE

Model 1: Use Fuel Economy and Price Separately

Variable	Functional Form	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Economy (Primary Vehicle)	Log	0.089	0.101	0.266
		0.039	0.033	0.058
Gas Price	Log	-0.261	-0.350	-0.273
		0.124	0.109	0.191
Vehicle Age	Linear	-0.024	-0.090	-0.092
		0.001	0.001	0.002
Income	Log	0.133	-	-
		0.009	-	-
Vehicles per Driver	Linear	-0.297	-0.161	-0.195
		0.028	0.019	0.027
Urban/Suburban	Dummy	-0.370	-0.260	-0.292
		0.016	0.013	0.022
Weekend	Dummy	-0.079	-0.128	-0.183
		0.015	0.013	0.023
Primary Vehicle Type = Van	Dummy	0.138	0.118	0.073
		0.026	0.022	0.039
Primary Vehicle Type = SUV	Dummy	0.155	0.037	0.095
		0.021	0.018	0.031
Primary Vehicle Type = Pickup	Dummy	0.147	-0.011	0.020
		0.028	0.021	0.036
N		31,217	68,911	23,071
Adjusted R-Squared		0.054	0.090	0.083

Red indicates statistical significance at the 10 percent levell in a two-tailed t-test
Table omits interactions between alternative vehicle type and alternative vehicle fuel economy included in two- and three-vehicle household regressions

Model 2: Use Fuel Cost per Mile (= fuel price/mpg)

Variable	Functional Form	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Cost per Mile	**Log**	**-0.006**	**-0.247**	**-0.335**
		0.020	0.026	0.049
Vehicle Age	**Linear**	**-0.025**	**-0.089**	**-0.091**
		0.001	0.001	0.002
Income	**Log**	**0.131**	**-**	**-**
		0.009	-	-
Vehicles per Driver	**Linear**	**-0.296**	**-0.155**	**-0.186**
		0.028	0.019	0.026
Urban/Suburban	**Dummy**	**-0.372**	**-0.264**	**-0.295**
		0.016	0.013	0.022
Weekend	**Dummy**	**-0.079**	**-0.128**	**-0.183**
		0.015	0.013	0.023
Primary Vehicle Type = Van	**Dummy**	**0.121**	**0.149**	**0.088**
		0.025	0.021	0.039
Primary Vehicle Type = SUV	**Dummy**	**0.134**	**0.082**	**0.117**
		0.019	0.017	0.029
Primary Vehicle Type = Pickup	**Dummy**	**0.120**	**0.046**	**0.049**
		0.026	0.019	0.034
N		**31,218**	**68,912**	**23,072**
Adjusted R-Squared		**0.054**	**0.089**	**0.083**

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Table omits interactions between alternative vehicle type and alternative vehicle fuel economy included in two- and three-vehicle household regressions

Model 3: Include Use of Secondary Vehicles

Variable	Functional Form	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Economy (Primary Vehicle)	Log	0.089	0.127	0.272
		0.039	0.032	0.055
Gas Price	Log	-0.261	-0.184	-0.200
		0.124	0.104	0.181
Vehicle Age	Linear	-0.024	-0.068	-0.068
		0.001	0.001	0.002
Income	Log	0.133	-	-
		0.009	-	-
Vehicles per Driver	Linear	-0.297	-0.380	-0.391
		0.028	0.019	0.025
Urban/Suburban	Dummy	-0.370	-0.247	-0.261
		0.016	0.013	0.021
Weekend	Dummy	-0.079	-0.233	-0.312
		0.015	0.013	0.022
Primary Vehicle Type = Van	Dummy	0.138	0.176	0.151
		0.026	0.021	0.037
Primary Vehicle Type = SUV	Dummy	0.155	0.080	0.120
		0.021	0.017	0.029
Primary Vehicle Type = Pickup	Dummy	0.147	0.000	0.020
		0.028	0.020	0.034
Daily Use (Alternative 1)	Log	-	-0.083	-0.090
		-	0.001	0.002
Daily Use (Alternative 2)	Log	-	-	-0.084
		-	-	0.002
N		31,217	68,910	23,069
Adjusted R-Squared		0.054	0.176	0.180

