Market structure and monetary non-neutrality

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Introduction

Monetary economics

- How do changes in nominal spending affect output vs. inflation?
- Nominal rigidity + Firms are non-strategic

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Motivation

- Markets dominated by a few large firms Fig. - Distributions of concentration

  e.g. Mayonnaise, Ohio, 2005:Q1 - Hellman's 45%, Kraft 33% (IRI data)

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Quantitative question

- How does market structure affect transmission of monetary shocks?

Framework

Quantitative model

- Firm heterogeneity - Idiosyncratic productivity shocks (z)
- Exog. changes in nominal spending - Aggregate money shocks (M)
- Nominal rigidity - Menu cost of changing prices (ξ)
- New - Two strategic firms in each sector. Dynamic oligopoly. Literature

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How does market structure affect transmission of monetary shocks?

- Compare: Oligopoly vs. Monopolistic competition
- Calibrate to match same data on good-level price dynamics
  - Frequency of adjustment, Size of adjustment, Average markup

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Main finding

- **2.5 times larger output fluctuations under duopoly**

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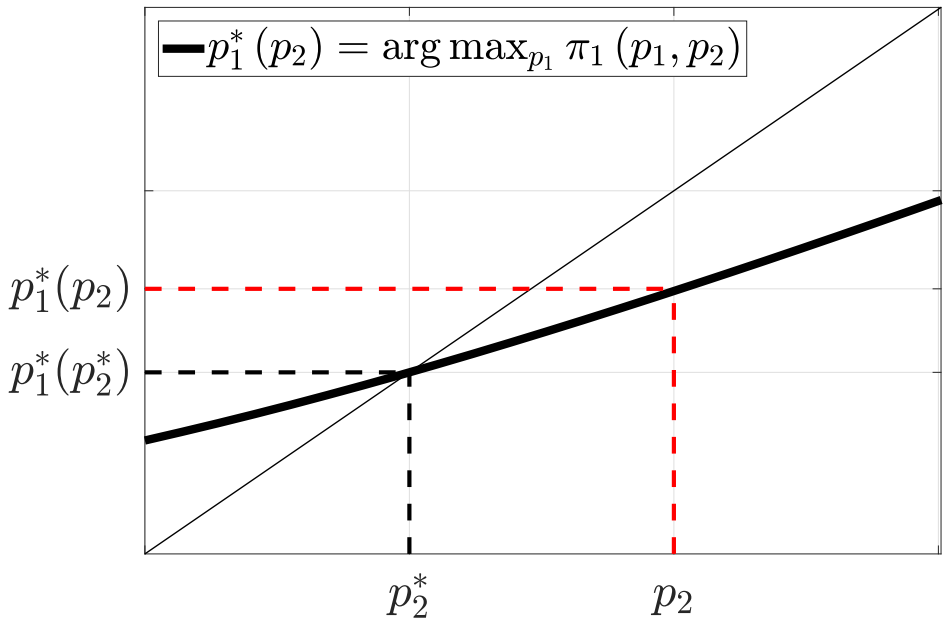
Main finding

- **2.5 times larger output fluctuations under duopoly**
  (75% flatter Phillips curve. Want: 95% flatter)

Complementarity

Under oligopoly, prices are static complements $(\pi_{12} > 0)$



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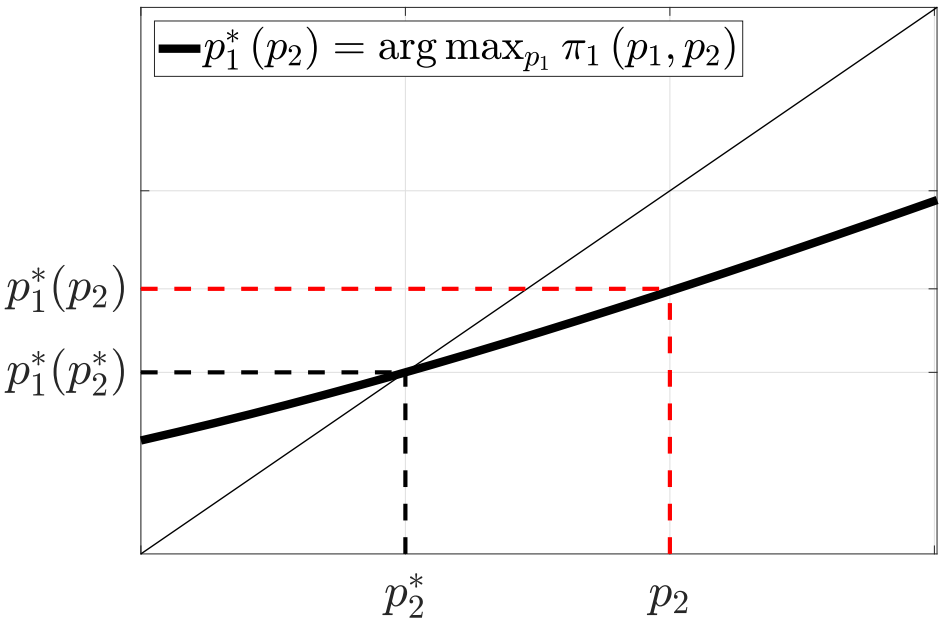

