Do U.S. Households Favor High Fuel Economy Vehicles When Gasoline Prices Increase?

A Discrete Choice Analysis

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Overview

- A simple question :
- Do U.S. households favor high fuel economy vehicles when gasoline prices increase?
  - Do households reduce fuel use proportionally more than vehicle travel in response to a fuel price increase?
  - Do two-vehicle households use their higher fuel economy vehicle more when fuel prices increase?
    - On a total travel basis?
    - On a per-trip basis?

Setup – Empirical strategy

- A natural experiment – gasoline price fluctuations 2008-2009
- Focus on short-run response – observe monthly cross-sections
- Focus on **price-per-mile savings** from switching – depends on gasoline price and fuel economy of vehicles owned
- **Estimation strategy (3 parts):**
  - **1) Elasticities** of fuel use and vehicle-miles traveled (VMT) with respect to fuel price

    (log-log robust ordinary least squares)
  - **2) Switching overall** – Effect of **price-per-mile savings** on **fraction of miles driven in more efficient vehicle**

    (generalized linear model with logit link)
  - **3) Switching by trip** – Effect of **price-per-mile savings** on **probability of choosing the more efficient vehicle** by trip

    (conditional logit model)
- Alternative model specifications – include or condition on household, vehicle, or trip characteristics

Setup – Data Set

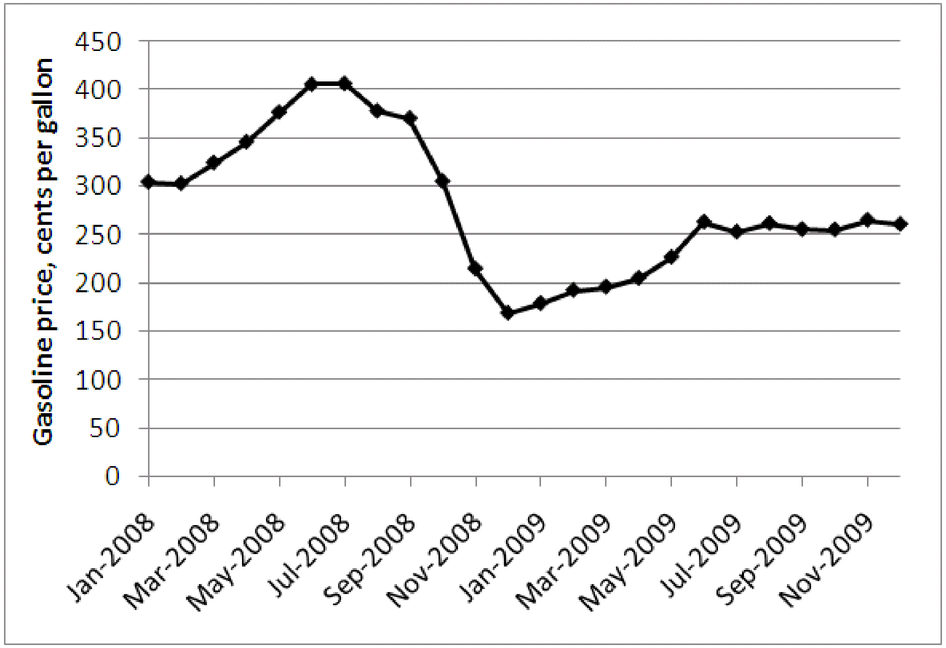
2009 U.S. National Household Transportation Survey :

- Monthly repeated cross-sections of U.S. households
- Household characteristics
- Vehicle ownership and vehicle attributes
- Travel in each vehicle on “travel day”

Supplemented with :

- City and highway fuel economy (Ward’s vehicle attribute data, 2008)
- Fuel price data (by U.S. state including taxes – NHTSA and EIA)

U.S. average gasoline price over survey period



$$\text{ppmile}_{Vi,\ HH} = (\$/\text{gal}) \ / \ (\text{mi/gal})$$

$$\text{ppmile}_{savings,\ HH} = \text{ppmile}_{V1} - \text{ppmile}_{V2}$$

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Result #1: Elasticities – Households reduce fuel use more than VMT in response to gasoline price increases

