# Why are Prices Sticky? A Test of Alternative Models of Price Adjustment

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# WHY ARE PRICES STICKY?

- Price stickiness required to drive a real money-output relationship.
  - The *form* of price stickiness is key to understanding inflation dynamics (Reis, 2006).
- "The idea that prices set by firms in concentrated industries might exhibit rigidities is an old concern of industrial-organization economists" (Slade, 1999).
- Understand pricing patterns on the microeconomic level to understand how best to model them on the macroeconomic level.

# A ROADMAP FOR THIS TALK

- Theoretical Background and Testable Implications
- Data: Why Gasoline Prices?
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- Methodology: Discreteness and time dependence (ACB)
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# 3 THEORIES OF PRICE ADJUSTMENT

1. Menu Cost
   - A firm must pay a fixed cost in order to change its price (Dixit, 1991).
   - Even though small, menu costs can exert a large impact on the business cycle (Mankiw, 1985; Fishman and Simhon, 2005).

2. Information Processing
   - Processing delays (Calvo, 1983; Sims, 1998; Mankiw and Reis, 2002).
   - "Inattentive producers" (Reis, 2006).
   - "Inattentive consumers" (Levy, Bergen, Dutta, and Venable, 2005; Ray, Chen, Bergen, and Levy, 2006).

3. Strategic Considerations
   - Customer Anger: Firms deliberately stretch out long price increases to avoid upsetting consumers (Rotemberg, 1982).
   - Fairness: Firms avoid changing the price if consumers believe such a change is "unfair" (Kahneman, Knetsch, and Thaler, 1986; Rotemberg, 2002, 2006)

# TESTABLE IMPLICATIONS: THE PROBABILITY OF A PRICE CHANGE

| | Current price gap | Auto-correlation | History of price changes | Remaining price gap | Symmetry |
|---|---|---|---|---|---|
| Menu Costs | Yes | 0 | No | No | Yes |
| Information processing | | | | | |
| “Inattentive producers” | | | | | |
| “Inattentive consumers” | | | | | |
| Strategic interactions | | | | | |
| Partial adjustment | | | | | |
| Fair pricing | | | | | |

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| Menu Costs | Yes | 0 | No | No | Yes |
| Information processing | Yes | - | - | No | |
| "Inattentive producers" | | | | | Yes |
| "Inattentive consumers" | | | | | No (in the "small") |
| Strategic interactions | | | | | |
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| Information processing | Yes | - | - | No | |
| "Inattentive producers" | | | | | Yes |
| "Inattentive consumers" | | | | | No (in the "small") |
| Strategic interactions | Yes | + | + | | |
| Partial adjustment | | | | Yes | |
| Fair pricing | | | | No | No (in the "large") |

# TESTABLE IMPLICATIONS: THE PROBABILITY OF A PRICE CHANGE

| | Current price gap | Auto-correlation | History of price changes | Remaining price gap | Symmetry |
|---|---|---|---|---|---|
| Menu Costs | Yes | 0 | No | No | Yes |
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| Partial adjustment | | | | Yes | |
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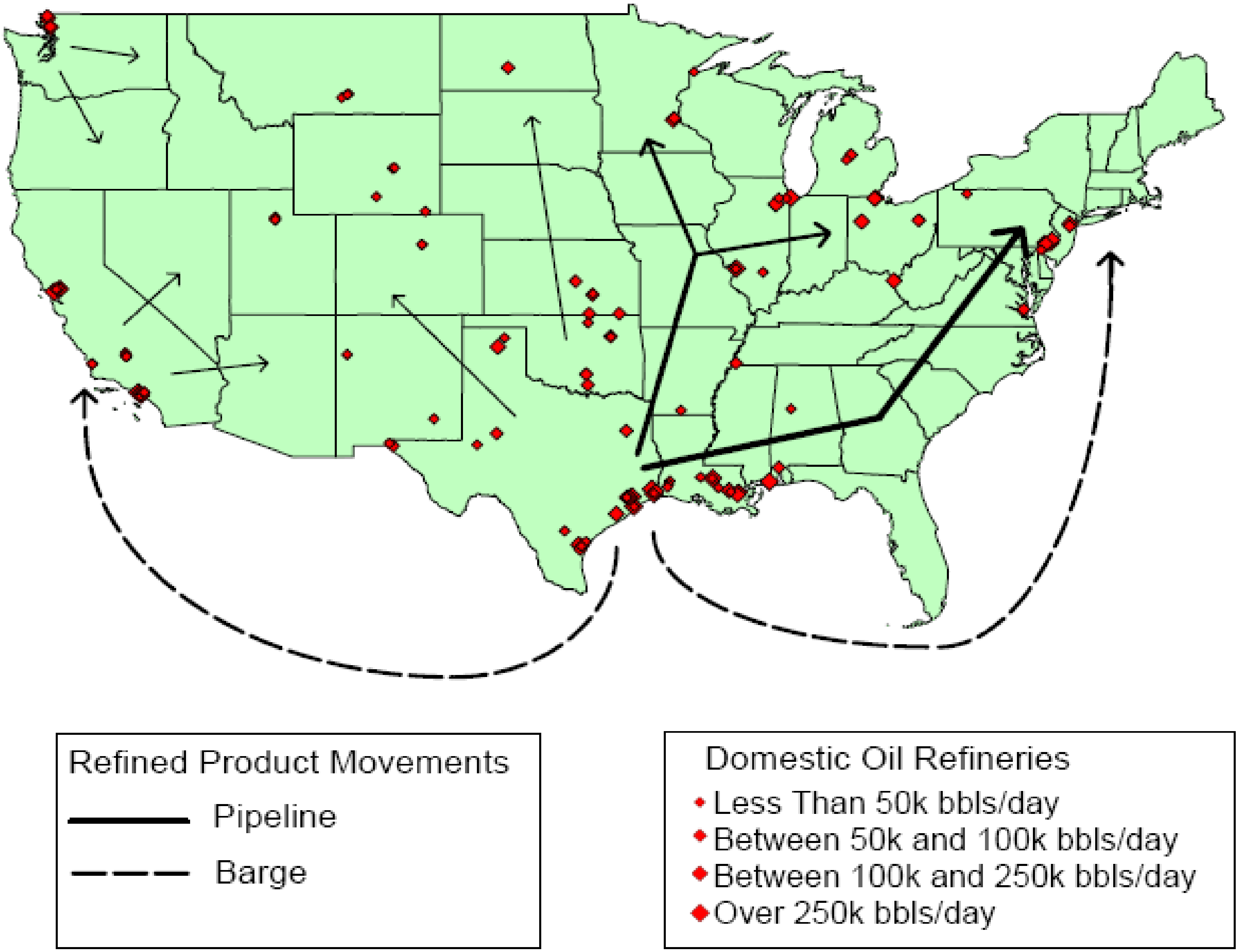
# DATA - WHOLESALE GASOLINE PRICES