+ Menu costs $\rightarrow$ Costly to cut prices

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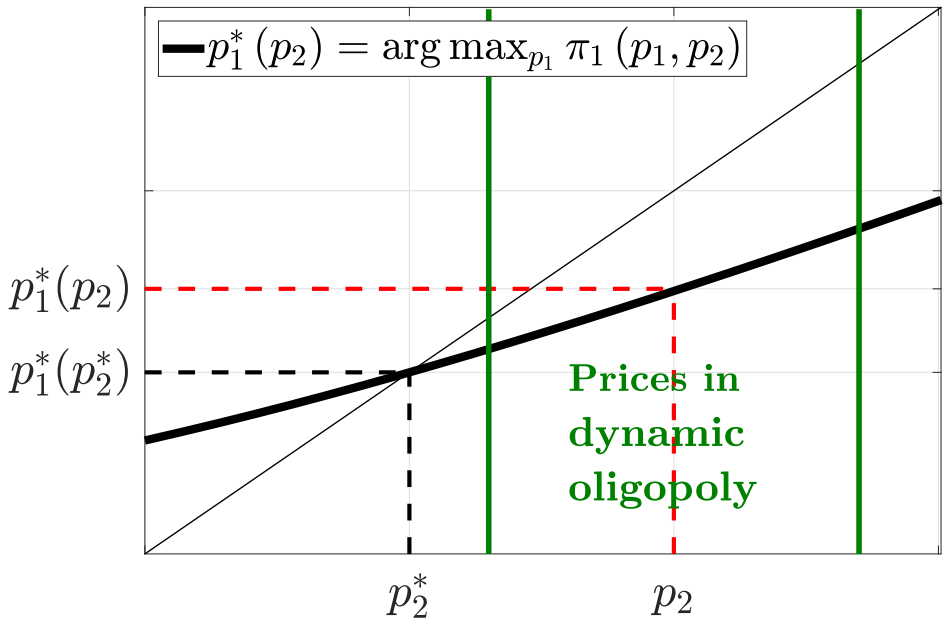

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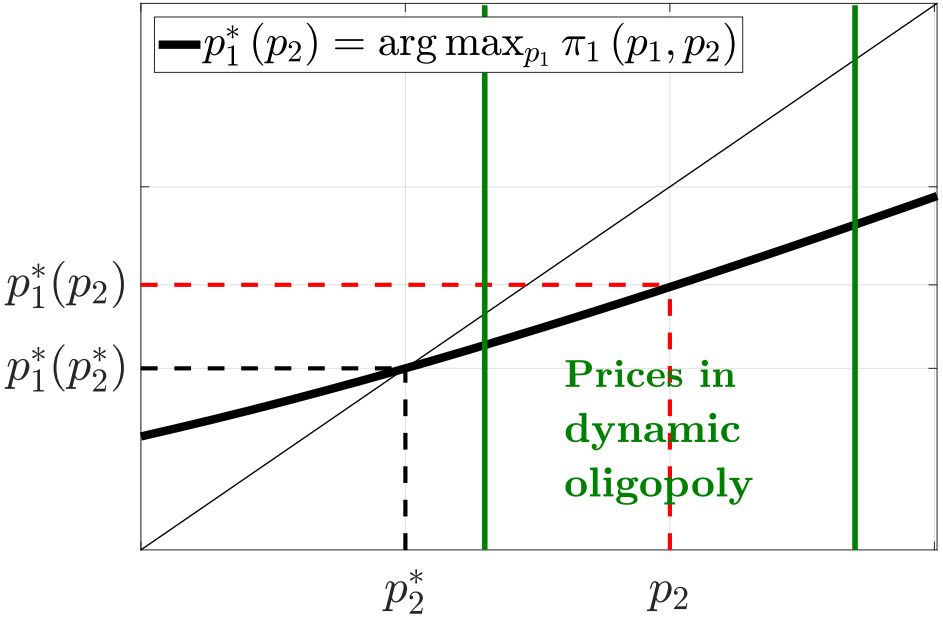

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= Prices are dynamic complements (Maskin Tirole '88, Lapham '94, Jun Vives '04)

Complementarity - Monetary non-neutrality

Take a sector with initially dispersed markups: $\mu = \frac{p}{M}$

$$\mu^* < \mu_L < \mathbb{E}[\mu] < \mu_H$$

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- High probability of large price increase $\uparrow \mu_L$
- Increase price to $\mu_L^* \in (\mathbb{E}[\mu], \mu_H)$

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Increase in money supply

1. Lower value of $\downarrow \mu_H$
2. Lowers real price of $\downarrow \mu_H$

$\rightarrow$ Both lower the probability and size of $\uparrow \mu_L$

Outline

1. Model
2. Policy functions
3. Calibration
4. Decompose inflation
5. Four additional results
   - (i) Large first order output losses due to nominal rigidity
   - (ii) ‘Optimal’—from firms’ perspective—level of nominal rigidity
   - (iii) Avoids issues discovered by Klenow-Willis, Burstein-Hellwig
   - (iv) Empirical relationship b/w concentration and price flexibility

Household

Flow utility

$$U(C,N) = \log C - N$$

$$C = \left[\int_0^1 C_j^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \quad , \quad \theta > 1$$

$$C_j = \left[c_{1j}^{\frac{\eta-1}{\eta}} + c_{2j}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad , \quad \eta > \theta$$

Total nominal expenditure

$$PC = \int_0^1 \left[p_{1j}c_{1j} + p_{2j}c_{2j}\right] dj \quad \leq M$$

▸ Details - Recursive household problem with dynamic budget constraint → Discount factor

Household - Solution

Labor supply

$$\frac{W}{P} = -\frac{U_N(C,N)}{U_C(C,N)} \quad \leftrightarrow \quad W = PC = M$$

Demand

$$d_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{-\eta} \left(\frac{P_j}{P}\right)^{-\theta} C$$

where

$$P_j = \left[{p_{1j}}^{1-\eta} + {p_{2j}}^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

$$P = \left[\int_0^1 {P_j}^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$$

Household - Solution

Markups

$$\underbrace{\mu_{ij} = \frac{p_{ij}}{W/z_{ij}}}_{\text{Firm}} \quad , \quad \underbrace{\mu_j = \frac{P_j}{W}}_{\text{Sector}} \quad , \quad \underbrace{\mu = \frac{P}{W} = \frac{1}{C}}_{\text{Aggregate}}$$

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Profits

$$\frac{\pi_{ij}}{W} = \underbrace{\left(\frac{\mu_{ij}}{\mu_j}\right)^{-\eta}\left(\frac{\mu_j}{\mu}\right)^{-\theta}\frac{1}{\mu}}_{\text{Demand } d_{ij}}\underbrace{\left(\mu_{ij}-1\right)}_{\text{Per-unit profit}}$$

where

$$\mu_j = \left[{\mu_{1j}}^{1-\eta} + {\mu_{2j}}^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

$$\mu = \left[\int_0^1 {\mu_j}^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$$

Technical details

Static best response

Household - Solution

Markups

$$\underbrace{\mu_{ij} = \frac{p_{ij}}{W / z_{ij}}}_{\text{Choice today}} \quad , \quad \underbrace{\bar{\mu}'_{ij} = \frac{p_{ij}}{W' / z'_{ij}}}_{\text{State tomorrow}}$$

