Gasoline Prices and the Demand for Fuel Efficiency: Evidence from Monthly New Vehicles Sales Data

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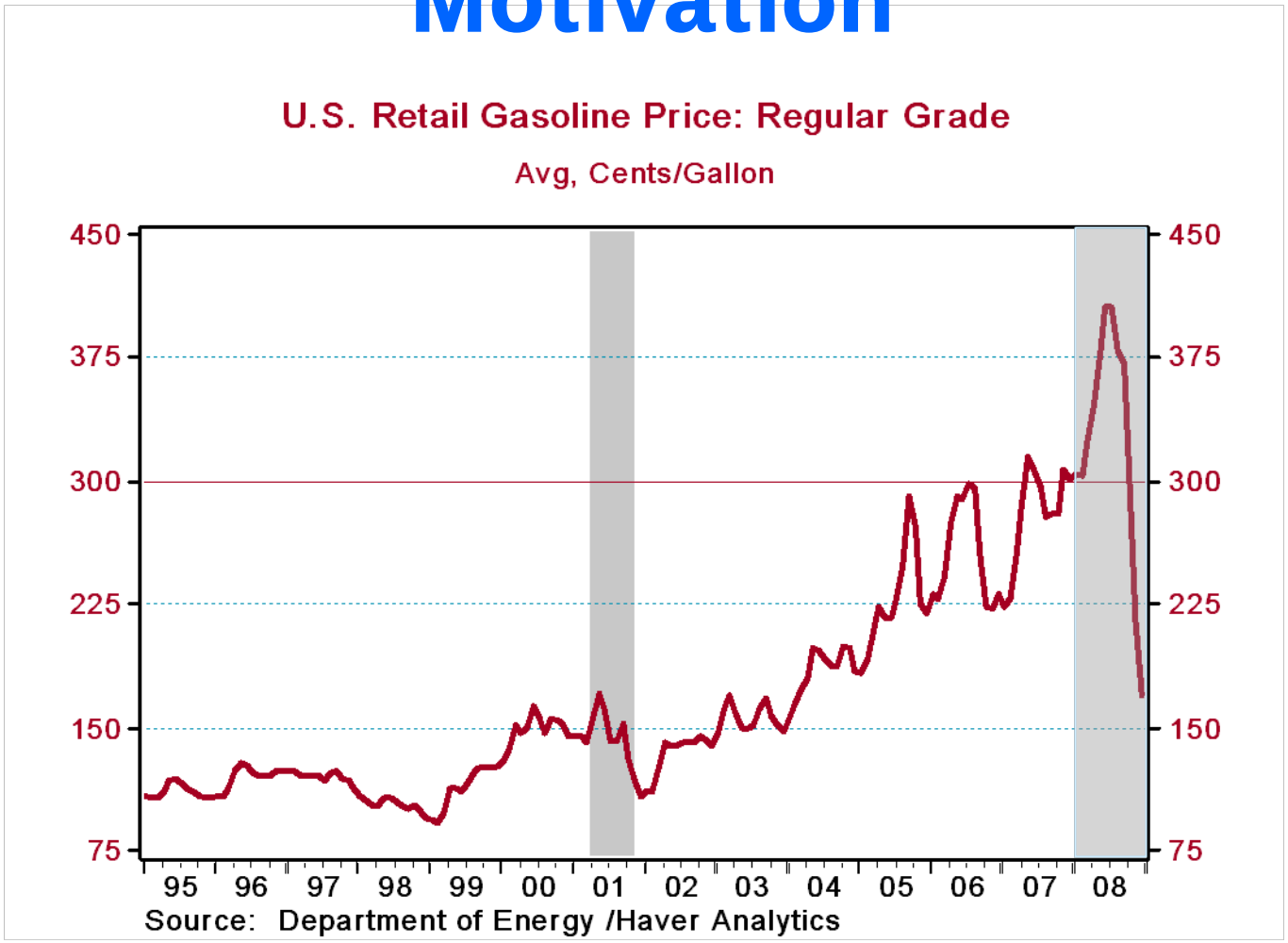
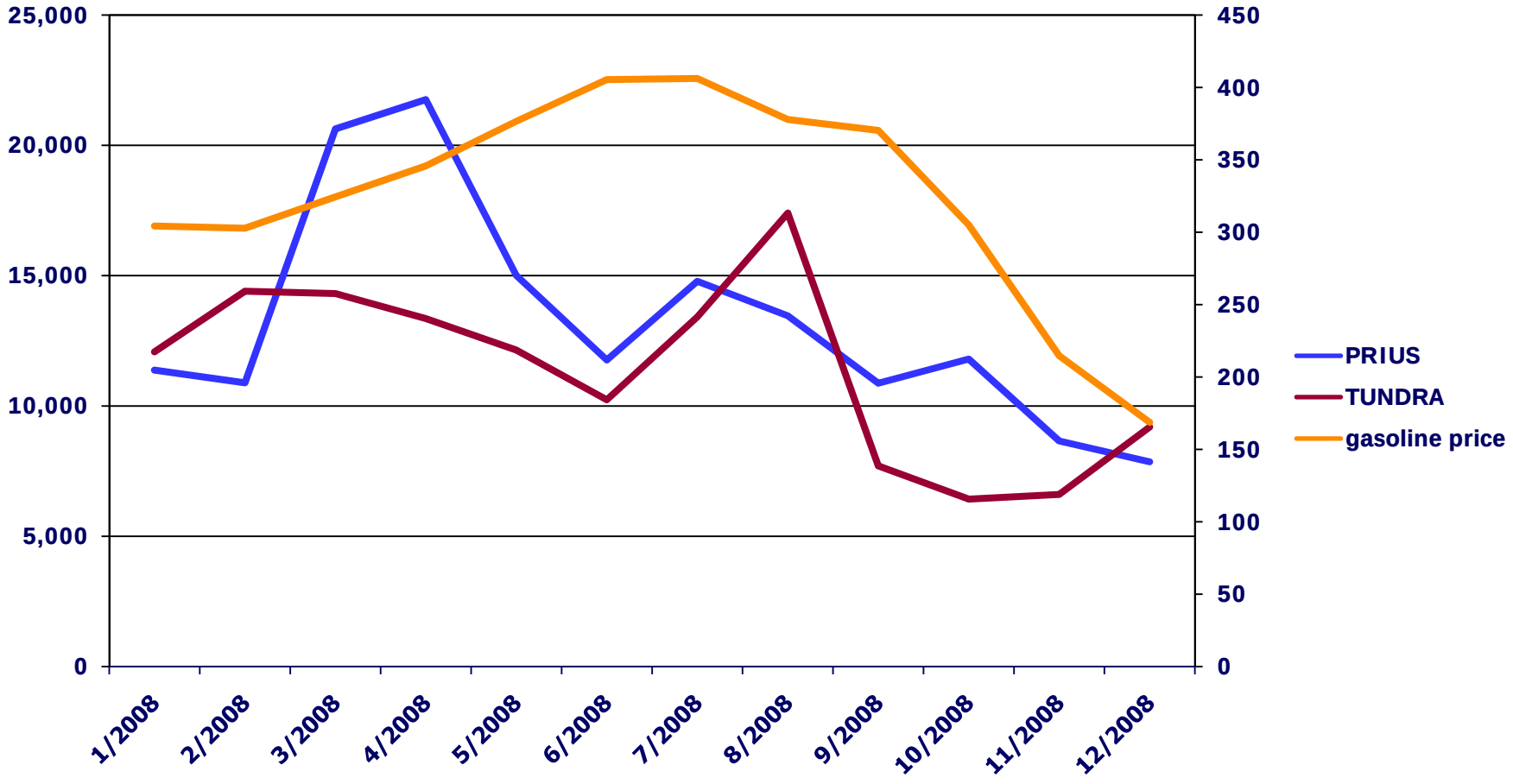
Motivation


