# The Dynamics of Automobile Expenditures

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September 17, 2010

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# Motivation

- A central question in durable goods analysis: how much do consumers time their purchase decisions?
- I focus on two issues arising with temporal substitution in the automobile market
  1. The degree of temporal substitution and its main patterns.
  2. Are dynamic pricing strategies important?
- I analyze the automobile market b/c
  1. Industry wisdom says consumers temporally substitute
  2. Seem to be large gains to temporally substituting
- With motor vehicles, have a unique window on timing of purchases
  1. detailed monthly price and sales vehicle data
  2. coordinated model-year cycle for motor vehicle
  3. demographic data

# Overview of the Paper

1. Analyze how consumers time their new vehicle purchase decisions
2. Focus on decisions within the model year
   - choice set constant, but prices vary (decline)
   - clear tradeoff of enjoying vehicle now vs. waiting for price decline
3. Consumers modeled as an optimal stopping problem
4. Estimate parameters in the consumer's indirect utility function
5. Results:
   1. Consumers are price sensitive and willing to time purchases
   2. Entry/exit and temporal substitution are dominant channels of substitution. Cross-sectional substitution is relatively small.
6. Dynamic pricing strategies matter
7. Circumstantial evidence of price discrimination

# Literature review

1. Durable goods - infrequently purchased
   - (closest) Gowrisankaran and Rysman (2007) - DVD players
   - Carranza (2003, 2006), Song and Chintagunta (2003), Gordon (2006) and Nair (2005)
2. Non-durable goods - frequently purchased (grocery retail data)
   - impact of high/low pricing and other optimal pricing schemes,
   - Slade (1998), Aguirregabiria (1999), Pesendorfer (2002), Erdem et al (2003), Hendel and Nevo (2006).
3. Automobile pricing: incentives, dealer inventories, price cues (Zettelmeyer et al (2003,2006,2007)).
4. Macroeconomic issues
   - aggregrate inventory behavior: Hall (2000) and Attanasio (2000)
   - GDP volatility: Ramey and Vine (2007)