Profits

$$\frac{\pi_{ij}}{W} = \underbrace{\left(\frac{\mu_{ij}}{\mu_j}\right)^{-\eta} \left(\frac{\mu_j}{\mu}\right)^{-\theta} \frac{1}{\mu}}_{\text{Demand } d_{ij}} \underbrace{\left(\mu_{ij} - 1\right)}_{\text{Per-unit profit}}$$

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Static best response

Firm problem

Markov states

- Sector — Markups $\bar{\mu}_i$, $\bar{\mu}_{-i}$ — $x = (\bar{\mu}_i, \bar{\mu}_{-i})$
- Aggregate — Distribution $\lambda(x)$, money growth g — $X = (\lambda, g)$

Firm problem

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Equilibrium functions

- Aggregate markup $\mu(X)$

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Timing and Information (Doraszelski Satterthwaite, 2007)

$$\underbrace{(x, X) \text{ determined}}_{\text{Public}} \rightarrow \underbrace{\text{Draw menu cost } \xi_i \sim U\left[0, \bar{\xi}\right]}_{iid + \text{Private}} \rightarrow \underbrace{\text{Pricing decisions}}_{\text{Simultaneous}}$$

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Competitor's policies

- Markup conditional on adjustment $\mu^*_{-i}(x, X)$ $\in \mathbb{R}_+$
- Markup adjustment $\gamma_{-i}(x, X, \xi_{-i})$ $\in \{0, 1\}$

Firm problem

Value

$$V_i(x, X, \xi_i) = \max_{\gamma_i \in \{0,1\}} \gamma_i \left[V_i^{adj}(x, X) - \xi_i \right] + (1 - \gamma_i) V_i^{stay}(x, X)$$

Firm problem

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$$V_i\left(x, X, \xi_i\right) \quad = \quad \max_{\gamma_i \in \{0,1\}} \; \gamma_i \left[V_i^{adj}\left(x, X\right) - \xi_i\right] + (1-\gamma_i) V_i^{stay}\left(x, X\right)$$

Value of adjusting price

$$V_i^{adj}\left(x, X\right) \quad = \quad \max_{\mu_i^* \in \mathbb{R}_+} \int_0^{\bar{\xi}} \left[\pi\Big(\mu_i^*, \mu_{-i}(x, X, \xi_{-i}), \mu(X)\Big) + \beta \mathbb{E}\Big[V_i\left(x', X', \xi_i'\right)\Big]\right] dF\left(\xi_{-i}\right)$$

$$\mu_{-i}(x, X, \xi_{-i}) \quad = \quad \underbrace{\gamma_{-i}(x, X, \xi_{-i}) \mu_{-i}^*(x, X)}_{\text{Competitor adjusts}} + \underbrace{\Big(1 - \gamma_{-i}(x, X, \xi_{-i})\Big) \bar{\mu}_{-i}}_{\text{Competitor stays}}$$

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Solution

- Probability of price adjustment $\gamma_i(x, X) = \int_0^{\bar{\xi}} \gamma_i(x, X, \xi_i) dF(\xi_i)$
- Markup conditional on adjustment $\mu_i^*(x, X)$

Recursive equilibrium

- Symmetric demand, value, adjustment prob. and markup functions

$$d(x, X),\ V(x, X),\ \gamma(x, X),\ \mu^*(x, X)$$

- Transition density for the distribution of sectors $\lambda' \sim H(\lambda|X)$
- Aggregate markup function $\mu(X)$

such that

1. Firm policies and values are Markov-Perfect at the sectoral level
2. $W = PC = M$ + Markup definitions $\leftrightarrow \mu(X) = \frac{1}{C(X)}$
3. Demand functions are consistent with household optimization
4. Transition function for λ is consistent with policies and processes
5. Aggregate mark-up is consistent with (i) mark-up policies, (ii) λ

Details - Computation

Monopolistically competitive market structure

- Continuum of sectors $j \in [0, 1]$
- Continuum of firms within each sector $i \in [0, 1]$

$$\mu_j = \left[\int_0^1 \mu_{ij}^{1-\eta} di \right]^{\frac{1}{1-\eta}}$$

- Competitive equilibrium
- Otherwise exactly the same environment
  - Household problem
  - Stochastic environment: ξ_{ij}, z_{ij}, g
  - Set of parameters: $\bar{\xi}$, σ_z, η, θ