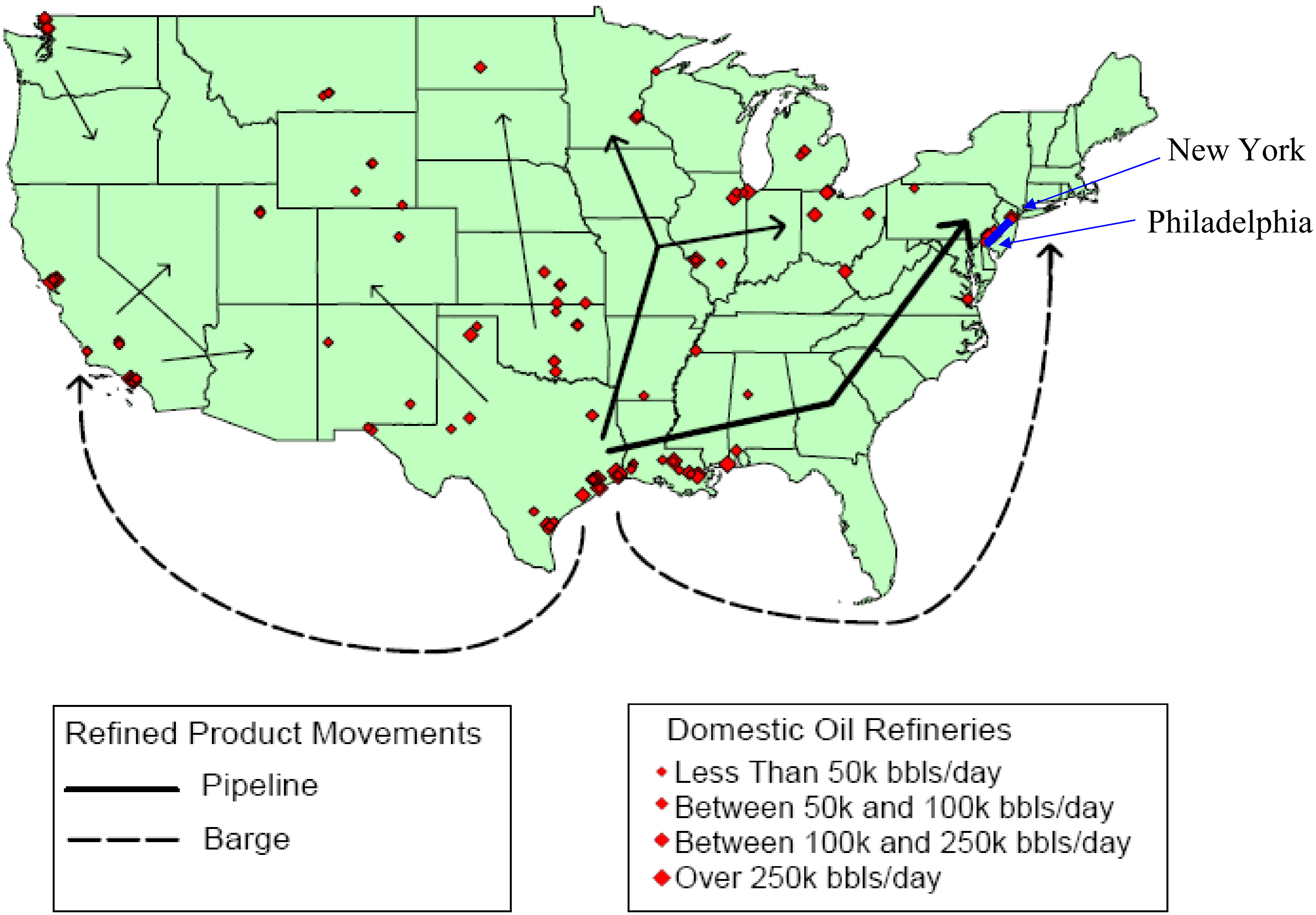
- Daily observations of prices charged by 9 Philadelphia gasoline wholesalers between January 1, 1989 and December 31, 1991.

- Why?
  - 5 reasons

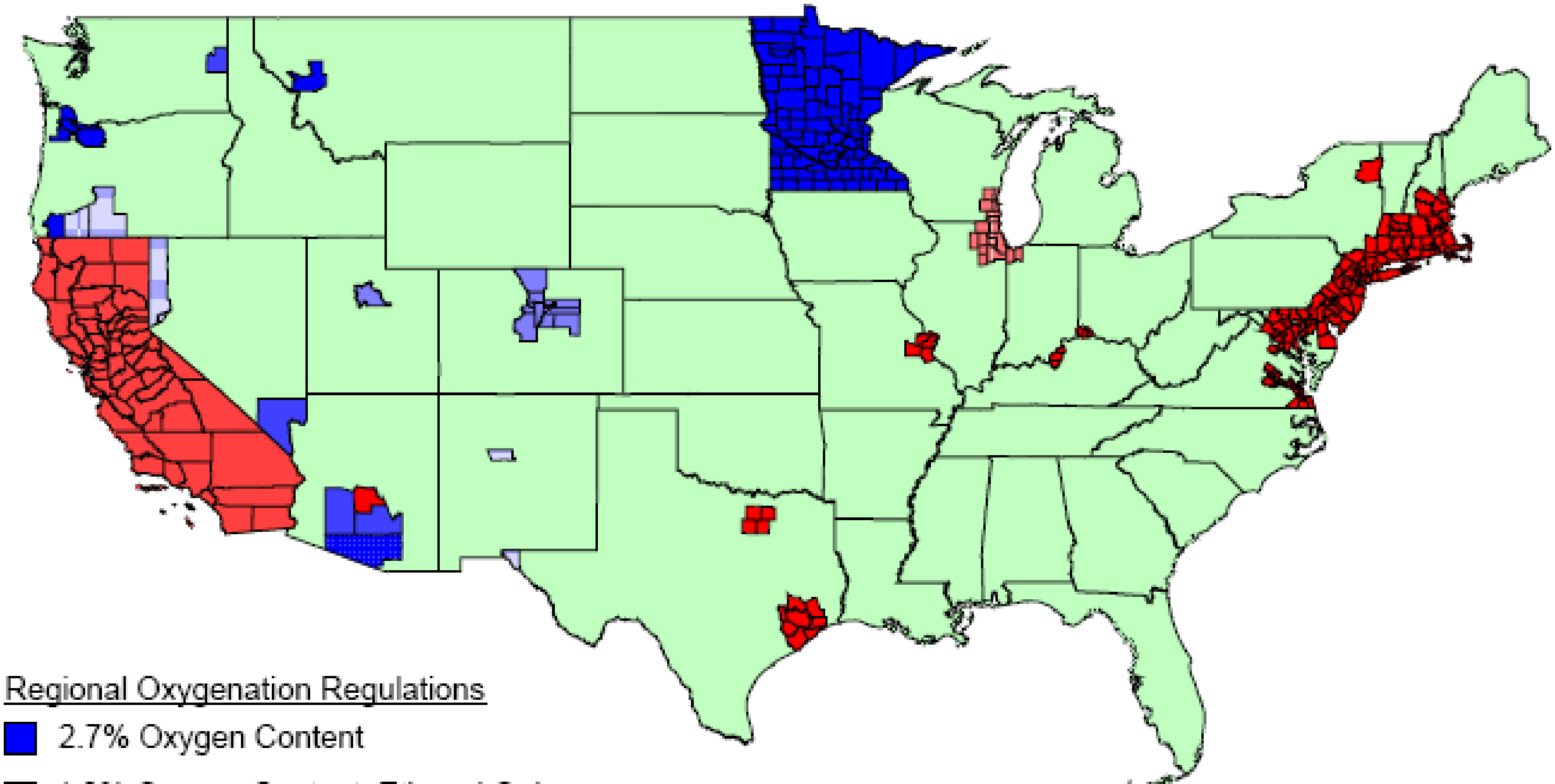
# OIL REFINERIES AND REFINED PRODUCT MOVEMENT