# Talk outline

1. Data
2. Model
3. Results

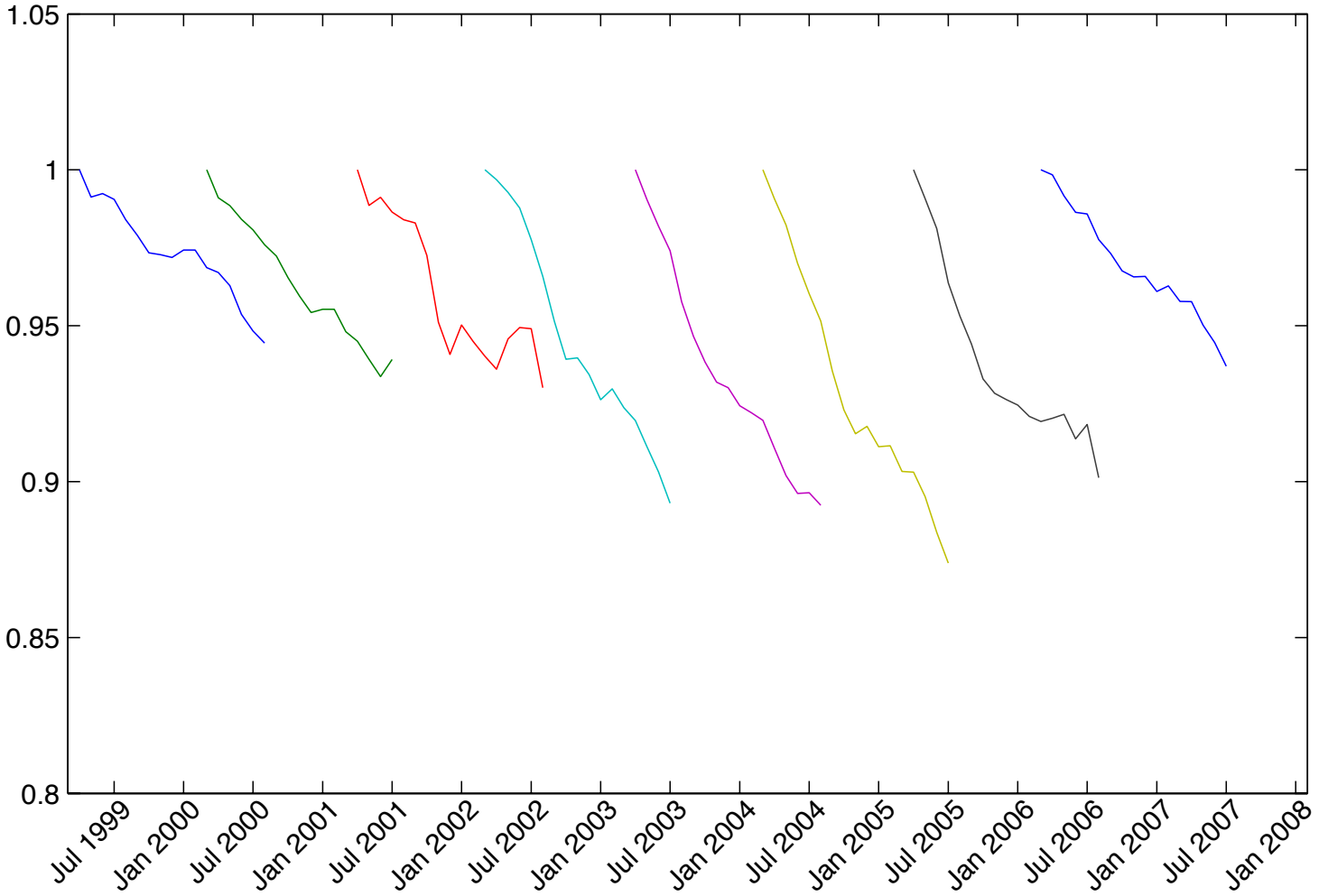
# Data - Combined 2 data sets

1. First: Power Information Database (PIN), from JDPA
   - Collected from dealerships, 15-20% of all U.S. retail sales.
   - Monthly observations by model/model-year from 1999 to 2008
   - Observe price, cash rebate, and financial details
   - Observe model-year distribution of sales by model
2. Second: Wards Communications - US monthly sales by model.
3. Combine both data sets to get:
   - Monthly series of sales by model & model-year,
   - Monthly series of real market prices by model & model-year,

# Data Facts

1. Prices fall over the model year at 9% annual rate
2. Mean income of new vehicle purchasers falls over model year
3. Model-level sales are hump-shaped
4. Aggregate sales volatile