Simulation

Results

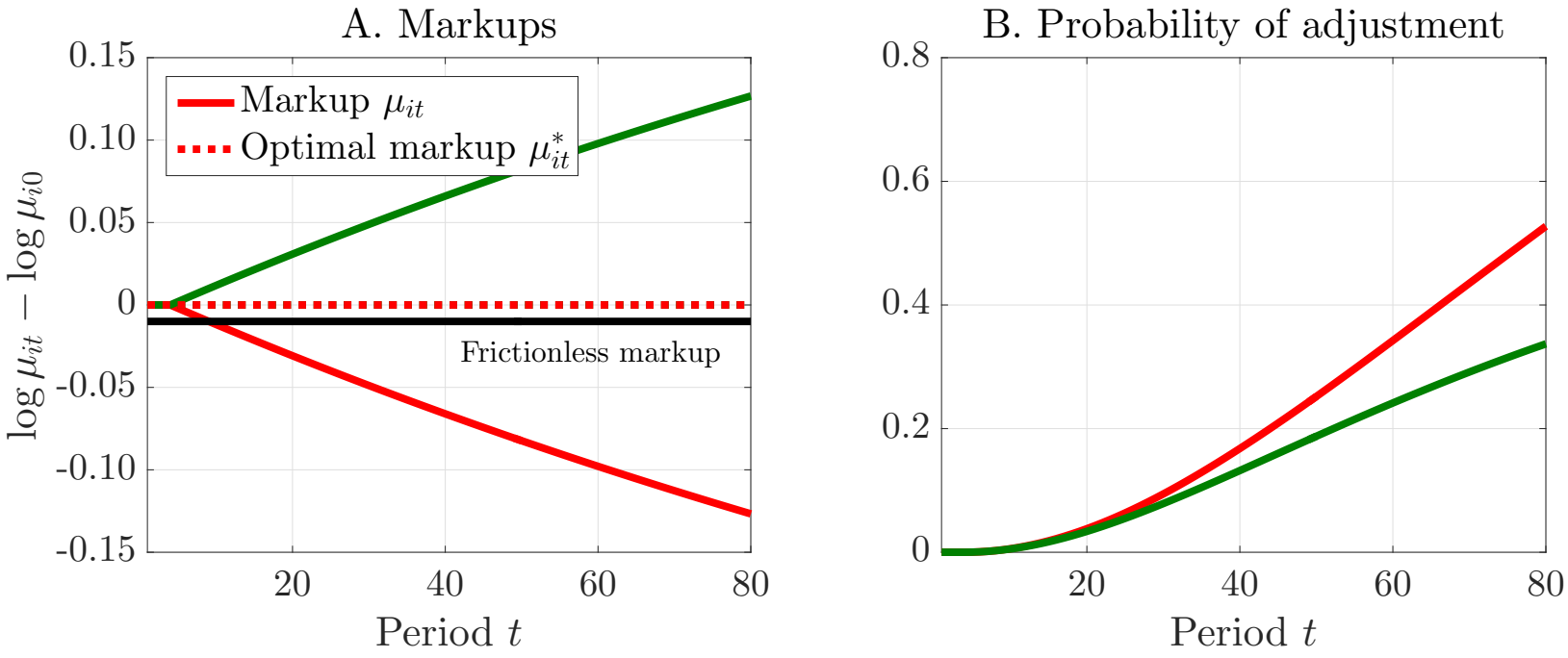
- Micro MPE policies attain high markups in equilibrium
- Macro Weaker intensive and extensive response to $\uparrow M$

Setup

- No aggregate shocks or inflation $g_t = 0$
- Fix paths for menu costs $\xi_{it} = \bar{\xi}$
- Fix paths for shocks $\bar{\mu}_{i0} = \mathbb{E}[\mu_{it}]$, $\{z_{it}\} \rightarrow \{\bar{\mu}_{it}\}$
- Plot equilibrium policies
  - (A.) Optimal markup $\mu^*_{it} = \mu^* (\bar{\mu}_{it}, \bar{\mu}_{-it})$
  - (B.) Probability of adjustment $\gamma_{it} = \gamma (\bar{\mu}_{it}, \bar{\mu}_{-it})$

Note: Using estimated parameters (next)

Monopolistic competition



Intensive margin

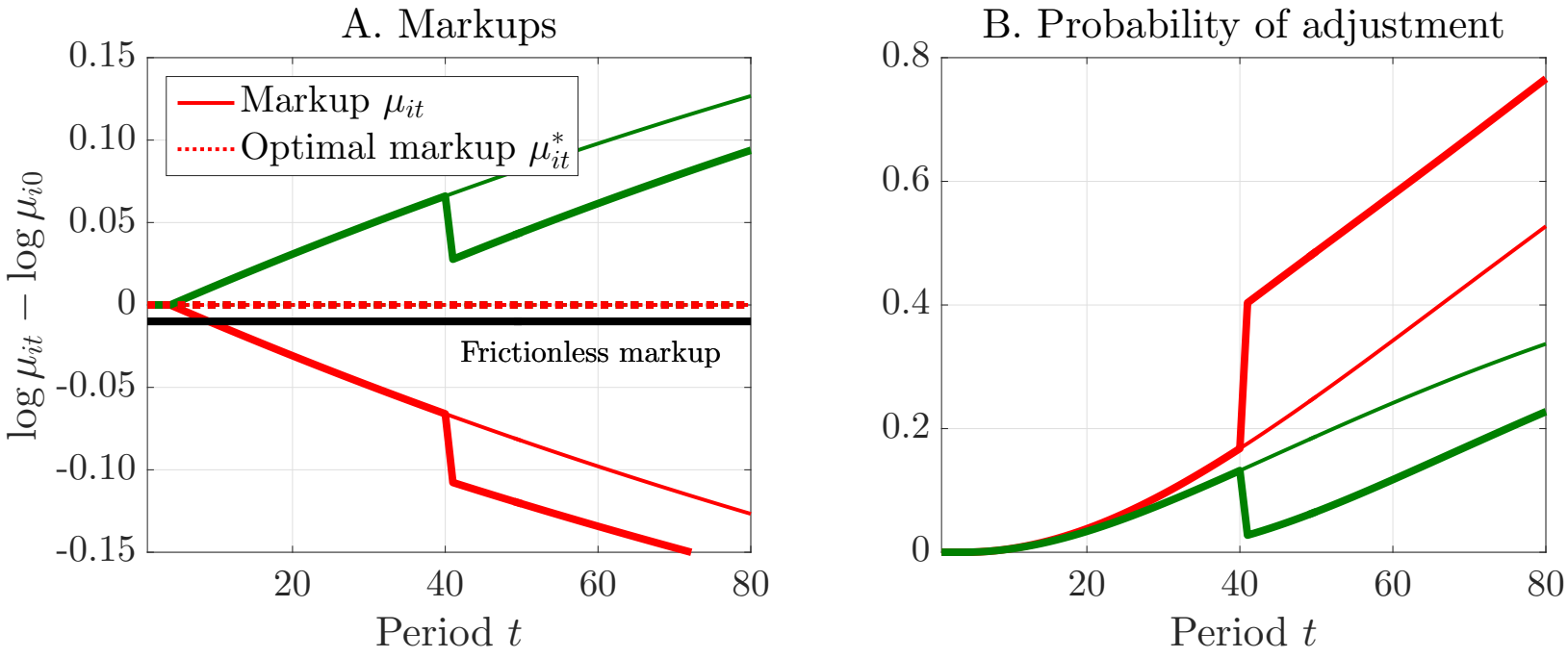
- Same optimal markup $\mu^*_L = \mu^*_H$