U.S. Retail Gasoline Price: Regular Grade
Avg, Cents/Gallon
450
375
300
225
150
75
95
96
97
98
99
00
01
02
03
04
05
06
07
08
Source: Department of Energy /Haver Analytics

Price of gasoline influences sales mix



...and the fleet MPG (here for cars)

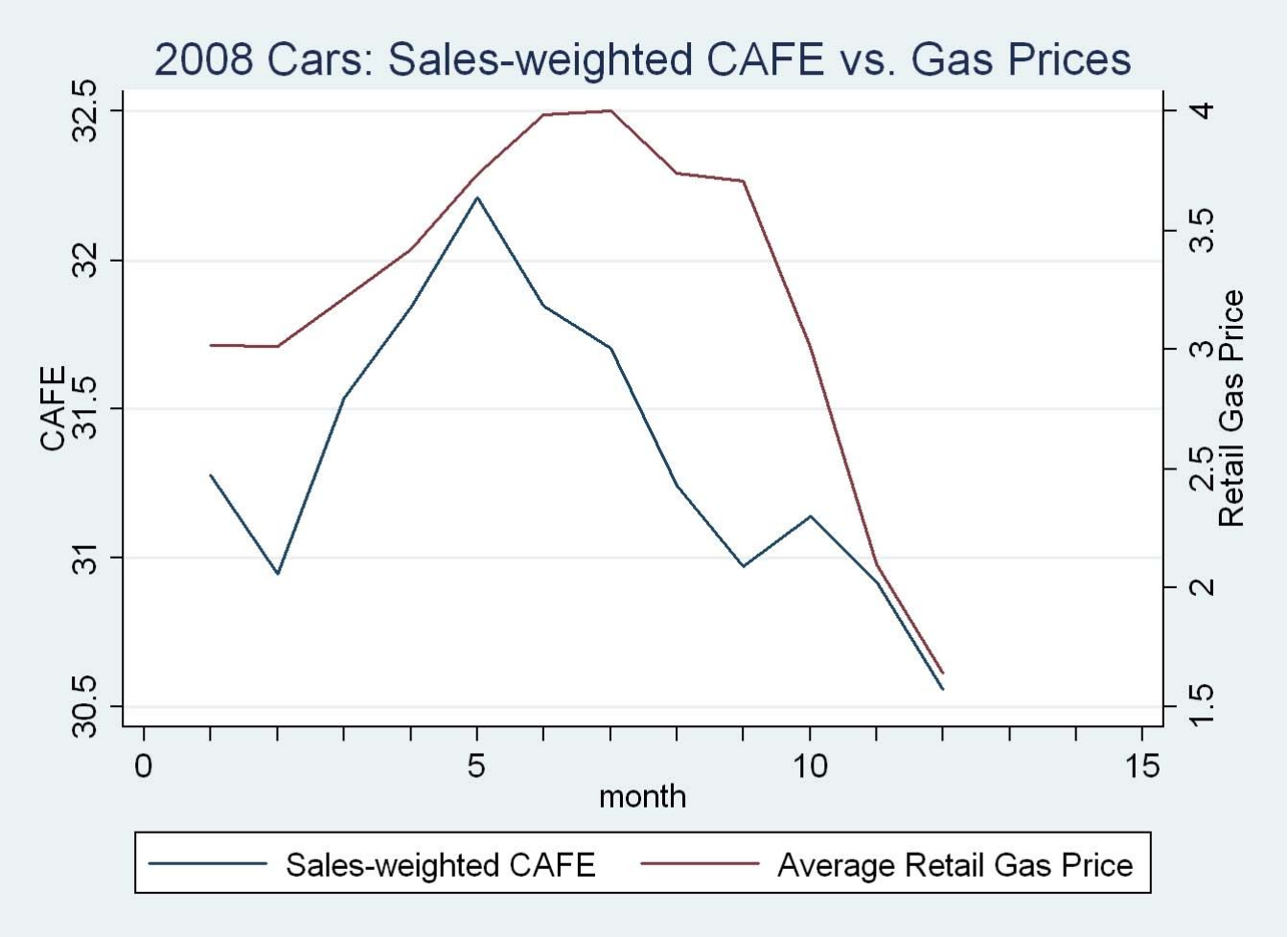
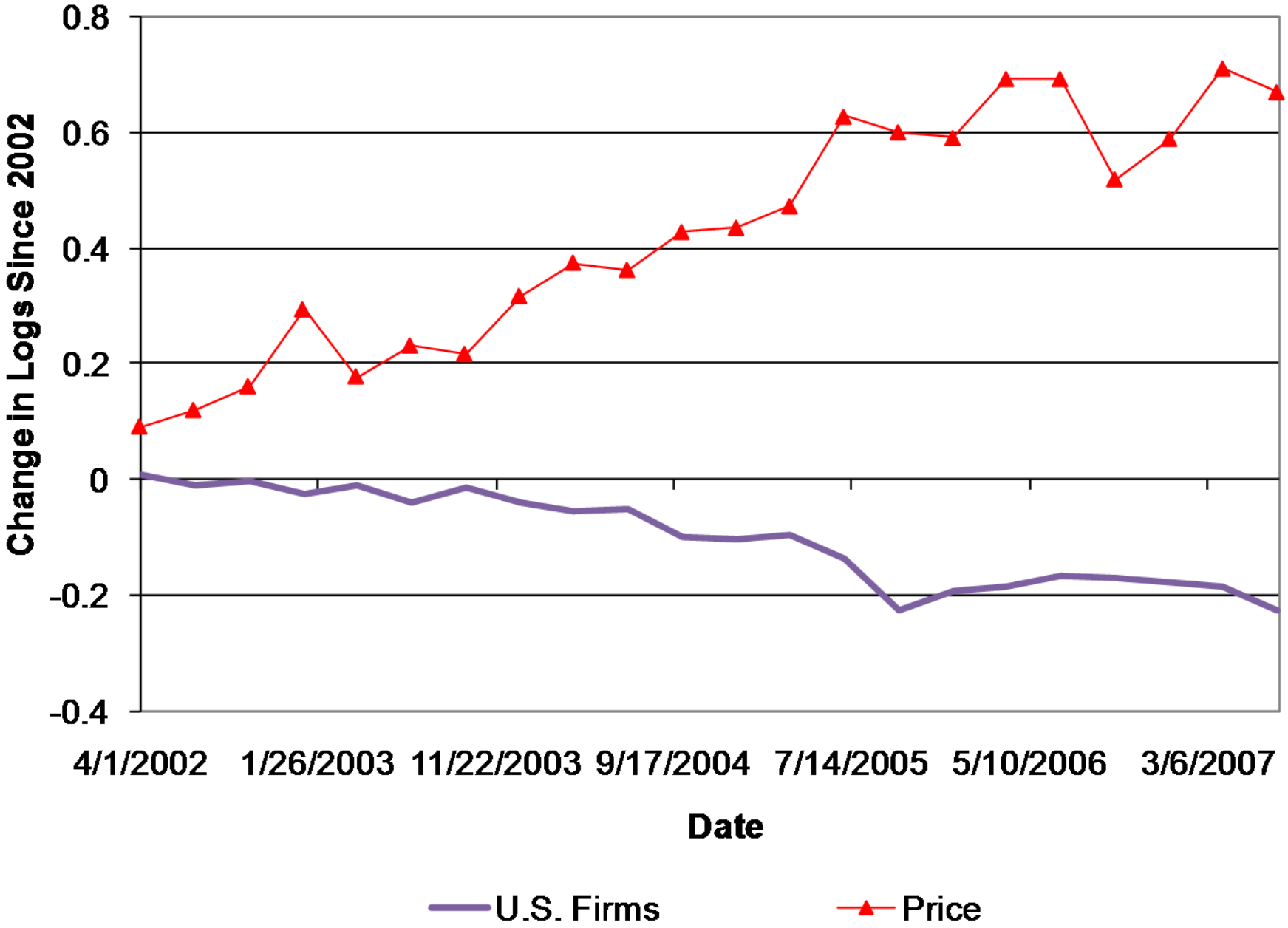