# Price indexes by model year: 2000 - 2007

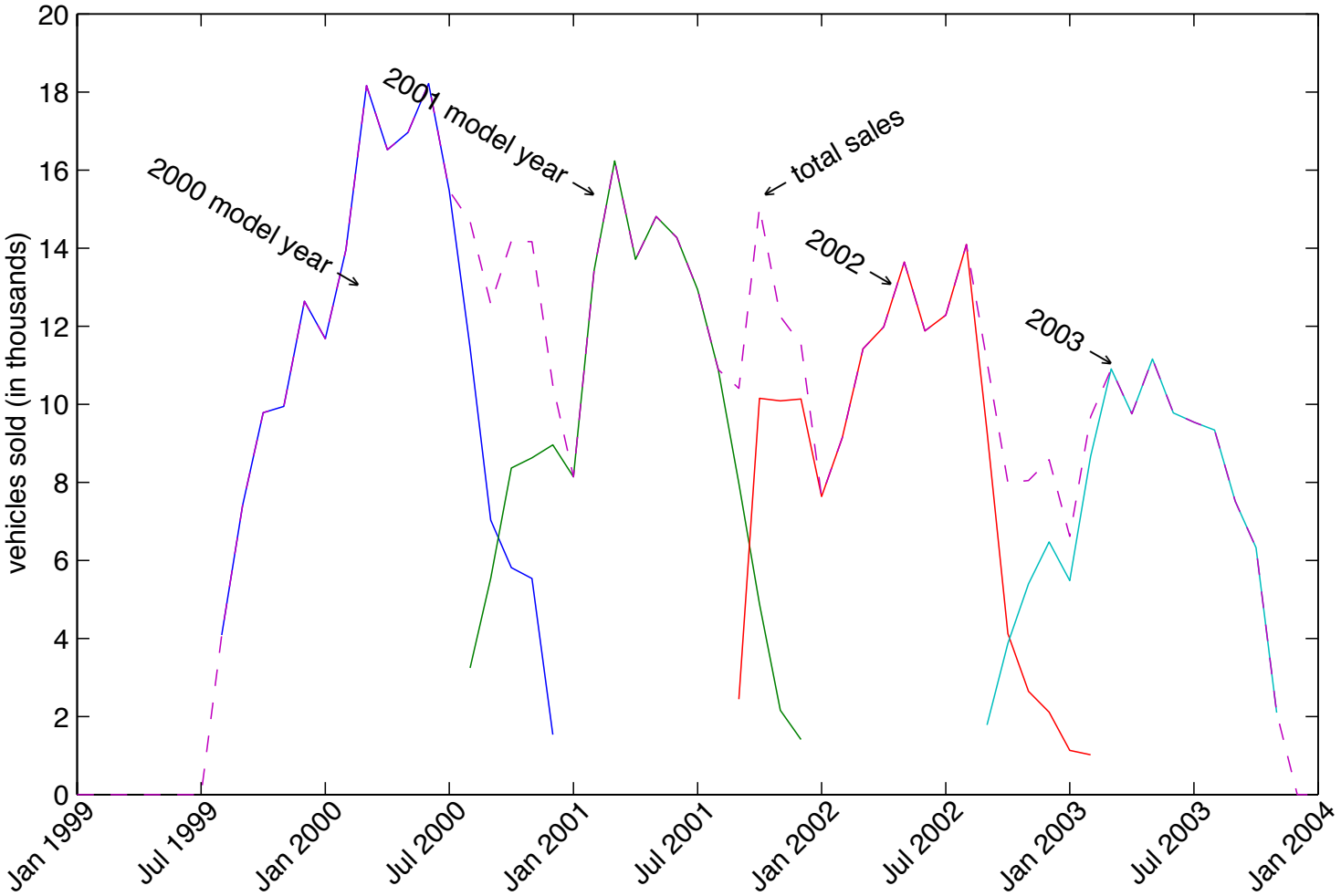


# Data from Aizcorbe-Bridgman-Nalewaik 2007

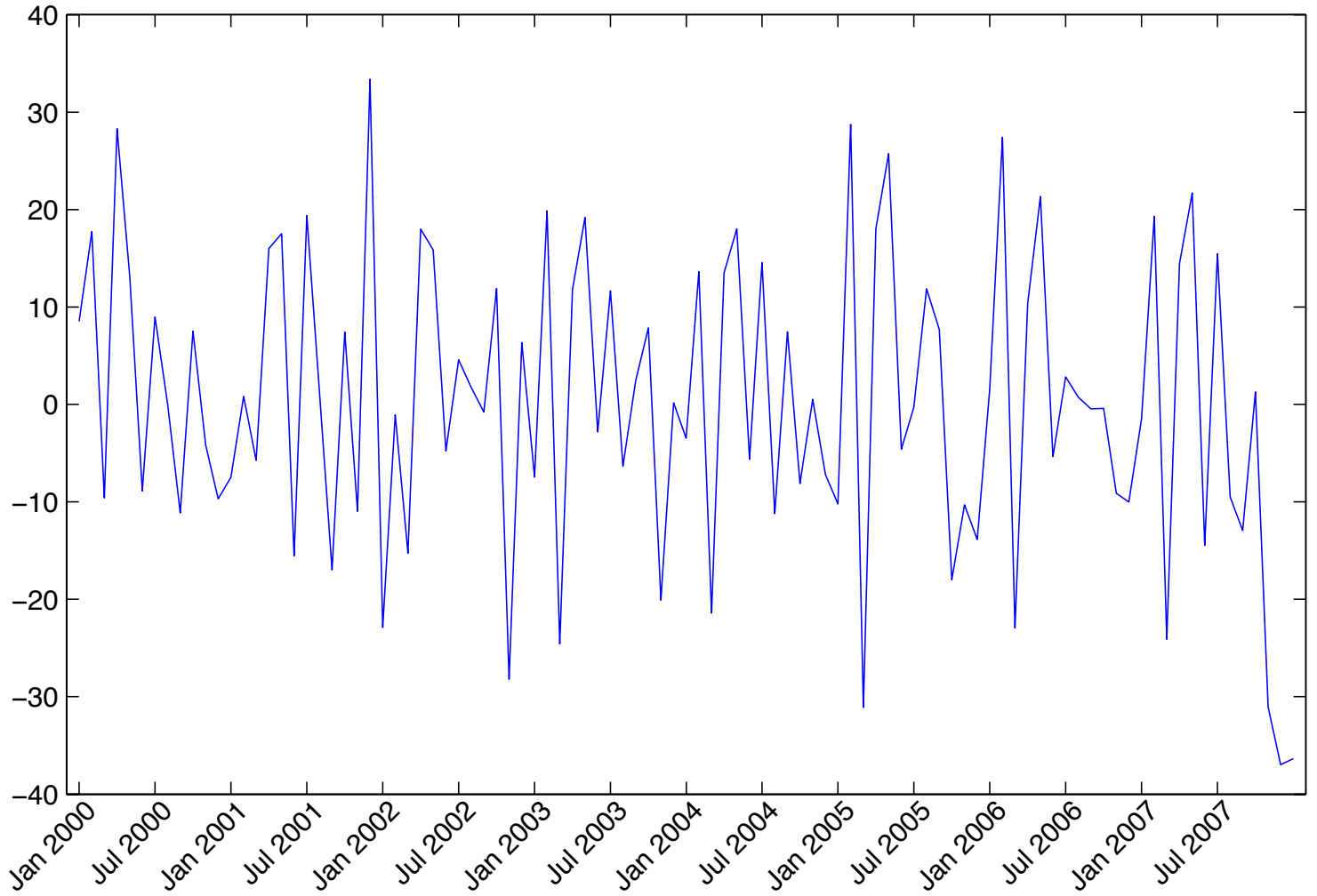
| | Income (thousands of dollars) |
|---|---|
| Quarter | Data |
| 1 | 74.973 |
| 2 | 73.075 |
| 3 | 71.460 |
| 4 | 68.603 |

Average Income of New Vehicle Purchasers

# Pickup sales by model year



# Percent Change in Aggregate Sales



# Reduced form analysis of prices and sales

- Is there positive correlation between $p_{t-1}$ and $s_t$?
- First stage: detrend $\log(p), \log(s)$ by model
- Second stage: for $n = \{1, 2, 3, \ldots, 10\}$

$$\hat{s}_{jt} - \hat{s}_{j,t-n} = \varsigma + \upsilon(\hat{p}_{jt} - \hat{p}_{j,t-1})$$

| periods of comparison | price coefficient | | obs. |
|---|---|---|---|
| t,t-1 | -0.434 | (0.066) | 33,566 |
| t,t-2 | -0.735 | (0.078) | 31,851 |
| t,t-3 | -1.087 | (0.088) | 30,135 |
| ⋮ | | | |
| t,t-9 | -0.567 | (0.126) | 19,878 |
| t,t-10 | -0.370 | (0.133) | 18,185 |

# Model: Optimal stopping problem within Model Year

- All consumers show up at the beginning of the model year.
- Every month, each decides whether to buy a new vehicle or wait. If buy, then leave the market.
- In last month of the model year, waiting means not buying a new vehicle that model year.
- Remainder of income goes towards alternative consumption good.
- Aggregate across consumers to get predicted market shares
- Employ discrete-choice framework (BLP-style), includes
  - Consumer heterogeneity
  - Product differentiation
  - Constant choice set, changing prices
  - Perfect foresight on prices