# REASON 1:
# MAIN INPUT COST IS EASILY OBSERVABLE



# REGIONAL GASOLINE CONTENT REGULATION



Regional Oxygenation Regulations

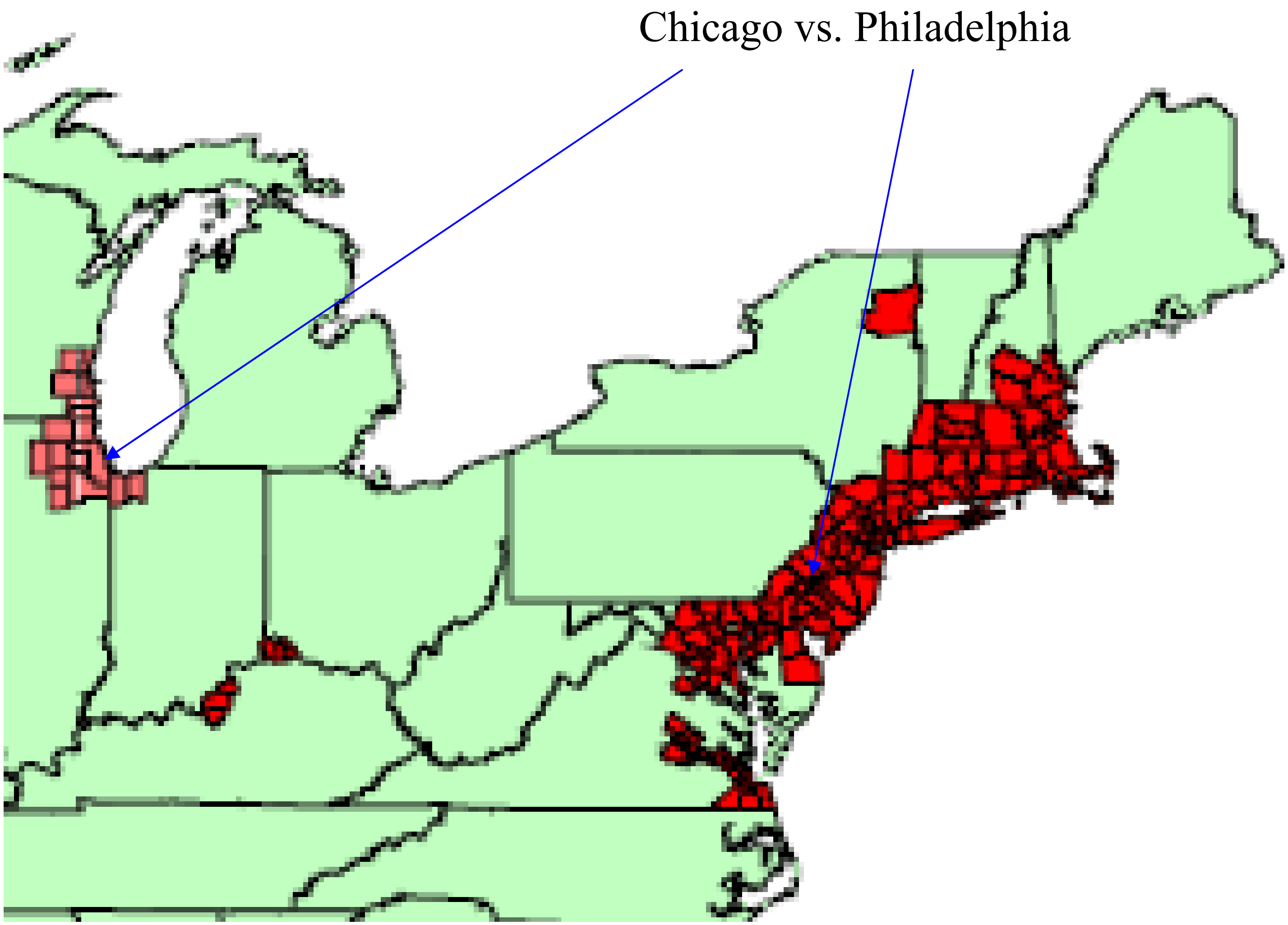
- 2.7% Oxygen Content
- 1.8% Oxygen Content, Ethanol Only
- 2.7% Oxygen Content, Ethanol Only
- 3.1% Oxygen Content, Ethanol Only
- 3.5% Oxygen Content, Ethanol Only