Extensive margin

- Precautionary motive $\gamma_L > \gamma_H$

Profit functions

Monopolistic competition - ↑ M



Intensive margin

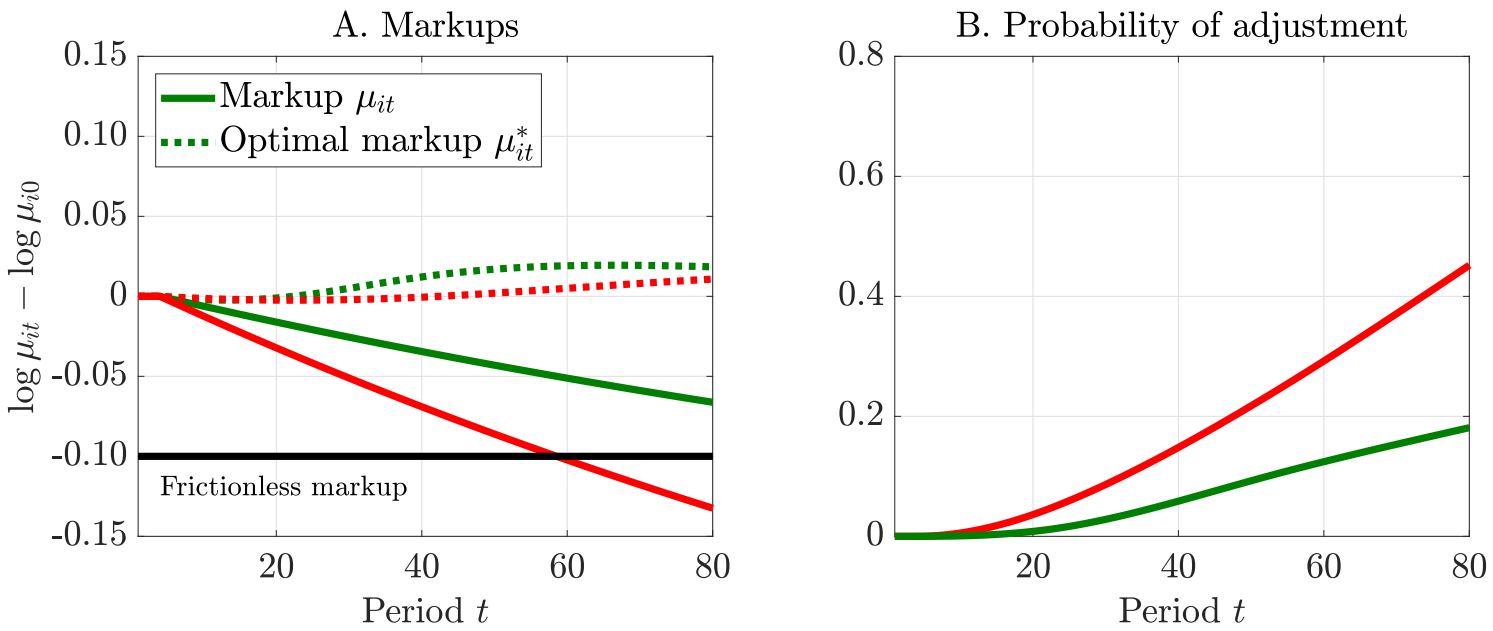
- Optimal price adjustment increases by ΔM

Extensive margin

- Jump in γ_L shifts distribution of price changes to price increases

▸ Profit functions

Duopoly - Case I



Intensive margin

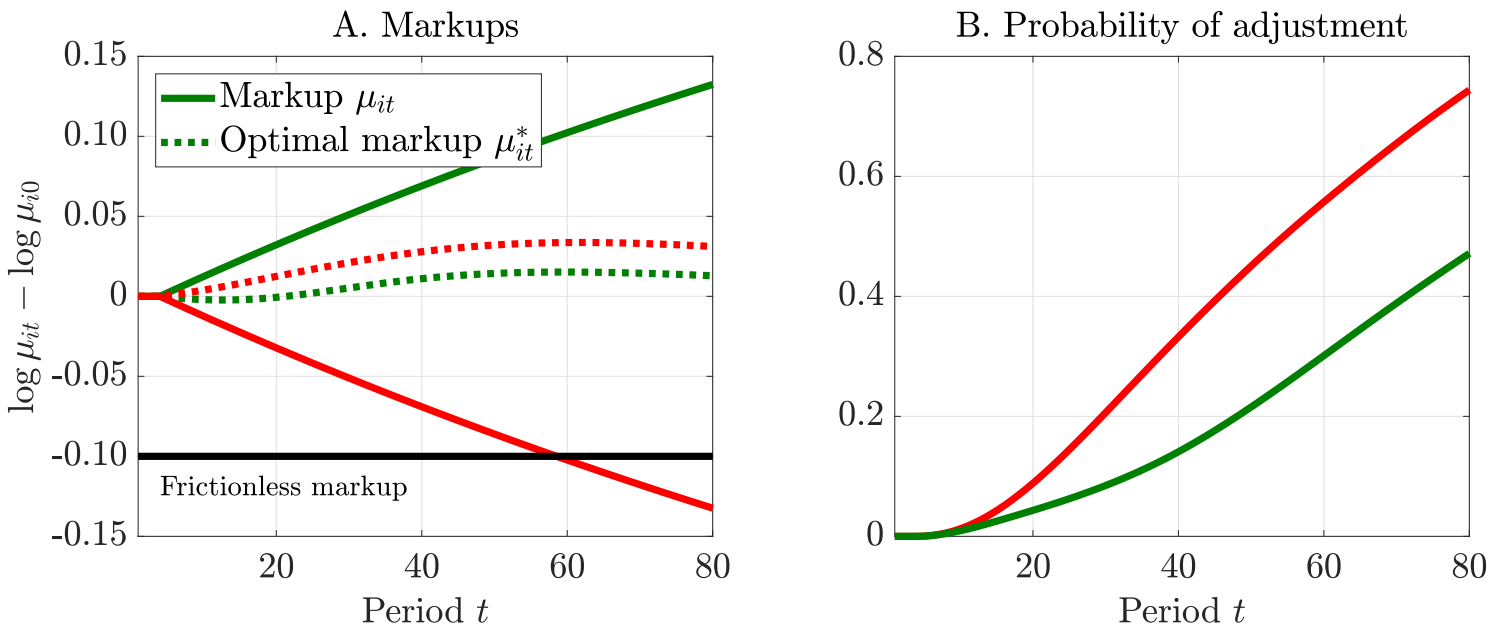
- Static optimum $\rightarrow$ Cut prices
- Dynamic optimum $\rightarrow$ Raise prices