# Dynamic model

- if consumer $i$ purchases vehicle $j$ at time $t$, gets a net flow utility of

$$\delta_{ijt}^{f} - \beta^{T-t}\eta_i p_{jt} + \epsilon_{ijt} \tag{1}$$

  where only $\delta_{ijt}^{f}$ persists over time.
- Let $\delta_{ijt} = \sum_{s=t}^{\infty} \beta^{s-t}\delta_{ijt}^{f}$, then indirect utility is

$$u_{ijt} = \delta_{ijt} - \beta^{T-t}\eta_i p_{jt} + \epsilon_{ijt}. \tag{2}$$

  $\longrightarrow$ fits into the random coefficients discrete choice framework.
- Substituting in for $\delta$,

$$u_{ijt} = X_{jt}\gamma + \sum_{s=1}^{11} 1_{C_t=s}\zeta_s + \xi_{jt} + \sum_{k=1}^{K} \sigma_k \nu_{ik} x_{jkt} - \beta^{T-t}\frac{\eta}{y_i} p_{jt} + \epsilon_{ijt}, \tag{3}$$

- Price discounted as if paid in last period of the model year
- Separates consumption of alternative good from timing of the vehicle purchase (perfect smoothing assumption)

# Dynamic Model – value functions

- Value function in last period

$$V_{iT} = \max\left\{\pi_{iT}, \max_{j \in J}\left\{u_{ijT}\right\}\right\}. \tag{4}$$

  where $\pi_{iT} = \delta^f_{i0T} + \epsilon_{i0T}$ is utility flow from outside option ($\delta^f_{i0t}$ is set to zero)
- Value function for $t \in \{1, \ldots, T-1\}$

$$V_{it} = \max\left\{\pi_{it} + \beta E[V_{i,t+1}], \max_{j \in J}\left\{u_{ijt}\right\}\right\}. \tag{5}$$

- Expectations only over taste-for-variety term
- Perfect foresight: choice set, characteristics, and prices

# Moment conditions & instruments

- GMM approach with 2 sets of moments:
  1. regular BLP moments: $E[\xi|X] = 0$
  2. average income of purchasers by quarter
- Problem with correlation between $\xi$ and price
  - Firms and consumers observe $\xi$. Higher $\xi$ likely implies higher price, violating moment condition
  - Usual instruments are competing vehicle characteristics.
  - Rely on vehicles' fuel efficiency and real gas price.
- Use real gas price as well as sum of fuel efficiencies across all other vehicles, all other manufacturers' vehicles, and all other vehicles produced by the same manufacturer.

# Identification & Measurement

- Because of parametric assumptions on indirect utility, technically the model is identified.
  - worry about multicollinearity of observed characteristics
- What's the variation in the data driving the estimates?
  1. Across model-years, have changes in choice set with corresponding changes in sales
  2. Within a model-year, have changes in instruments and corresponding changes in sales
  3. Income moments are essential to pin-down distaste-for-price parameter
- caveat: is there a unique solution to the double loop iteration?

# Model Results

Used variation on the estimation strategy detailed in Gowrisankaran & Rsyman (2007).

- Parameters are precisely estimated
- Estimate heterogeneity in consumer tastes
- Positive trend in indirect utility over model year (consistent with inventories generating sales)
- Temporal substitution is a large force

| Parameter | | Estimate | Std Error |
|---|---|---|---|
| Mean | Constant | -4.594 | (0.324) |
| | Acceleration | 2.727 | (0.441) |
| | Height | 2.174 | (0.594) |
| | Size | 2.129 | (0.729) |
| | Miles per Dollar | -2.906 | (0.467) |
| Variance | Constant | 3.746 | (0.145) |
| | Acceleration | 3.016 | (0.391) |
| | Height | 0.410 | (0.224) |
| | Size | 1.494 | (0.127) |
| Distaste-for-price | $\eta$ | 4.565 | (0.365) |
| Loss Criterion | | 155.50 | |
| Observations | | 21,073 | |