Regional RFG Regulations

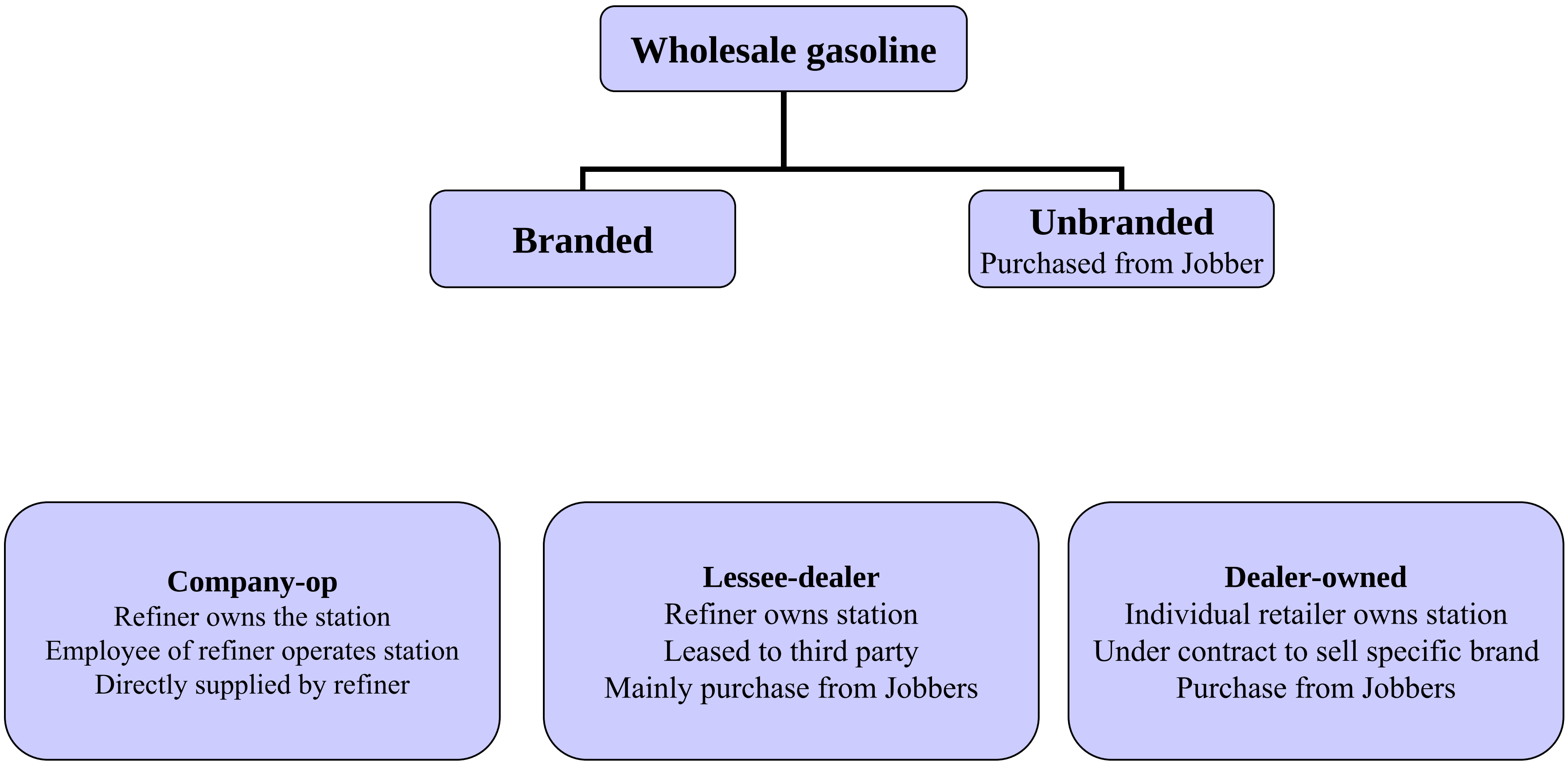
- Federal Reformulated Gasoline
- CARB Gasoline
- Ethanol-Blended RFG

Note: Minnesota mandates year-round oxygenation. Other oxygenation mandates only affect winter gasoline content.

# REASON 2: HOMOGENEOUS GOOD



# WHOLSALER-RETAIL STATION RELATION



# REASON 3:
# PRICE CHANGES IN LIEU OF QUANTITY

Lots of 1 gallon

# BUT… ARE GASOLINE PRICES STICKY?

- Bils and Klenow (JPE, 2004)
  - “Prices seldom change for some goods; for example, prices of newspapers, men’s haircuts, and taxi fares change less than 5 percent of months. But some prices change very frequently, with prices of gasoline, tomatoes, and airfares changing more than 70 percent of months.”
  - The monthly frequency of price changes ranges from 1.2 percent for coin-operated apparel laundry and dry cleaning to 79 percent for regular unleaded gasoline.

# REASON 4: STICKINESS IN WHOLESALE GASOLINE PRICE

| Firm | Brand | Number of observations | Frequency of price change | Frequency of price increase | Frequency of price decrease | Average increase | Average decrease |
|---|---|---|---|---|---|---|---|
| 1 | Amoco | 782 | 0.35 | 0.16 | 0.19 | 0.87 | 0.70 |
| 2 | ARCO | 782 | 0.46 | 0.21 | 0.25 | 0.85 | 0.70 |
| 3 | BP | 782 | 0.57 | 0.24 | 0.33 | 1.42 | 1.03 |
| 4 | Chevron | 641 | 0.37 | 0.29 | 0.28 | 0.95 | 0.81 |
| 5 | Exxon | 782 | 0.48 | 0.23 | 0.25 | 0.83 | 0.74 |
| 6 | Gulf | 743 | 0.41 | 0.20 | 0.21 | 0.87 | 0.70 |
| 7 | Mobil | 779 | 0.45 | 0.21 | 0.24 | 0.82 | 0.65 |
| 8 | Sunoco | 782 | 0.45 | 0.21 | 0.24 | 0.76 | 0.66 |
| 9 | Texaco | 681 | 0.40 | 0.19 | 0.21 | 0.90 | 0.66 |

- In contrast, the frequency of price changes for the NYMEX price of unleaded gasoline delivered at the New York Harbor was 0.95

# REASON 5: HOW TO MODEL DISCRETENESS OF PRICES AND TIME DEPENDENCE?

| Firm | Number of price changes | Increase following increase | Increase following a decrease | Decrease following a increase | Decrease following a decrease |
|---|---|---|---|---|---|
| 1 | 269 | 102 | 22 | 23 | 122 |
| 2 | 360 | 124 | 42 | 43 | 151 |
| 3 | 445 | 122 | 68 | 67 | 188 |
| 4 | 235 | 98 | 20 | 21 | 96 |
| 5 | 377 | 134 | 47 | 48 | 148 |
| 6 | 303 | 117 | 28 | 28 | 130 |
| 7 | 348 | 126 | 34 | 35 | 153 |
| 8 | 349 | 139 | 26 | 27 | 157 |
| 9 | 272 | 104 | 22 | 22 | 124 |

- Evidence of time dependence in data…but there is no evidence in Autoregressive Conditional Hazard Model (Davis and Hamilton, 2004)

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# WHY ARE GASOLINE PRICES STICKY? THE EXISTING LITERATURE

- Industrial Organization literature: focus on "rockets and feathers"
  - Question: is there a systematic tendency for downstream prices in the oil well-to-service station gasoline industry to respond to increases in upstream prices more rapidly than downstream prices respond to decreases in upstream prices?
  - Data and Methodology:
    - Error Correction Models with or without dynamics

# WHY ARE GASOLINE PRICES STICKY? THE EXISTING LITERATURE

- Davis and Hamilton (JMCB, 2004)
  - Dixit's menu cost model:

Firm chooses $t_1$, $t_2$,… to minimize

$$E_{t_0}\left\{\sum_{i=1}^{t_i}\left[\left(\int_{t_{i-1}}^{t_i} e^{-\rho t}k\left[p(t_{i-1})-p^*(t)\right]^2 dt+ge^{-\rho t_i}\right)\right]\right\}$$

  - then the probability of a price change is given by

$$h_{t+1}=h\left[p(t),p^*(t)\right]=1+\Phi\left(\frac{p(t)-p^*(t)-b}{\sigma}\right)-\Phi\left(\frac{p(t)-p^*(t)+b}{\sigma}\right)$$

Optimal decision rule is for the firm to change the price whenever

$$\left|p(t_{i-1})-p^*(t_i)\right|>b=\left(\frac{6g\sigma^2}{k}\right)^{1/4}$$

# DAVIS AND HAMILTON (Continued)

- Findings:
  - Dixit's model is "broadly consistent" with the data

    Yet…
    - Implied menu costs are too large
    - A logit model with the same explanatory variable (price-cost gap) outperforms a structural menu cost model.