Extensive margin

- Adjustment incurs temporary losses, but future gains

Profit functions Profit functions - 3 panel

Duopoly - Case II



Intensive margin

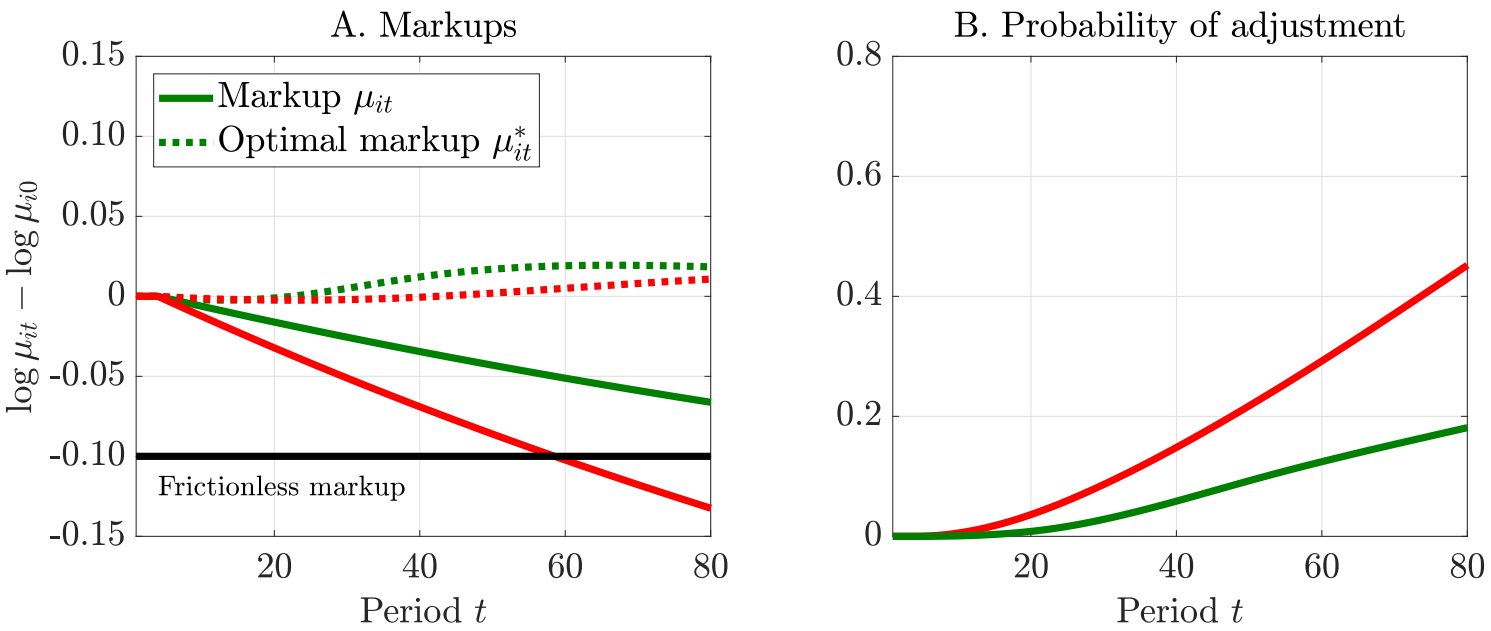
- Higher μ_H requires higher μ_L
- Policies flatten out due to small $\bar{\xi}$

Extensive margin

- Higher μ_H requires higher γ_L

Profit functions

Duopoly - Case I - ↑ M



Intensive margin

-

-

Extensive margin

-

Profit functions

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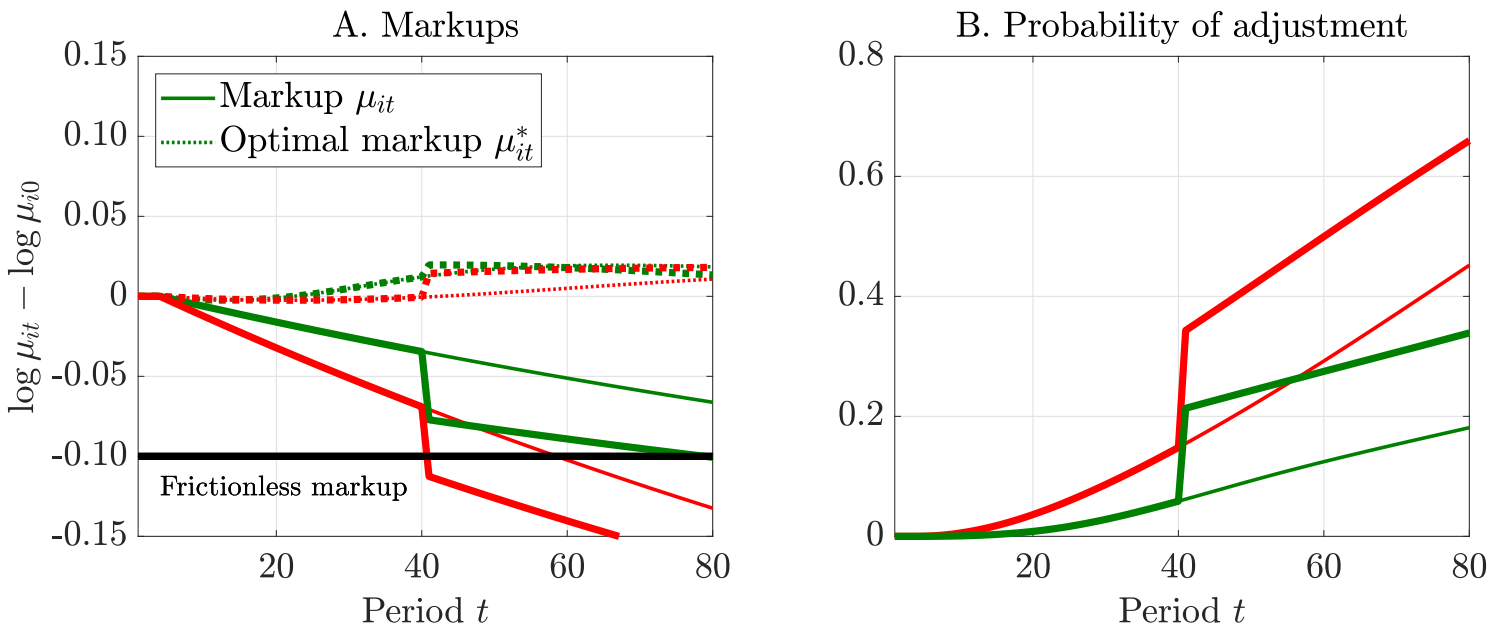