| Parameter | | Estimate | Std Error |
|---|---|---|---|
| Month | 1 | -0.728 | (0.050) |
| Dummies | 2 | -0.294 | (0.046) |
| | 3 | -0.221 | (0.051) |
| | 4 | -0.037 | (0.055) |
| | 5 | -0.206 | (0.052) |
| | 6 | -0.015 | (0.047) |
| | 7 | 0.255 | (0.037) |
| | 8 | 0.252 | (0.028) |
| | 9 | 0.334 | (0.024) |
| | 10 | 0.256 | (0.023) |
| | 11 | 0.122 | (0.021) |

| Quarter | Data | Dynamic Model |
|---|---|---|
| 1 | \$74,973 | \$73,702 |
| 2 | \$73,075 | \$72,438 |
| 3 | \$71,460 | \$71,163 |
| 4 | \$68,603 | \$70,002 |

Table: Average Income of New Vehicle Purchasers

Table: Own Price Elasticities for the 2002 Model Year (absolute value)

| Market Segment | Dynamic Model Quartiles | | |
|---|---|---|---|
| | 1/4 | 1/2 | 3/4 |
| CUV | 1.40 | 1.51 | 2.27 |
| Large car | 1.50 | 1.59 | 1.67 |
| Luxury car | 2.05 | 2.41 | 2.94 |
| Midsize car | 1.25 | 1.41 | 1.50 |
| Pickup | 1.23 | 1.60 | 1.77 |
| Compact car | 0.87 | 0.94 | 1.07 |
| SUV | 1.63 | 1.90 | 2.30 |
| Van | 1.41 | 1.47 | 1.61 |
| All | 1.35 | 1.62 | 2.20 |

Table: Within Market Segment Cross-Price Elasticities for the 2002 Model Year

| Market Segment | Dynamic Model | | |
|---|---|---|---|
| | Min | Mean | Max |
| CUV | 0 | 0.00017 | 0.00129 |
| Large car | 0 | 0.00030 | 0.00123 |
| Luxury car | 0 | 0.00004 | 0.00287 |
| Midsize car | 0 | 0.00028 | 0.00302 |
| Pickup | 0 | 0.00093 | 0.00726 |
| Compact car | 0 | 0.00016 | 0.00171 |
| SUV | 0 | 0.00038 | 0.00437 |
| Van | 0 | 0.00024 | 0.00207 |

note: Statistics are computed only over vehicles within the same market segment.

Three counterfactuals

1. A temporary price discount on GM pickups, holding all else constant
2. A temporary price discount on GM pickups, allowing for price responses
3. All firms collude to not offer incentives.

Table: $500 Incentive for GM Pickups in month 6

| Month | Chrysler | Ford | GM | All others |
|---|---|---|---|---|
| Unit sales: difference between data and counterfactual | | | | |
| 6 | -32 | -49 | 3,332 | -76 |
| 7 | -30 | -47 | -63 | -69 |
| 8 | -29 | -45 | -64 | -66 |
| 9 | -31 | -48 | -62 | -72 |
| 10 | -30 | -48 | -72 | -70 |
| 11 | -28 | -45 | -76 | -71 |
| 12 | -31 | -51 | -73 | -79 |
| Total | -210 | -332 | 2,923 | -503 |

$\longrightarrow$ 1,877 consumers entered the market

# Estimating price responses

- Assume GM is the price leader for pickups
- $d_j$ denotes price incentives on pickup $j$, $d_{GM}$ is the average price incentive on GM pickups and $m$ is a monthly trend
- $\text{inv}_j$ are inventories of vehicle $j$, included to capture aggregate shocks
- Estimate regression

$$d_{jt} = \rho m_t + \omega \text{inv}_{jt} + \sum_{j=1}^{J} I_{v_t=j}\alpha_j + \sum_{k=1}^{5} I_{C_t=k}(\kappa_k^0 d_{GM,t} + \kappa_k^1 d_{GM,t-1} + \kappa_k^2 d_{GM,t-2}) + \varepsilon_{jt} \quad (6)$$

- $\alpha$ are model fixed effects, $(\kappa^0, \kappa^1, \kappa^2)$ estimated for each company