  - No time dependence present in the pricing decision (Autoregressive Conditional Hazard outperformed by logit).

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# WHEN WILL THE NEXT PRICE CHANGE OCCUR? A POINT PROCESS

- A point process can be described either in terms of the sequence of arrival times $t_i$ or the sequence of durations $u_i$.

- Engle and Russell (1998) propose the Autoregressive Conditional Duration (ACD) to model the distribution of waiting times $u_i$ conditional on the history of arrival times.

- Many point processes have been used in other fields of statistics

# AUTOREGRESSIVE CONDITIONAL HAZARD

The ACH Model

$$h_{t+1} = \frac{1}{\psi_{N(t)} + \gamma' \mathbf{z_t}}$$

where

$$\psi_n = \alpha \sum_{i=1}^{n-1} \beta^{i-1} u_{n-i} + \beta^{n-1} \overline{u}$$

$h_{t+1}$ : probability of a price change

$\psi_{N(t)}$ : expected duration between $N^{th}$ and $(N-1)^{th}$ price changes

$u_{n-i}$ : observed duration

$\overline{u}$ : average duration

# ACH SPECIFICATION AND FLEXIBILITY LOSS

- Some of the flexibility of the ACD is lost by using a linear specification for the mean $\psi_i$

- Need to use a smoothing function

$$h_{t+1} = \frac{1}{\psi_{N(t)} + \gamma' \mathbf{z_t}}$$

- Time dependence is captured only through dependence in arrival times (durations)

# AUTOREGRESSIVE CONDITIONAL BINOMIAL MODEL (ACB)

Let the response probability be given by:

$$h_t \equiv prob(x_t = 1 \mid x_t, x_{t-1}, \ldots, x_1, \mathbf{z}_{t-1})$$

Then, the *ACB(q,r,s)* model is given by:

$$G^{-1}(h_t) = \omega + \sum_{j=1}^{q} \alpha(x_{t-j} - h_{t-j}) + \sum_{j=1}^{r} \beta G^{-1}(h_{t-j}) + \sum_{j=1}^{s} \delta x_{t-j} + \gamma \mathbf{z}_{t-1}$$

The dynamics of the response probability are given by:

$$h_t = G\left[\omega + \sum_{j=1}^{q} \alpha(x_{t-j} - h_{t-j}) + \sum_{j=1}^{r} \beta G^{-1}(h_{t-j}) + \sum_{j=1}^{s} \delta x_{t-j} + \gamma \mathbf{z}_{t-1}\right]$$

# THE ACB (Continued)

- Conditional on $x_t$, and $h_t$ the log-likelihood can be written recursively and maximized via MLE.
- Time dynamics are captured by:
  - History of price changes
  - History of probabilities of a price change.
- The ACB(0,0,0) is a standard logit model
- *Advantages*:
  - Testing time dynamics is straight-forward.
  - Testing implications of alternative models of price stickiness is easy.

# THE ACB (Continued)

- *Furthermore:* We can also investigate the role of durations by combining ACB with Autoregressive Conditional Duration (ACD) model.
  - Use Nelson's (1991) ACD form

$$\ln\left(\psi_{N(t)}\right) = \phi + \rho \frac{u_{N(t)-1}}{\psi_{N(t)-1}} + \xi \ln\left(\psi_{N(t)-1}\right)$$

  - Include $\ln\left(u_{N(t)}\right)$ as an explanatory variable in the ACB model
  - Estimate the ACB-ACD model jointly

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# TESTABLE IMPLICATIONS IN THE ACB FRAMEWORK: THE PROBABILITY OF A PRICE CHANGE

| | Current price gap $\lvert P_t - P_t^* \rvert$ | Auto-correlation $G^{-1}(h_{t-1})$ | History of price changes $x_{t-1}$ |
|---|---|---|---|
| Menu Costs | $\gamma \neq 0$ | $\beta = 0$ | $\delta = 0$ |
| Information processing | $\gamma \neq 0$ | $\beta < 0$ | $\delta < 0$ |
| "Inattentive producers" | | | |
| "Inattentive consumers" | | | |
| Strategic interactions | $\gamma \neq 0$ | $\beta > 0$ | $\delta > 0$ |
| Partial adjustment | | | |
| Fair pricing | | | |

$$h_t = G\left[\omega + \sum_{j=1}^{r} \beta G^{-1}\left(h_{t-j}\right) + \sum_{j=1}^{s} \delta x_{t-j} + \gamma \left|P_{t-1} - P_{t-1}^*\right|\right]$$

# ALTERNATIVE SPECIFICATIONS

- Basic specification
  - $|P_t\text{-}P^*_t|$: price-cost gap. Optimal price defined as input cost plus average mark-up.
- Additional Dynamics
  - $|P_{t-1}\text{-}P^*_{t-1}|$: one day lag of gap.
- Alternatives
  - $|P_{w1(t)}\text{-}P^*_{w1(t)}|$: amount of gap remaining after previous correction, dated by w1(t).
  - Asymmetry: $z_t=[\theta_t, \theta_t(P_t\text{-}P^*_t), (1\text{-} \theta_t), \text{-} (1\text{-} \theta_t)(P_t\text{-}P^*_t)]$ where $\theta_t = 1$ if $P_t\text{-}P^*_t \geq 0$
    - For "small gaps": $P^*(t)\text{-}P(t) \approx 0$ => is the constant different?
    - For "large gaps": $P^*(t)\text{-}P(t) \neq 0$ => is the slope different?
  - $u_{N(t)}$: duration between price changes

# TESTABLE IMPLICATIONS IN THE ACB FRAMEWORK: THE PROBABILITY OF A PRICE CHANGE

| | Current price gap $\lvert P_t - P_t^* \rvert$ | Auto-correlation $G^{-1}(h_{t-1})$ | History of price changes $x_{t-1}$ | Remaining price gap $\lvert P_{w1(t)} - P^*_{w1(t)} \rvert$ | Symmetry |
|---|---|---|---|---|---|
| Menu Costs | $\gamma \neq 0$ | $\beta = 0$ | $\delta = 0$ | No | Yes |
| Information processing | $\gamma \neq 0$ | $\beta < 0$ | $\delta < 0$ | No | |
| "Inattentive producers" | | | | | Yes |
| "Inattentive consumers" | | | | | No (in the "small") |
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# ESTIMATION RESULTS