Intensive margin

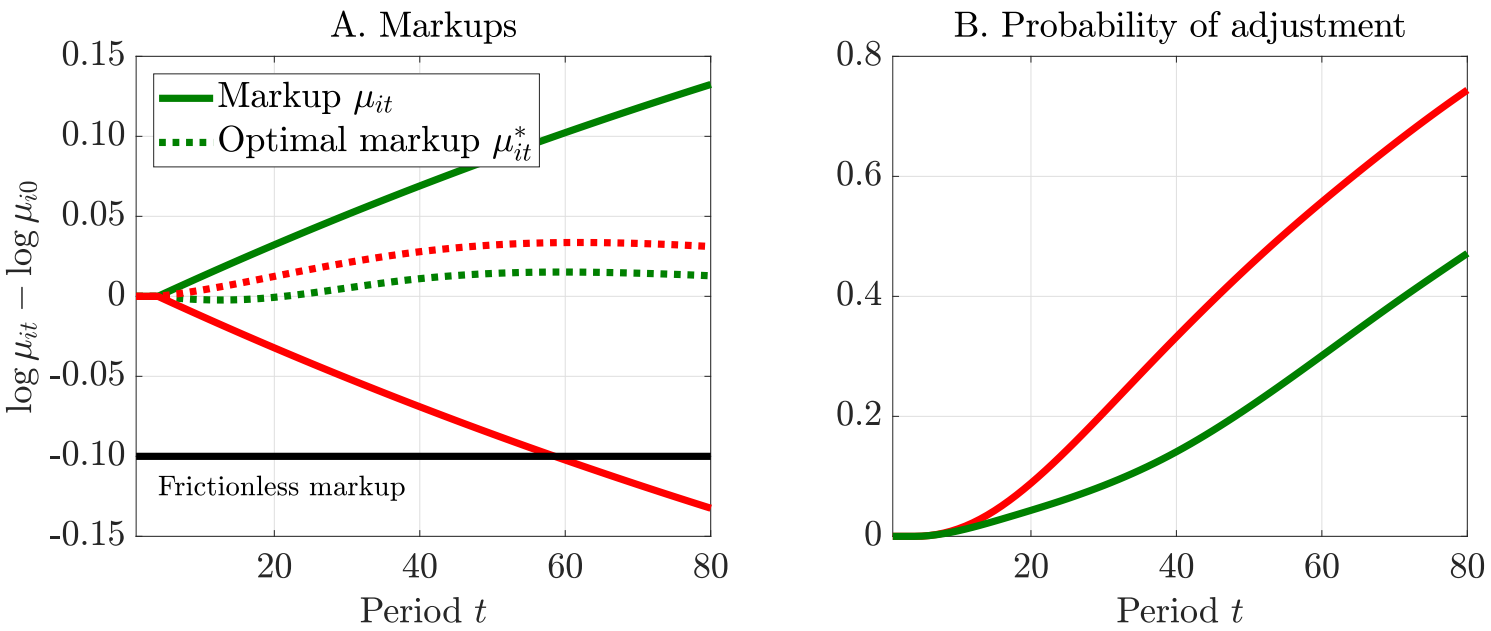
- Over-adjust to reset markup

Extensive margin

- Large increases in value / probability of adjustment

▸ Profit functions

Duopoly - Case II - ↑ M



Intensive margin

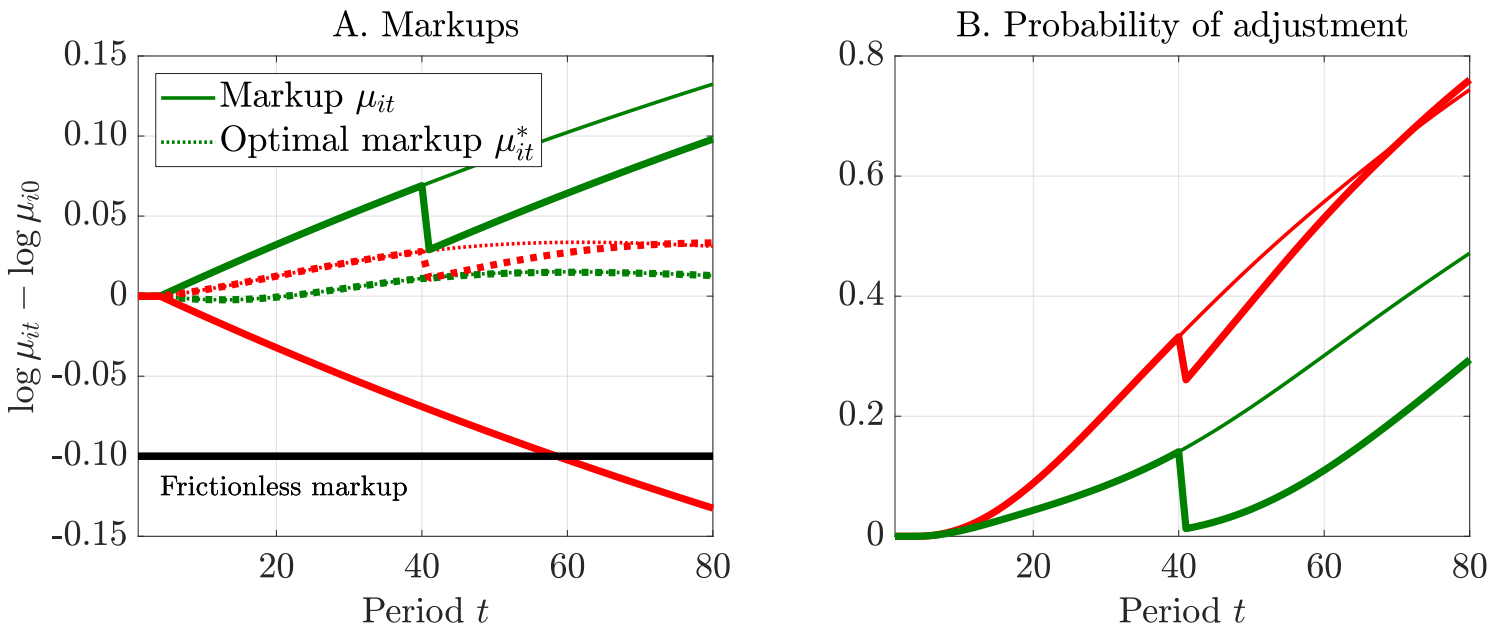
-

Extensive margin

-

Profit functions

Duopoly - Case II - $\uparrow M$



Intensive margin

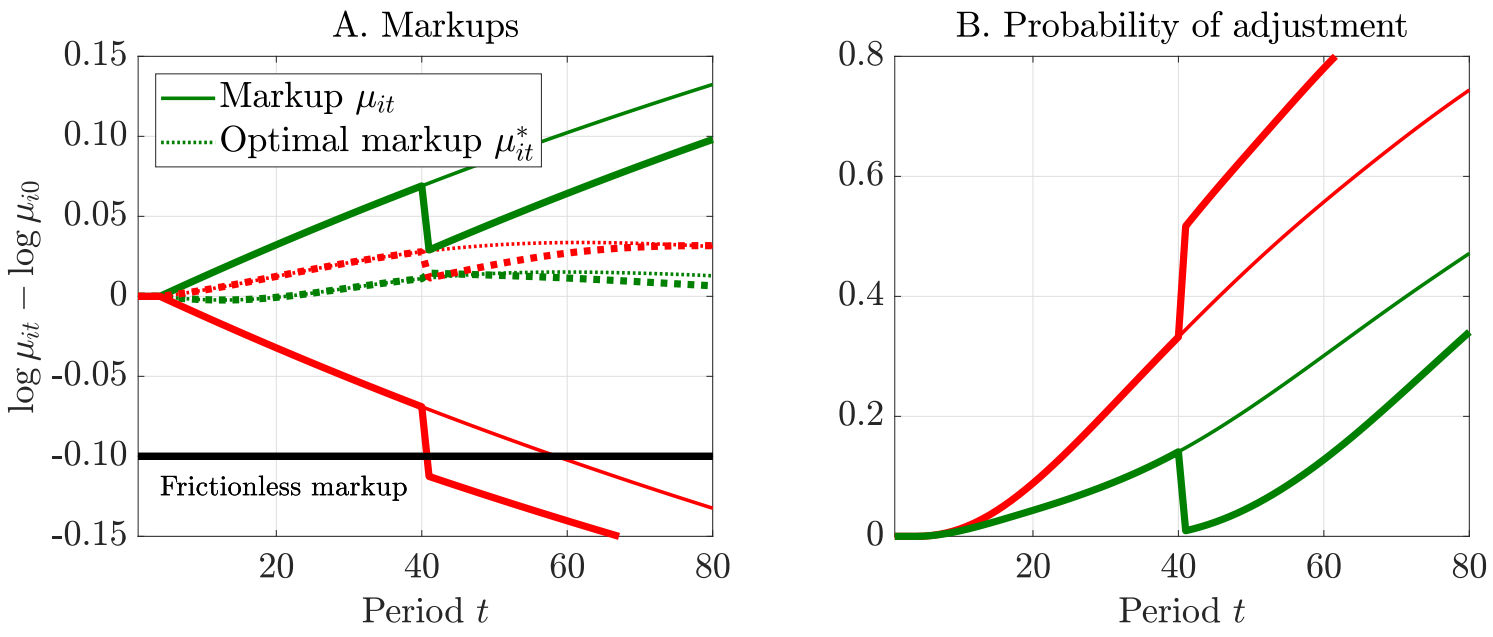
- Optimal adjustment $\Delta p_L = \mu^*_L / \mu_L$ increases by less than ΔM

Extensive margin

- Dampened increase in γ_L

▸ Profit functions

Duopoly - Case II - $\uparrow M$



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Profit functions

Calibration - What contributes to larger output effects?

In the MPE, when does a firm respond to another's price?

Static complementarity

- More substitutable within sectors η, less across sectors θ

Dynamic complementarity

- Menu costs are large $\uparrow \bar{\xi}$
- Idiosyncratic shocks are small $\downarrow \sigma_z$
- Firms choose when to change price
- Lower $\bar{g}$? Lower σ_g?