Table: Predicted Incentive Responses to a $500 GM Incentive in Month 6

| | Month | | | |
|---|---|---|---|---|
| | 6 | 7 | 8 | 9 |
| GM | 500 | 0 | 0 | 0 |
| Chrysler | 20 | 237 | 213 | 0 |
| Ford | 96 | 259 | 79 | 0 |
| All others | 50 | 20 | 52 | 0 |

Table: $500 Price Decline for GM Pickups in month 6, with price responses

| Month | Chrysler | Ford | GM | All others |
|---|---|---|---|---|
| Unit sales: difference between data and counterfactual | | | | |
| 6 | -17 | 378 | 3,237 | -91 |
| 7 | 603 | 1,539 | -156 | -139 |
| 8 | 572 | 360 | -148 | -61 |
| 9 | -72 | -110 | -139 | -168 |
| 10 | -70 | -109 | -161 | -162 |
| 11 | -65 | -103 | -167 | -165 |
| 12 | -71 | -115 | -161 | -182 |
| Total | 881 | 1,839 | 2,304 | -969 |

$\longrightarrow$ 4,055 consumers entered the market

Table: Comparing flows with and without the price response

| | Chrysler | Ford | GM | All others |
|---|---|---|---|---|
| *Units* | | | | |
| no p.r. | -210 | -332 | 2,923 | -503 |
| p.r. | 881 | 1,839 | 2,304 | -969 |
| *Revenue ($ thousands)* | | | | |
| no p.r. | -4,889 | -8,104 | 19,767 | -12,721 |
| p.r. | 2,517 | 4,517 | 4,495 | -28,351 |

Table: Average Cash Rebate over the 2002 Model Year

| Months within the Automotive Model Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 312 | 234 | 251 | 345 | 654 | 805 | 757 | 805 | 861 | 938 | 827 | 846 |

Table: 2002 Model Year Sales and Revenue with and without Incentives

| Month | Unit Sales (thousands) | | | | Revenue ($ million) | | | |
|---|---|---|---|---|---|---|---|---|
| | CF | Data | diff. | cdiff. | CF | Data | diff. | cdiff. |
| 1 | 514 | 505 | 9 | 9 | 13,254 | 12,902 | 352 | 352 |
| 2 | 1,135 | 1,117 | 18 | 27 | 29,168 | 28,379 | 790 | 1,142 |
| 3 | 1,112 | 1,094 | 19 | 46 | 29,113 | 28,339 | 774 | 1,915 |
| 4 | 1,186 | 1,175 | 10 | 56 | 31,159 | 30,421 | 738 | 2,653 |
| 5 | 1,020 | 1,038 | -18 | 38 | 26,242 | 25,868 | 374 | 3,027 |
| 6 | 1,195 | 1,242 | -46 | -8 | 30,608 | 30,403 | 204 | 3,231 |
| 7 | 1,390 | 1,436 | -45 | -54 | 35,498 | 35,145 | 352 | 3,583 |
| 8 | 1,324 | 1,374 | -49 | -103 | 33,582 | 33,287 | 295 | 3,878 |
| 9 | 1,374 | 1,429 | -55 | -158 | 34,566 | 34,302 | 265 | 4,143 |
| 10 | 1,372 | 1,441 | -69 | -227 | 34,340 | 34,233 | 107 | 4,250 |
| 11 | 1,356 | 1,410 | -54 | -280 | 34,322 | 34,140 | 182 | 4,432 |
| 12 | 1,413 | 1,466 | -54 | -334 | 35,810 | 35,606 | 204 | 4,636 |

# Conclusion

- With motor vehicles, have a excellent opportunity to measure temporal substitution
- Find consumers are price sensitive and willing to substitute temporally across many months
- Temporal substitution and exit/entry are the main channels of substitution
- B/c of temporal substitution, accounting for dynamic pricing strategies is important. For example revenue gains are vastly overestimated (5 times in my example).
- Circumstantial evidence that automakers take advantage of consumers' ability to temporally substitute and price discriminate.