Table 2 Aggregate gasoline price elasticity of demand for VMT and gasoline. Log indicates natural log. (* p<0.05 ** p<0.01 *** p<0.001)

	Log VMT	Log Gasoline Use
Log gasoline price	-0.112***	-0.144***
	(-3.74)	(-4.88)
Fall	0.0491**	0.0681***
	(2.89)	(4.08)
Household size	0.251***	0.259***
	(63.87)	(67.05)
Weekday	-0.0942***	-0.0895***
	(-9.73)	(-9.41)
Constant	0.107	-2.645***
	(1.22)	(-30.56)
N	73321	73321

Elasticities with respect to fuel price:

Vehicle-miles	-0.112
Gasoline use	-0.144

Estimated elasticities increase (in magnitude) with income, decrease with degree of urbanization, and increase with the number of vehicles owned.

Result #2: Switching by total distance – Households (modestly) increase use of high efficiency vehicles

savings	Marginal effect (*milfrac*|*savings*)	
(cents per mile)	Estimate	S.E.
0	0.013734	0.001262
2.5	0.013764	0.001278
5	0.013665	0.001259
7	0.01344	0.001205
10	0.013099	0.00112
15	0.012117	0.00088
20	0.010843	0.000589

Table 6 (b) Effect of per mile cost savings on switching behavior in aggregate sample with predictive margins and marginal effects for the GLM model. (abridged) S.E. – standard errors

Every one-cent increase in price-per-mile savings leads to an increase in the fraction of miles traveled in the more efficient vehicle of 0.014.

milfrac – fraction of miles driven in higher fuel economy vehicle

Switching varies strongly by income level

Table 7 Predictive margins and marginal effects of per mile savings on fraction of miles traveled in the higher efficiency vehicle, by income category. (evaluated at 5 cents per mile, abridged)

Income category	Marginal effect	
	(*milfrac*|*savings*)	**S.E.**
< US $25,000	0.0236	0.0047
US $25,000 - $60,000	0.0216	0.0022
US $60,000 - $100,000	0.0101	0.0023
> US $100,000	0.0062	0.0022

The effect of price-per-mile savings on switching decreases as income increases.

Result #3: Switching by trip – the probability of high efficiency vehicle use increases with price per mile

Table 9 Effect of price per mile savings on the choice of a high efficiency vehicle by trip for the aggregate sample.

	(1)	(2)	(3)	(4)
Per mile savings	0.0280***	0.0285***	0.0284***	0.0286***
	(9.88)	(10.06)	(10.02)	(10.08)
Household size		-0.0769***	-0.0711***	-0.0703***
		(-11.24)	(-10.10)	(-9.97)
Average passengers			-0.0735***	-0.0962***
			(-3.52)	(-4.20)
Trip distance				[illegible]

Table 10 Routine daily trips showed highest probability of switching, while effect for vacation trips and work not significant.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	To / From Work	**Work-related business**	**Shopping**	**Other family / personal business**	**School / church**	**Medical / dental**	**Vacation**	**Visit friends / relatives**	**Other social / recreation**
Per mile savings	0.0330***	0.0220	0.0366***	0.0306***	0.0332***	0.0471***	-0.0206	0.0424***	0.0344***
	(6.21)	(1.73)	(8.50)	(6.46)	(4.29)	(4.59)	(-1.07)	(4.98)	(7.50)

Conclusions

Elasticities (1)

- In the short run households reduce fuel use more than they reduce VMT – elasticities vary with income, urbanization, vehicle ownership

Vehicle switching (2 & 3)

- Switching occurs on both **total distance** and **per trip** basis – but modest! (On average households realize only 5% of available savings, and switching nationwide corresponds to a less than 1% reduction in gasoline use in response to $2/gal gasoline price increase.)
- Reduced switching at higher income levels → consistent with share of fuel cost in total household expenditures declining with income

Implications and future work

- Implications
  - Energy / GHG policy impact – need to consider vehicle *usage* as well as vehicle *purchase* response and how it will differ across households
  - Role of income – as incomes rise, importance of switching response may diminish
  - Impact of switching is small – but could still affect results if omitted from highly aggregated energy-economic models used in policy analysis
- Future work
  - Non-linear switching behavior (e.g. price thresholds – $4/gal?)
  - Alternative fuel vehicles as part of household fleets

Thank you!