| Firm | $\omega$ | $\beta$ | $\delta$ | $\|P_t - P_t^*\|$ | $P_{t-1} - P_{t-1}^*$ | log L | LR | RV |
|---|---|---|---|---|---|---|---|---|
| 1 | -1.601 | -0.505** | -0.184 | -0.0364 | 0.196** | -478.97 | 0.00070** | 1.82 |
| | (0.234) | (0.145) | (0.151) | (0.0386) | (0.0402) | | | .0344 |
| 2 | -0.110 | 0.828** | 0.149 | 0.107** | -0.102** | -529.43 | 0.0324* | 0.968 |
| | (0.0595) | (0.117) | (0.0802) | (0.0350) | (0.0331) | | | .1665 |
| 3 | -0.0898 | 0.368* | 0.320* | 0.296** | -0.247** | -512.83 | 0.0000** | 2.33 |
| | (0.0987) | (0.174) | (0.140) | (0.0551) | (0.0525) | | | .0099 |
| 4 | -0.638 | 0.467* | 0.508** | 0.106* | -0.0680 | -405.37 | 0.00530** | 2.26 |
| | (0.272) | (0.239) | (0.174) | (0.0433) | (0.0581) | | | .0119 |
| 5 | -0.0992 | 0.901** | 0.202** | 0.113** | -0.114** | -520.52 | 0.0000** | 1.38 |
| | (0.0513) | (0.0464) | (0.0900) | (0.0296) | (0.0292) | | | .0838 |
| 6 | -0.209 | 0.827** | 0.206 | 0.185** | -0.169** | -471.30 | 0.0183* | 3.45 |
| | (0.129) | (0.105) | (0.121) | (0.0333) | (0.0352) | | | .0003 |
| 7 | -0.0672 | 0.899** | 0.0686 | 0.121** | -0.117** | -521.19 | 0.1136 | 1.59 |
| | (0.0507) | (0.0608) | (0.0696) | (0.0276) | (0.0267) | | | .0559 |
| 8 | -0.868 | -0.570* | -0.00605 | 0.0223 | 0.126** | -524.31 | 0.0990 | 2.11 |
| | (0.253) | (0.256) | (0.210) | (0.0467) | (0.0419) | | | .0174 |
| 9 | -0.267 | 0.780** | 0.259* | 0.157** | -0.141** | -432.65 | 0.0186* | 2.09 |
| | (0.101) | (0.0798) | (0.115) | (0.0321) | (0.0330) | | | .0183 |

# ESTIMATION RESULTS

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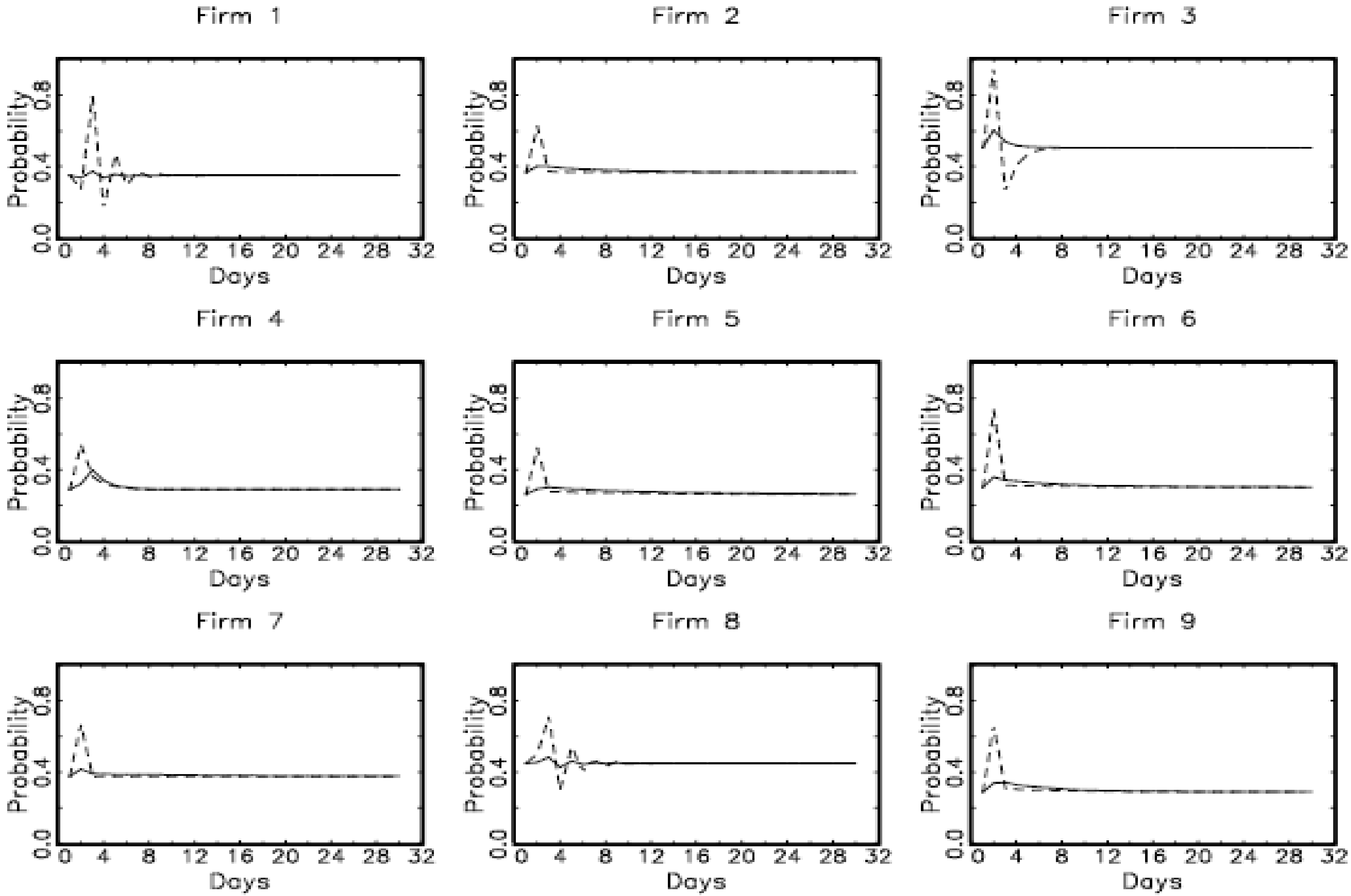
| | (0.101) | (0.0798) | (0.115) | (0.0321) | (0.0330) | | |