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Table omits interactions between alternative vehicle type and alternative vehicle fuel economy included in two- and three-vehicle household regressions

Heckman Sample Selection Model

Variable	Functional Form	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Inverse Mills Ratio	Linear	-2.317	-0.784	0.471
		0.119	0.068	0.181
Fuel Economy (Primary Vehicle)	Log	0.036	0.106	0.255
		0.039	0.033	0.058
Gas Price	Log	0.022	-0.476	-0.254
		0.124	0.109	0.192
Vehicle Age	Linear	0.013	-0.062	-0.125
		0.002	0.003	0.013
Income	Log	0.087	-	-
		0.009	-	-
Vehicles per Driver	Linear	-0.255	-0.055	-0.226
		0.028	0.022	0.029
Urban/Suburban	Dummy	-0.377	-0.267	-0.290
		0.016	0.013	0.022
Weekend	Dummy	0.157	-0.046	-0.229
		0.019	0.015	0.029
Primary Vehicle Type = Van	Dummy	0.100	0.064	0.109
		0.026	0.022	0.042
Primary Vehicle Type = SUV	Dummy	0.126	0.028	0.107
		0.021	0.018	0.031
Primary Vehicle Type = Pickup	Dummy	0.280	0.098	-0.039
		0.029	0.023	0.043
N		31,216	68,910	23,070
Adjusted R-Squared		0.066	0.092	0.083

Red indicates statistical significance at the 10 percent levell in a two-tailed t-test
Table omits interactions between alternative vehicle type and alternative vehicle fuel economy included in two- and three-vehicle household regressions
First stage probit model estimates not shown

Highlights of Results

- Effects of fuel economy and price differ from each other, but variation by vehicle ownership is more pronounced
- Fuel economy “rebound effect” is prominent, but may be overstated due to simultaneity between use and MPG
- Main effect of household income on travel demand works through vehicle ownership, not vehicle use
- Association of use with age much stronger in multiple-vehicle households: more old ones, but driven less
- Multiple vehicles in household function as substitutes, not complements
- “Censoring” of vehicle use (large number of zero-VMT vehicles) doesn’t affect estimation results heavily

Frustrations

- Instruments for MPG do not adequately control for simultaneity between vehicle use and fuel economy
- Fuel prices at time of vehicle purchase, CAFE standards, and income *should* work, but don't yield robust results
- One-day survey produces surprisingly large fraction of unused vehicles, complicates identifying factors influencing extent of use
- Lack of fuel purchase data forces reliance on test MPG ratings and (possibly outdated) adjustments, but NHTS is not intended to duplicate RTECS

Next Steps

- Find appropriate instruments for fuel economy; test effect on estimated magnitude of elasticity
- Improve ability of “selection probability” model to predict which vehicles were driven on survey day
- Extend analysis to four-plus vehicle households
- Replicate all results using 2001 NHTS data
- Calculate composite (weighted average) elasticities of vehicle use with respect to fuel price, MPG, etc., for all households

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Stratified Model Results: OLS Model 1

Variable	Functional Form	Passenger Cars			SUVs		
		One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Economy (Primary Vehicle)	Log	0.170	0.190	0.308	0.023	0.046	0.059
		0.046	0.043	0.075	0.097	0.070	0.118
Gas Price	Log	-0.096	-0.421	-0.322	-0.705	-0.173	-0.419
		0.150	0.153	0.274	0.296	0.217	0.378
Vehicle Age	Linear	-0.024	-0.087	-0.094	-0.020	-0.099	-0.101
		0.002	0.002	0.003	0.004	0.003	0.006
Income	Log	0.150	-	-	0.126	-	-
		0.011	-	-	0.022	-	-
Vehicles per Driver	Linear	-0.355	-0.136	-0.127	-0.167	-0.302	-0.296
		0.035	0.027	0.037	0.065	0.045	0.056
Urban/Suburban	Dummy	-0.390	-0.286	-0.304	-0.329	-0.236	-0.265
		0.021	0.020	0.033	0.037	0.026	0.044
Weekend	Dummy	-0.078	-0.104	-0.236	-0.091	-0.156	-0.160
		0.018	0.019	0.034	0.037	0.026	0.045
N		20,772	34,172	11,084	5,480	16,594	5,750
Adjusted R-Squared		0.054	0.094	0.092	0.033	0.075	0.075