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Elasticities conditional on income

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	< $25,000/yr		$25,000-$60,000/yr		$60,000-$100,000/yr		>$100,000/yr	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	0.00436	-0.0354	-0.141**	-0.170***	-0.0993	-0.119*	-0.133*	-0.178**
	(0.05)	(-0.38)	(-2.76)	(-3.38)	(-1.76)	(-2.15)	(-2.33)	(-3.18)
Spring	0.108	0.131	0.0912*	0.126**	0.109*	0.133**	0.139**	0.172***
	(1.33)	(1.63)	(2.05)	(2.86)	(2.22)	(2.75)	(2.86)	(3.62)
Summer	0.0000312	0.0300	0.140**	0.159***	0.157**	0.173***	0.156**	0.185***
	(0.00)	(0.37)	(3.14)	(3.62)	(3.24)	(3.62)	(3.19)	(3.84)
Fall	-0.0340	-0.00789	0.0559	0.0733*	0.0358	0.0533	0.0895**	0.109***
	(-0.63)	(-0.15)	(1.91)	(2.54)	(1.13)	(1.73)	(2.79)	(3.47)
Household size	0.271***	0.276***	0.271***	0.279***	0.243***	0.252***	0.222***	0.234***
	(21.58)	(22.15)	(37.37)	(39.17)	(34.76)	(36.32)	(32.54)	(35.22)
Weekday	-0.0726*	-0.0682*	-0.0738***	-0.0686***	-0.0720***	-0.0682***	-0.150***	-0.145***
	(-2.47)	(-2.34)	(-4.45)	(-4.20)	(-3.91)	(-3.76)	(-8.15)	(-8.05)
Constant	3.044***	0.157*	3.447***	0.534***	3.654***	0.722***	3.892***	0.966***
	(45.41)	(2.38)	(91.49)	(14.37)	(87.27)	(17.47)	(92.51)	(23.47)
N	11709	11709	26697	26697	18395	18395	16520	16520

Elasticities conditional on urbanization

	(1)	(2)	(3)	(4)	(5)	(6)
	Urban		Semi-urban		Rural	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	-0.0916**	-0.130***	-0.0931	-0.106	-0.0642	-0.0781
	(-2.70)	(-3.89)	(-0.71)	(-0.83)	(-0.97)	(-1.21)
Log household income	0.357***	0.344***	0.337***	0.322***	0.259***	0.235***
	(38.00)	(37.05)	(10.12)	(9.91)	(15.47)	(14.18)
Spring	0.0775**	0.110***	0.0641	0.0676	0.0922	0.116*
	(2.63)	(3.81)	(0.57)	(0.62)	(1.65)	(2.13)
Summer	0.110***	0.136***	0.101	0.105	0.0880	0.0986
	(3.75)	(4.71)	(0.89)	(0.95)	(1.55)	(1.77)
Fall	0.0423*	0.0650***	0.0543	0.0601	0.0259	0.0351
	(2.22)	(3.47)	(0.71)	(0.80)	(0.68)	(0.93)
Household size	0.252***	0.263***	0.256***	0.253***	0.243***	0.245***
	(56.69)	(60.04)	(14.58)	(14.73)	(28.87)	(29.31)
Weekday	-0.0952***	-0.0879***	-0.105*	-0.107**	-0.0825***	-0.0860***
	(-8.66)	(-8.12)	(-2.52)	(-2.64)	(-3.88)	(-4.14)
Constant	-0.451***	-3.230***	-0.110	-2.831***	1.088***	-1.562***
	(-4.44)	(-32.16)	(-0.30)	(-7.88)	(5.97)	(-8.66)
N	53628	53628	4833	4833	14859	14859