# DYNAMIC RESPONSE TO 10¢ and a 1.36 ¢ SHOCK




Dashed Line: 10¢ shock; Solid Line: 1.36¢ shock

# ASYMMETRY

| Firm | Pos const | Neg const | Pos gap | Neg gap | Lag pos gap | Lag neg gap |
|---|---|---|---|---|---|---|
| 1 | -1.7162** | -1.5107** | 0.0120 | -0.0649 | 0.2139** | 0.1831** |
| | (0.2787) | (0.3082) | (0.0910) | (0.0473) | (0.0777) | (0.0485) |
| 2 | -0.2568 | -0.0156 | 0.1528** | 0.1273** | -0.0877 | -0.1502** |
| | (0.1570) | (0.1026) | (0.0548) | (0.0464) | (0.0573) | (0.0485) |
| 3 | -0.1039 | -0.0628 | 0.3601** | 0.2574** | -0.2704** | -0.2490** |
| | (0.1278) | (0.1362) | (0.0855) | (0.0695) | (0.0884) | (0.0609) |
| 4 | -1.2550** | -0.6091** | 0.1222* | 0.0623 | 0.0421 | -0.0492 |
| | (0.3817) | (0.2257) | (0.0587) | (0.0570) | (0.0799) | (0.0623) |
| 5 | -0.1180 | -0.1460** | 0.1347** | 0.1420** | -0.1357** | -0.1419** |
| | (0.0626) | (0.0566) | (0.0441) | (0.0386) | (0.0448) | (0.0382) |
| 6 | -1.9085** | -0.8220** | 0.1689** | 0.0700 | 0.1567* | 0.0212 |
| | (0.3541) | (0.2607) | (0.0677) | (0.0476) | (0.0789) | (0.0535) |
| 7 | -0.0509 | -0.1281 | 0.0826 | 0.1587** | -0.0710 | -0.1507** |
| | (0.0654) | (0.0666) | (0.0474) | (0.0406) | (0.0521) | (0.0392) |
| 8 | -0.8584** | -0.6660 | 0.0283 | 0.0200 | 0.1526* | 0.0756 |
| | (0.2434) | (0.4345) | (0.0570) | (0.0502) | (0.0688) | (0.0900) |
| 9 | -0.3476** | -0.1961* | 0.1640** | 0.1506** | -0.1286* | -0.1445** |
| | (0.1280) | (0.0948) | (0.0495) | (0.0400) | (0.0504) | (0.0411) |

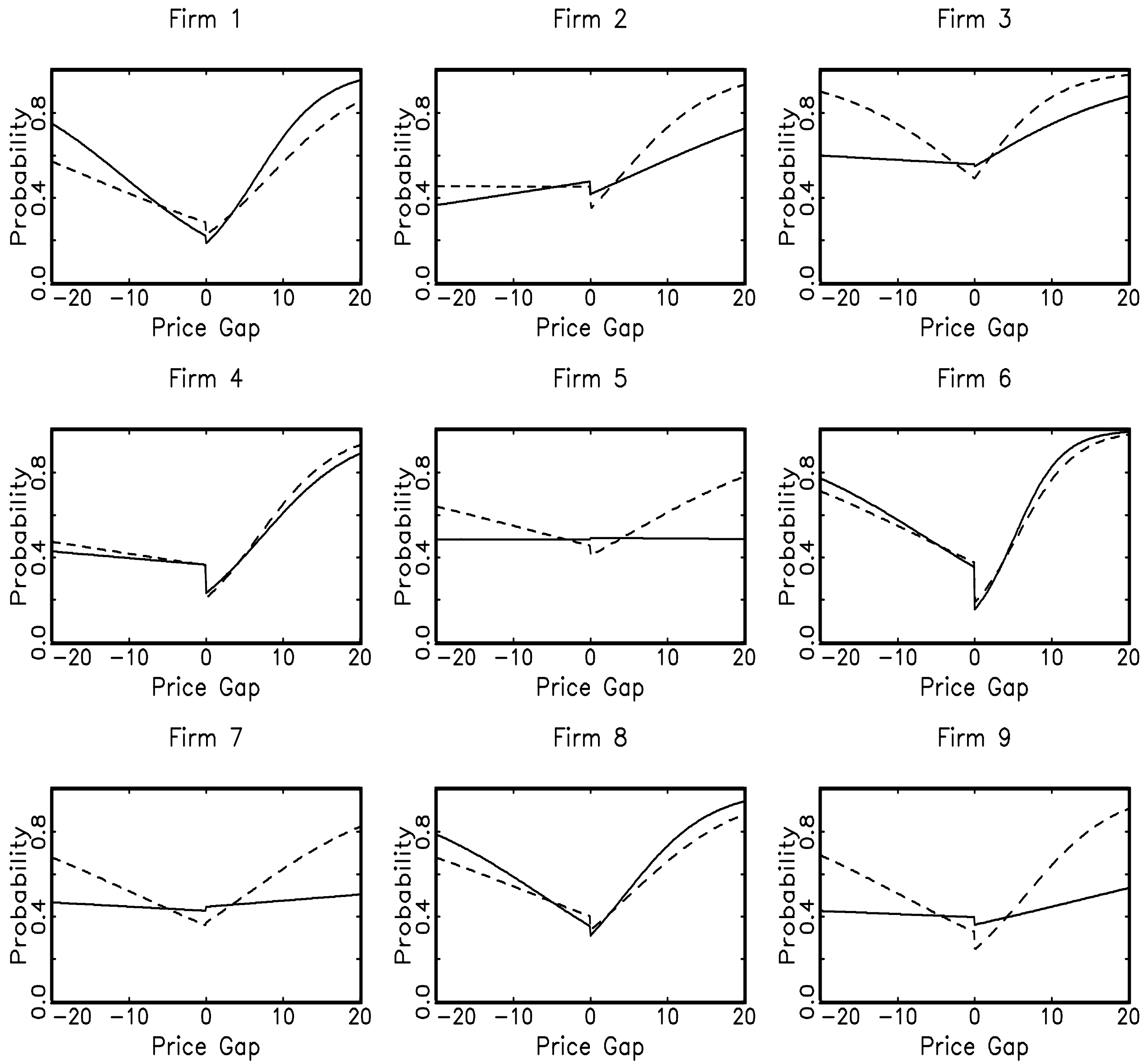
# ASYMMETRY

| Firm | Pos const | Neg const | Pos gap | Neg gap | Lag pos gap | Lag neg gap |
|---|---|---|---|---|---|---|
| 1 | -1.7162** | -1.5107** | 0.0120 | -0.0649 | 0.2139** | 0.1831** |
| | (0.2787) | (0.3082) | (0.0910) | (0.0473) | (0.0777) | (0.0485) |
| 2 | -0.2568 | -0.0156 | 0.1528** | 0.1273** | -0.0877 | -0.1502** |
| | (0.1570) | (0.1026) | (0.0548) | (0.0464) | (0.0573) | (0.0485) |
| 3 | -0.1039 | -0.0628 | 0.3601** | 0.2574** | -0.2704** | -0.2490** |
| | (0.1278) | (0.1362) | (0.0855) | (0.0695) | (0.0884) | (0.0609) |
| 4 | -1.2550** | -0.6091** | 0.1222* | 0.0623 | 0.0421 | -0.0492 |
| | (0.3817) | (0.2257) | (0.0587) | (0.0570) | (0.0799) | (0.0623) |
| 5 | -0.1180 | -0.1460** | 0.1347** | 0.1420** | -0.1357** | -0.1419** |
| | (0.0626) | (0.0566) | (0.0441) | (0.0386) | (0.0448) | (0.0382) |
| 6 | -1.9085** | -0.8220** | 0.1689** | 0.0700 | 0.1567* | 0.0212 |
| | (0.3541) | (0.2607) | (0.0677) | (0.0476) | (0.0789) | (0.0535) |
| 7 | -0.0509 | -0.1281 | 0.0826 | 0.1587** | -0.0710 | -0.1507** |
| | (0.0654) | (0.0666) | (0.0474) | (0.0406) | (0.0521) | (0.0392) |
| 8 | -0.8584** | -0.6660 | 0.0283 | 0.0200 | 0.1526* | 0.0756 |
| | (0.2434) | (0.4345) | (0.0570) | (0.0502) | (0.0688) | (0.0900) |
| 9 | -0.3476** | -0.1961* | 0.1640** | 0.1506** | -0.1286* | -0.1445** |
| | (0.1280) | (0.0948) | (0.0495) | (0.0400) | (0.0504) | (0.0411) |