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Table omits interactions between alternative vehicle type and alternative vehicle fuel economy included in two- and three-vehicle household regressions

Stratified Model Results: OLS Model 2

Variable	Functional Form	Passenger Cars			SUVs		
		One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Cost per Mile	**Log**	**0.004**	**-0.312**	**-0.309**	**-0.081**	**-0.170**	**-0.274**
		0.024	0.036	0.066	0.049	0.055	0.097
Vehicle Age	**Linear**	**-0.025**	**-0.086**	**-0.094**	**-0.019**	**-0.097**	**-0.098**
		0.002	0.002	0.003	0.004	0.003	0.006
Income	**Log**	**0.148**	**-**	**-**	**0.127**	**-**	**-**
		0.011	-	-	0.022	-	-
Vehicles per Driver	**Linear**	**-0.353**	**-0.128**	**-0.126**	**-0.167**	**-0.300**	**-0.272**
		0.035	0.027	0.037	0.065	0.045	0.055
Urban/Suburban	**Dummy**	**-0.389**	**-0.292**	**-0.306**	**-0.336**	**-0.236**	**-0.271**
		0.021	0.020	0.033	0.037	0.026	0.043
Weekend	**Dummy**	**-0.078**	**-0.102**	**-0.237**	**-0.090**	**-0.158**	**-0.160**
		0.018	0.019	0.034	0.037	0.026	0.045
N		**20,773**	**34,173**	**11,085**	**5,481**	**16,595**	**5,751**
Adjusted R-Squared		**0.054**	**0.093**	**0.092**	**0.032**	**0.074**	**0.074**

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Stratified Model Results: OLS Model 3

Variable	Functional Form	Passenger Cars			SUVs		
		One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs	One-Vehicle HHs	Two-Vehicle HHs	Three-Vehicle HHs
Fuel Economy (Primary Vehicle)	Log	0.170	0.260	0.341	0.023	-0.047	0.054
		0.046	0.041	0.071	0.097	0.067	0.111
Gas Price	Log	-0.096	-0.163	-0.188	-0.705	-0.128	-0.415
		0.150	0.146	0.259	0.296	0.206	0.356
Vehicle Age	Linear	-0.024	-0.065	-0.069	-0.020	-0.078	-0.078
		0.002	0.002	0.003	0.004	0.003	0.006
Income	Log	0.150	-	-	0.126	-	-
		0.011	-	-	0.022	-	-
Vehicles per Driver	Linear	-0.355	-0.350	-0.321	-0.167	-0.505	-0.478
		0.035	0.026	0.036	0.065	0.044	0.053
Urban/Suburban	Dummy	-0.390	-0.274	-0.277	-0.329	-0.227	-0.236
		0.021	0.019	0.031	0.037	0.025	0.041
Weekend	Dummy	-0.091	-0.266	-0.297	-0.091	-0.266	-0.297
		0.037	0.025	0.043	0.037	0.025	0.043
Daily Use (VMT of Alternative 1)	Log	-	-0.081	-0.088	-	-0.081	-0.088
		-	0.002	0.004	-	0.002	0.004
Daily Use (VMT of Alternative 2)	Log	-	-	-0.084	-	-	-0.084
		-	-	0.004	-	-	0.004
N		20,772	34,171	11,082	5,480	16,593	5,748
Adjusted R-Squared		0.054	0.179	0.188	0.033	0.162	0.176

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Heckman Stage 1 Probit Model Variables

- Gas price (PADD 12 month trailing average)
- Vehicle age
- Household size
- Number of workers in household
- Weekend (dummy)
- Seasonal controls (dummies for spring and summer)
- Vehicle type (dummies for SUV, van, pickup)