Figure 1: Change in Market Shares of U.S. Firms and Gasoline Price, 2002-2007



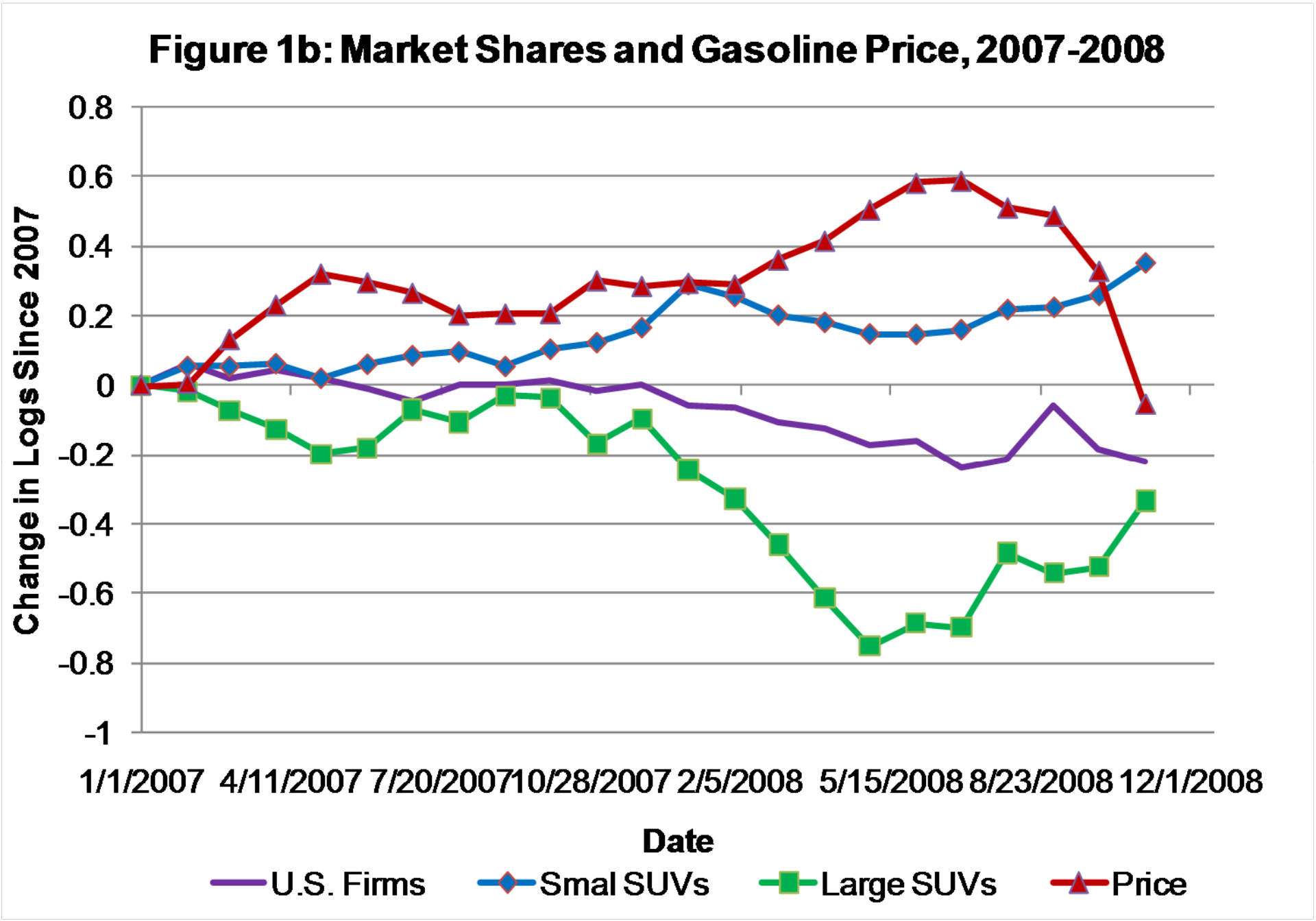


Figure 1b: Market Shares and Gasoline Price, 2007-2008
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Change in Logs Since 2007
1/1/2007
4/11/2007
7/20/2007
10/28/2007
2/5/2008
5/15/2008
8/23/2008
12/1/2008
Date
U.S. Firms
Smal SUVs
Large SUVs
Price

Why this paper?

Question of interest

- What is the effect of gasoline prices on new vehicle demand?

- We investigate two (related) aspects of this price increase:

  - How have these changes affected the new vehicles market?
  - Effect of gasoline (or carbon) tax on average fuel efficiency?

Gasoline Prices and New Vehicle Demand

Framework

- Demand for depends on:
  - Expectations of gasoline prices (fuel costs) and other observables
  - Unobserved consumer and vehicle characteristics (Berry, Levinsohn and Pakes, 1995)
- Most empirical work relies on cross sectional variation, e.g., CEX
- Correlation of regional gasoline prices with preferences/demographics, difficulty of controlling for unobservables in time series

Empirical strategy

- Vehicle characteristics don't change within model-year (e.g., 2005 Ford Focus)
- Exploit within model-year changes in sales and gasoline prices
- Time series (nearly 40 years) and cross sectional variation (about 200 models per year)
- Price increase affects expected fuel costs of "gas guzzlers" by more
- Estimate monthly effect of price of gasoline on sales

Results

Robust relationship between gas prices and sales

- Price increase explains about half the decrease in D3 market shares
- Price of gasoline has significant effect in new vehicles market
- One dollar price increase raises fuel efficiency by 0.5-1 MPG (2-5%)

Other results

- Larger effect in 1970s and 2000s (nonlinear?)
- Little evidence for asymmetric or delayed response
- Short run elasticity appears to be similar to medium/long run

Empirical Framework

Standard vehicle choice model

- Utility depends on fuel costs, vehicle price, unobserved and observed characteristics:

$$U_{ijt} = \alpha(F_{jt} + p_j) + X_j\beta + \xi_j + \varepsilon_{ijt}$$

Model fixed effects eliminate unobserved and observed vehicle characteristics

- Most models begin production July or August
- Characteristics don't change during year
- Model-year constant:

$$I_j = \alpha p_j + X_j\beta + \xi_j + \bar{\varepsilon}_{ij}$$

Estimating Equation

Standard assumption on error term yields aggregate logit equation:

$$\ln s_{jt} - \ln s_{0t} = \alpha F_{jt} + I_j + \eta_{jt}$$

Estimate linear equation by OLS

- Assume gasoline price follows random walk
- Expected fuel costs proportional to dollars-per-mile

$$\ln s_{jt} = \alpha \frac{P_t^g}{M_{jy}} + \tau_t + I_{jy} + \eta_{jt}$$

Baseline specification

- Dependent variable is log share of sales by model, month and year
- Independent variable is dollars-per-mile
- Estimate in first differences, including only time dummies

Identification and Interpretation

Main coefficient is α

- Time series and cross sectional variation
- Price increase raises fuel costs of gas guzzlers by more
- Model-year intercepts control for unobserved vehicle characteristics
- Time dummies control for aggregate demand

Interpretation

- Does a within model-year price increase raise the relative demand for fuel efficient vehicles?
- If α is negative, gas price increase would reduce market shares of gas guzzlers
- Reduced form: equilibrium effect of gas prices on market shares (exogeneity of gasoline prices)
- Equilibrium response includes price response (incentives); i.e., movement along short run supply curve

Data

Sales from Wards Auto

- Sales by model, year and month, 1970-2007
- Aggregate characteristics to model-year level: retail price, engine size and weight (used in robustness checks)

Fuel economy from EPA

- MPG by model and year from fueleconomy.gov
- Impute MPG for 1970s based on relationship between MPG and other characteristics in 1980s
- Assume model-year begins in September

Real price of gasoline from BLS

- Impute price for 1970-1975
- Seasonally detrend using X-12 ARIMA

Summary Statistics

Price and fuel efficiency (Figure 2a)