Elasticities conditional on household vehicle ownership

	(1)	(2)	(3)	(4)	(5)	(6)
	One-vehicle households		Two-vehicle households		Three-vehicle households	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	-0.154*	-0.181**	-0.0865*	-0.115**	-0.192**	-0.230***
	(-2.35)	(-2.77)	(-2.05)	(-2.75)	(-2.89)	(-3.56)
Log household income	0.157***	0.135***	0.212***	0.192***	0.211***	0.191***
	(10.56)	(9.20)	(16.42)	(15.08)	(10.53)	(9.56)
Spring	0.157**	0.189***	0.100**	0.125***	0.129*	0.165**
	(2.78)	(3.37)	(2.72)	(3.44)	(2.28)	(3.00)
Summer	0.162**	0.184**	0.115**	0.126***	0.185**	0.224***
	(2.84)	(3.25)	(3.14)	(3.47)	(3.28)	(4.06)
Fall	0.0894*	0.111**	0.0537*	0.0679**	0.0789*	0.0999**
	(2.39)	(3.00)	(2.22)	(2.84)	(2.12)	(2.75)
Household size	0.255***	0.270***	0.196***	0.207***	0.181***	0.186***
	(21.26)	(23.01)	(31.41)	(33.44)	(22.27)	(22.97)
Weekday	-0.0325	-0.0295	-0.0932***	-0.0876***	-0.120***	-0.114***
	(-1.54)	(-1.41)	(-6.68)	(-6.38)	(-5.95)	(-5.76)
Constant	1.433***	-1.281***	1.385***	-1.310***	1.705***	-0.975***
	(8.87)	(-8.03)	(9.77)	(-9.37)	(7.63)	(-4.40)
N	19949	19949	32778	32778	13701	13701

Switching, by trip purpose

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	To / From Work	**Work-related business**	**Shopping**	**Other family / personal business**	**School / church**	**Medical / dental**	**Vacation**	**Visit friends / relatives**	**Other social / recreation**
Per mile savings	0.0330***	0.0220	0.0366***	0.0306***	0.0332***	0.0471***	-0.0206	0.0424***	0.0344***
	(6.21)	(1.73)	(8.50)	(6.46)	(4.29)	(4.59)	(-1.07)	(4.98)	(7.50)
Household size	0.0155	0.0808**	-0.103***	-0.0942***	-0.175***	-0.114***	-0.170**	-0.160***	-0.110***
	(1.20)	(2.62)	(-9.15)	(-8.46)	(-10.17)	(-4.12)	(-3.27)	(-7.49)	(-9.24)
Average passengers	-0.00573	0.0299	-0.0829**	-0.0933**	-0.0334	-0.0740	-0.0710	-0.0614	-0.109**
	(-0.10)	(0.32)	(-2.61)	(-2.61)	(-0.56)	(-0.82)	(-0.87)	(-1.19)	(-3.28)
Trip distance (miles)	0.00151***	0.000697	0.0000884	0.000367	-0.0000493	0.00158**	-0.000158	0.000376	0.000191
	(4.36)	(1.49)	(0.67)	(1.94)	(-0.14)	(2.97)	(-0.81)	(1.85)	(1.37)
Constant	-0.0934	-0.391*	0.415***	0.447***	0.667***	0.406**	0.652***	0.539***	0.526***
	(-0.90)	(-2.07)	(7.21)	(6.87)	(6.15)	(2.59)	(3.34)	(5.50)	(8.63)
N	19077	3218	27929	23774	9099	5055	1302	7535	24060

Elasticities depend on household characteristics

Income

Table 3	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	< $25,000/yr		$25,000-$60,000/yr		$60,000-$100,000/yr		>$100,000/yr	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	0.00436	-0.0354	-0.141**	-0.170***	-0.0993	-0.119*	-0.133*	-0.178**
	(0.05)	(-0.38)	(-2.76)	(-3.38)	(-1.76)	(-2.15)	(-2.33)	(-3.18)

Urbanization

Table 4	(1)	(2)	(3)	(4)	(5)	(6)
	Urban		Semi-urban		Rural	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	-0.0916**	-0.130***	-0.0931	-0.106	-0.0642	-0.0781
	(-2.70)	(-3.89)	(-0.71)	(-0.83)	(-0.97)	(-1.21)

Number of vehicles owned

Table 5	(1)	(2)	(3)	(4)	(5)	(6)
	One-vehicle households		Two-vehicle households		Three-vehicle households	
	VMT	Gasoline	VMT	Gasoline	VMT	Gasoline
Log gasoline price	-0.154*	-0.181**	-0.0865*	-0.115**	-0.192**	-0.230***
	(-2.35)	(-2.77)	(-2.05)	(-2.75)	(-2.89)	(-3.56)