# ASYMMETRY

| Firm | Pos const | Neg const | Pos gap | Neg gap | Lag pos gap | Lag neg gap |
|---|---|---|---|---|---|---|
| 1 | -1.7162** | -1.5107** | 0.0120 | -0.0649 | 0.2139** | 0.1831** |
| | (0.2787) | (0.3082) | (0.0910) | (0.0473) | (0.0777) | (0.0485) |
| 2 | -0.2568 | -0.0156 | 0.1528** | 0.1273** | -0.0877 | -0.1502** |
| | (0.1570) | (0.1026) | (0.0548) | (0.0464) | (0.0573) | (0.0485) |
| 3 | -0.1039 | -0.0628 | 0.3601** | 0.2574** | -0.2704** | -0.2490** |
| | (0.1278) | (0.1362) | (0.0855) | (0.0695) | (0.0884) | (0.0609) |
| 4 | -1.2550** | -0.6091** | 0.1222* | 0.0623 | 0.0421 | -0.0492 |
| | (0.3817) | (0.2257) | (0.0587) | (0.0570) | (0.0799) | (0.0623) |
| 5 | -0.1180 | -0.1460** | 0.1347** | 0.1420** | -0.1357** | -0.1419** |
| | (0.0626) | (0.0566) | (0.0441) | (0.0386) | (0.0448) | (0.0382) |
| 6 | -1.9085** | -0.8220** | 0.1689** | 0.0700 | 0.1567* | 0.0212 |
| | (0.3541) | (0.2607) | (0.0677) | (0.0476) | (0.0789) | (0.0535) |
| 7 | -0.0509 | -0.1281 | 0.0826 | 0.1587** | -0.0710 | -0.1507** |
| | (0.0654) | (0.0666) | (0.0474) | (0.0406) | (0.0521) | (0.0392) |
| 8 | -0.8584** | -0.6660 | 0.0283 | 0.0200 | 0.1526* | 0.0756 |
| | (0.2434) | (0.4345) | (0.0570) | (0.0502) | (0.0688) | (0.0900) |
| 9 | -0.3476** | -0.1961* | 0.1640** | 0.1506** | -0.1286* | -0.1445** |
| | (0.1280) | (0.0948) | (0.0495) | (0.0400) | (0.0504) | (0.0411) |

# ASYMMETRY


Firm 1
Firm 2
Firm 3
Firm 4
Firm 5
Firm 6
Firm 7
Firm 8
Firm 9
Probability
Price Gap
0.0
0.4
0.8
−20
−10
0
10
20

# THE ROLE OF DURATIONS

| Firm | $\ln\left(u_{N(t)}\right)$ | $\ln\left(u_{N(t)-1}\right)$ | $u_{N(t-1)-1}$ |
|---|---|---|---|
| 1 | $0.0080^{**}$ | 0.644 | 0.0513 |
| 2 | 0.7323 | 0.0557 | 1.000 |
| 3 | $0.0161^{*}$ | 0.1797 | 0.1573 |
| 4 | 0.2404 | 0.1923 | 0.9542 |
| 5 | 0.1948 | 0.1897 | $0.00130^{***}$ |
| 6 | 0.2744 | 0.1512 | 0.2184 |
| 7 | 0.4074 | 0.5271 | 0.8559 |
| 8 | 0.2806 | 0.8415 | 1.000 |
| 9 | 0.7675 | 0.4976 | 0.1505 |

# THE ROLE OF DURATIONS

| Firm | $\ln\left(u_{N(t)}\right)$ | $\ln\left(u_{N(t)-1}\right)$ | $u_{N(t-1)-1}$ |
|---|---|---|---|
| 1 | $0.0080^{**}$ | 0.644 | 0.0513 |
| 2 | 0.7323 | 0.0557 | 1.000 |
| 3 | $0.0161^{*}$ | 0.1797 | 0.1573 |
| 4 | 0.2404 | 0.1923 | 0.9542 |
| 5 | 0.1948 | 0.1897 | $0.00130^{***}$ |
| 6 | 0.2744 | 0.1512 | 0.2184 |
| 7 | 0.4074 | 0.5271 | 0.8559 |
| 8 | 0.2806 | 0.8415 | 1.000 |
| 9 | 0.7675 | 0.4976 | 0.1505 |

# SUMMARY OF ESTIMATION RESULTS

- Autocorrelation: $\beta > 0$ for 7 of 9 firms

- Dynamics: Cost shocks instantly passed through to retail stations.

- Asymmetry:
  - *"In the small"* for 5 out of 9 firms: More likely to raise price when gap is small and negative than lower price when gap is small and positive.

  - *"In the large"* for 6 out of 9 firms: More likely to lower price when gap is large and positive than raise price when gap is large and negative.

# TESTABLE IMPLICATIONS IN THE ACB FRAMEWORK: THE PROBABILITY OF A PRICE CHANGE

| | Current price gap $\lvert P_t - P_t^* \rvert$ | Auto-correlation $G^{-1}(h_{t-1})$ | History of price changes $x_{t-1}$ | Remaining price gap $\lvert P_{w1(t)} - P^*_{w1(t)} \rvert$ | Symmetry |
|---|---|---|---|---|---|
| Menu Costs | $\gamma \neq 0$ | $\beta = 0$ | $\delta = 0$ | No | Yes |
| Information processing | $\gamma \neq 0$ | $\beta < 0$ | $\delta < 0$ | No | |
| "Inattentive producers" | | | | | Yes |
| "Inattentive consumers" | | | | | No (in the "small") |
| Strategic interactions | $\gamma \neq 0$ | $\beta > 0$ | $\delta > 0$ | | |
| Partial adjustment | | | | Yes | |
| Fair pricing | | | | No | No (in the "large") |

# CONCLUSION: WHY ARE PRICES STICKY?

- Results are consistent with "fair pricing".
  - $\beta > 0$: since retailers feel entitled to their "reference transaction price", wholesalers keep probability of price change consistent over time.
  - Cost shocks instantly passed to retailers, since they threaten wholesaler's "reference profit".
  - Asymmetry "in the large", wholesalers are adverse to large upswings in price.
    - Kahneman et al (1986): Shortages will be rationed, instead of a price increase to avoid "unfair windfall".
    - Henly, Potter, and Town (1996): Since wholesalers are tied to retailers via long term contracts, wholesalers use non-price methods of rationing in lieu of large price increases.

# CONCLUSION: WHY ARE PRICES STICKY?

- Asymmetry "in the small" consistent with rational inattention by consumers (retailers).
  - Summary statistics: average magnitude of price increase < $0.01.
  - But, retailers must change price in increments of $0.01 or greater.
  - Thus, wholesalers have incentive to make small price increases, because they know retailers cannot follow suit.
  - Perhaps related to menu costs… but in conjunction with strategic interactions.