- Real price of gasoline and average MPG
- Two price shocks in 1970s, decline in 1980s, stable in 1990s and increase since 2002
- CAFE causes increase in MPG, then SUVs become popular
- Strong positive relationship since 2000 (Figure 2b)

Other summary statistics (Table 1)

- MPG distribution is fairly stable over time
- Variation remains after taking first differences

Figure 2a: Quarterly Average MPG and Gasoline Price, 1970-2007

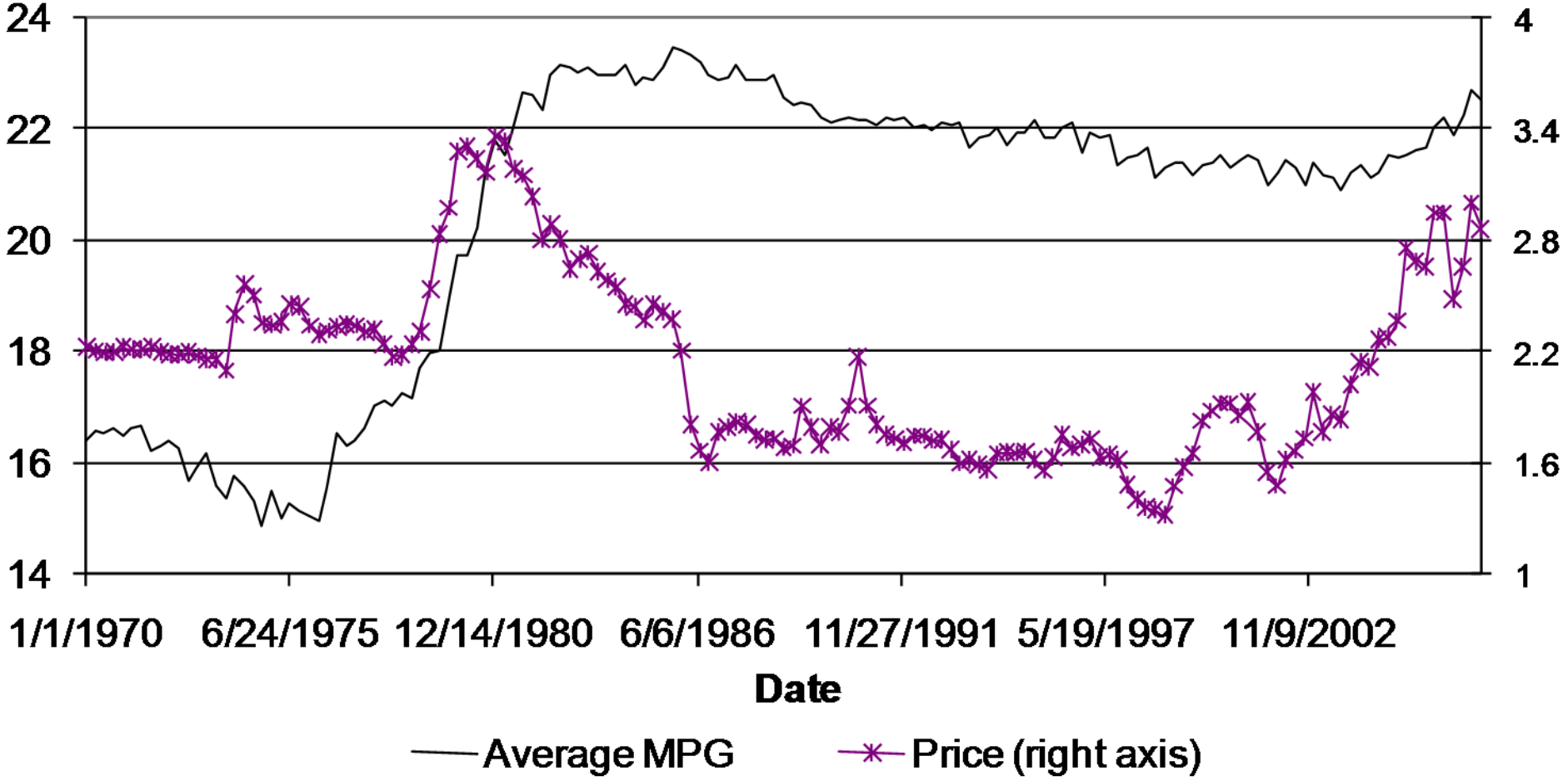


Figure 2b: Quarterly Average MPG and Gasoline Price, 2000-2007

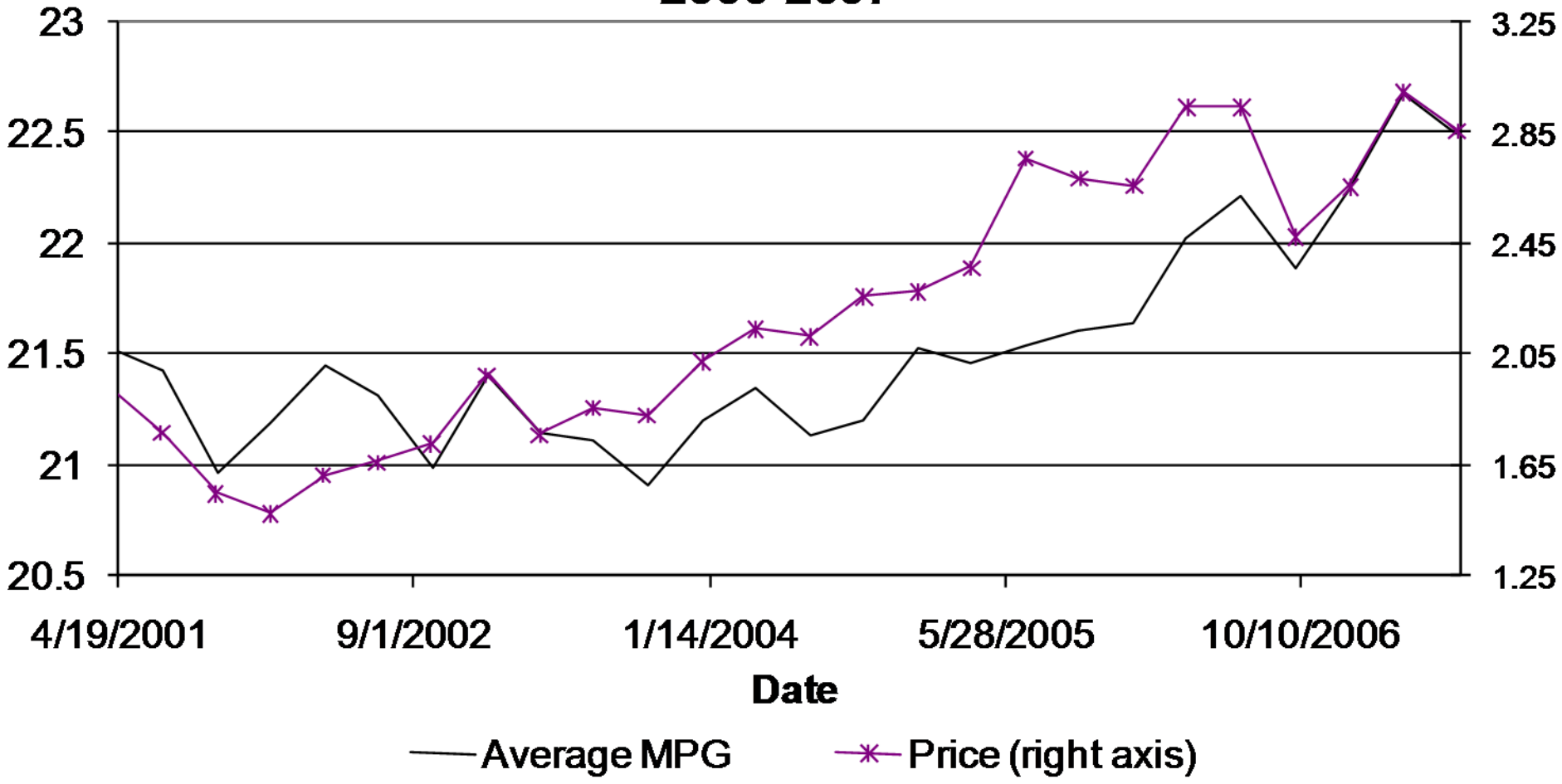


Table 1:

Summary Statistics

	1970-1979	1980-1989	1990-1999	2000-2007
	Panel A: Sample Means and Standard Deviations			
Gasoline Price	2.32 (0.18)	2.41 (0.59)	1.65 (0.16)	2.23 (0.53)
MPG	15.91 (2.88)	22.06 (5.04)	21.91 (4.66)	21.50 (5.45)
Dollars-Per-Mile	0.15 (0.03)	0.11 (0.04)	0.08 (0.02)	0.11 (0.03)
Log Sales	8.95 (1.07)	7.89 (1.57)	7.58 (1.88)	7.69 (1.81)
	Panel B: Standard Deviations After First Differencing			
Dollars-Per-Mile	0.0027	0.0031	0.0023	0.0057
Log Sales	0.36	0.37	0.39	0.39

Main Results

Average response, 1970-2007:

- Negative and statistically significant
- Similar using fixed effects and first differences

Response by decade

- Negative and small when prices are low
- Much larger effect in 1970s and 2000s

Table 2:

Effect of the Price of Gasoline on New Vehicle Sales, 1970-2007

	Dependent Variable: Log Share of Sales		
	(1)	(2)	(3)
Dollars-Per-Mile	-12.64 (2.52)	-10.45 (1.78)	
Dollars-Per-Mile x 1970-1985			-10.10 (3.48)
Dollars-Per-Mile x 1986-2001			-1.50 (2.93)
Dollars-Per-Mile x 2002-2007			-15.28 (2.58)
Number of Observations	76,049	69,089	70,855
R^2	0.94	0.02	0.02
First Differences?	No	Yes	Yes

Implications

Recent market trends

- August 2002 – August 2007: real gasoline price increases $1
- U.S. automakers' market share decreases 10 percentage points
- Use initial gasoline price to predict counterfactual market shares
- Gas prices explain about half of the decrease

Gasoline tax or carbon price

- Simulate effect of $1 price increase on market shares
- Calculate change in sales-weighted MPG
- Increase of about 1 MPG

Comparison with previous literature

- Elasticity smaller than Austin and Dinan (2005)
- Similar to Busse *et al*. (2008)

Summary: Empirical Results

Estimate effect of gasoline prices on new vehicle demand

- Monthly sales data allows us to control for unobserved model-year specific characteristics
- Cross-sectional and time-series variation in expected fuel costs

Short run vs. medium and long run

- Lagged dependent variable, long lags
- Short run response similar in magnitude to medium and long run

Comparison with recent literature

- Busse *et al.* (2008): gasoline prices and market shares, vehicle prices, trade-ins, inventories (shorter sample but additional margins)
- Miller and Langer (2008): vehicle prices and lagged and current gas prices
- Elasticity is about one-half of Austin and Dinan (2005)
- Previous studies may over-estimate advantage of gasoline tax

Conclusions and Policy Implications

Recent trends in market shares: preferences or prices?

- About half decrease in U.S. market shares due to gasoline prices
- Implications for bailout?
- Caveat: recent decline in total sales volume also played a role

Gasoline tax vs. other policies

- Previous work may overstate advantage of tax over CAFE
- What is the long run marginal abatement cost curve for the transportation sector?
- Long run supply response?

Extras

Greenhouse Gas Policy

What is the effect of gasoline prices on average fuel efficiency?

- Greenhouse gas regulation: many policy options, but what do they cost?
- Studies on cap-and-trade, CAFE, gas tax (Kleit, 2004, Austin and Dinan, 2005 Jacobsen, 2006, Klier and Linn, 2008)
- Conclusion: gas tax would be less costly than CAFE
- Gas tax affects miles traveled and vehicle purchases
- Study the effects jointly (e.g., Hughes *et al.*, 2008) or separately (e.g., West, 2004 and Small and van Dender, 2007)
- Some empirical work on new vehicles, but limitations discussed below

Connection between market shares and gas tax

- Effect of gasoline prices on new vehicle demand is important for both questions
- Same empirical approach
- What are distributional effects on producers of increasing the gas tax?

Short Run vs. Long Run

Relationship between short and long run

- Empirical strategy identifies monthly demand response
- What is the long run demand response? Supply?
- Short run production and inventory constraints? Sticky prices?

Lag fuel costs

- Consumers may respond to last month's price shock
- Delayed production response
- Some evidence for one-month lag

Lag dependent variable

- Positive coefficient would suggest increasing effect over time
- If anything, within-year response smaller than monthly response

Lag demand shocks

- Do firms reallocate production based on last year's demand shock?
- Little evidence for longer lags

Table 3:

Lagged Demand Responses

	Dependent Variable: Log Share of Sales				
	(1)	(2)	(3)	(4)	(5)
Dollars-Per-Mile	-15.91 (2.54)	-13.98 (4.75)	-17.11 (3.68)	-14.72 (4.44)	-13.96 (4.46)
One Month Lag Dollars-Per-Mile		-5.01 (4.27)		-6.48 (3.90)	-5.80 (4.02)
One Month Lag Dependent			-0.16 (0.03)	-0.16 (0.03)	-0.16 (0.03)
Lag Demand Shock					-2.77 (2.32)
N	15,810	11,493	11,214	11,214	10,902
R^2	0.02	0.02	0.04	0.04	0.04

Other Empirical Issues

Asymmetric demand response (results in paper)

- Does demand respond more to price increases or when prices are high?
- Some evidence of greater response when prices are high, no evidence within sub-periods

Functional form assumptions

- Allow different α for each model-year (analogous to IIA)
- AIDS-type specification

$$w_{jt} = \gamma_j \ln P_t^g + \lambda_j \ln \hat{Q}_t + \phi_{jy} + \upsilon_{jt}$$

- Aggregate specification

$$\ln M_t = \delta \ln P_t^g + \mu_m + \tau_y + \omega_t$$

- Similar results across specifications

Exogeneity of gasoline prices: vehicle price trends or consumer purchasing patterns (results in text)