Result #2: Households (modestly) increase use of high efficiency vehicles when per-mile savings increase

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Per mile savings	0.0540***	0.0517***	0.0541***	0.0562***	0.0556***	0.0556***	0.0136***
	(11.68)	(10.83)	(10.52)	(10.94)	(10.77)	(10.78)	(11.00)
Log of household income		-0.176***	-0.177***	-0.142***	-0.151***	-0.151***	-0.0371***
		(-6.57)	(-6.58)	(-5.20)	(-5.53)	(-5.53)	(-5.58)
Seasonal dummies omitted due to space							
Household size				-0.104***	-0.0488***	-0.0482***	-0.0119***
				(-8.84)	(-3.69)	(-3.64)	(-3.66)
Average passengers per vehicle					-0.140***	-0.141***	-0.0347***
					(-7.00)	(-7.06)	(-7.17)
Weekday						-0.0251	-0.00611
						(-0.84)	(-0.83)
Constant	-0.0954***	1.857***	1.870***	1.784***	1.992***	2.012***	0.994***
	(-4.69)	(6.22)	(6.24)	(5.95)	(6.60)	(6.66)	(13.55)
N	17965	16766	16766	16766	16766	16766	16766

Predicted *milfrac* and marginal effects

savings	**Predicted *milfrac***		**Marginal effect (*milfrac*|*savings*)**	
(cents per mile)	**Estimate**	**S.E.**	**Estimate**	**S.E.**
0	0.474555	0.005482	0.013734	0.001262
2.5	0.508954	0.003452	0.013764	0.001278
5	0.543266	0.003718	0.013665	0.001259
7	0.577173	0.0059	0.01344	0.001205
10	0.61037	0.008479	0.013099	0.00112
15	0.673561	0.013241	0.012117	0.00088
20	0.731053	0.016796	0.010843	0.000589

Switching varies strongly by income level

	Marginal effect	
Income <$25,000		
Per mile savings (cents)	**(*milfrac*|*savings*)**	**S.E.**
0	0.0245	0.0049
2.5	0.0244	0.0050
5	0.0236	0.0047
7	0.0222	0.0040
10	0.0203	0.0031
15	0.0158	0.0012
20	0.0114	0.0006
Income $25,000 - $60,000		
Per mile savings (cents)	**(*milfrac*|*savings*)**	**S.E.**
0	0.0221	0.0023
2.5	0.0221	0.0023
5	0.0216	0.0022
7	0.0206	0.0020
10	0.0192	0.0016
15	0.0157	0.0008
20	0.0120	0.0002

	Marginal effect	
Income $60,000 - $100,000		
Per mile savings (cents)	**(*milfrac*|*savings*)**	**S.E.**
0	0.0102	0.0023
2.5	0.0102	0.0023
5	0.0101	0.0023
7	0.0101	0.0023
10	0.0099	0.0022
15	0.0095	0.0019
20	0.0089	0.0016
Income >$100,000		
Per mile savings (cents)	**(*milfrac*|*savings*)**	**S.E.**
0	0.0062	0.0022
2.5	0.0062	0.0022
5	0.0062	0.0022
7	0.0062	0.0022
10	0.0062	0.0022
15	0.0061	0.0021
20	0.0060	0.0020

Structural equations

- Elasticities (1)

Gasoline use

$$\ln G_i = \beta_0 + \beta_1 \ln P_i + \beta_2 \ln Y_i + \gamma(Z_i) + s_i + \varepsilon_i$$

Vehicle-miles traveled

$$\ln VMT_i = \beta_0 + \beta_1 \ln P_i + \beta_2 \ln Y_i + \gamma(Z_i) + s_i + \varepsilon_i$$

- Effect of price per mile savings on switching (2)

$$E(y_i|x_i) = G(X_i\beta), 0 \le G(z) \le 1 \; \forall z \in R$$

$$milfrac_i(0 < y < 1) = G(\beta_0 + \beta_1(savings_i) + \beta X_i + \epsilon_i)$$

$$G(u) = \ln\left(\frac{u}{1-u}\right)$$

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