$$\log g_{t+1} = (1 - \rho_g) \log \bar{g} + \rho_g \log g_t + \sigma_g \varepsilon_{t+1}$$

Quantification - Calibration strategy (monthly)

External

- Money growth parameters $\rho_g = 0.6$, $\sigma_g = 0.002$, $\bar{g} = 1.025^{1/12}$
- Cross-sector elasticity of substitution $\theta = 1.5$

Internal

- Menu cost $\bar{\xi}$, Size of shocks σ_z
- Within-sector elasticity of substitution η

Moments

- Average absolute size of regular price changes (IRI) - 10%
- Average frequency of regular price changes (IRI) - 13%
- Average markup $\mathbb{E}\left[\mu_{it}\right] = 1.30$

Robustness to η in MC model | Data details | Identification argument for σ_z, $\bar{\xi}$, η | Firm vs Sector shocks

Quantification - Parameters and results

		Duopoly	MC
A. Parameter			
Cross-sector demand elasticity	θ	1.5	1.5
Within-sector demand elasticity	η	10.5	4.5
Size of menu cost	$\bar{\xi}$	0.17	0.21
Size of idiosyncratic shocks (%)	σ_z	3.80	4.00
B. Moments matched			
Average markup	$\mathbb{E}\left[\mu_{it}\right]$	1.30	1.30
Frequency of price change		0.13	0.13
Ave. absolute size of price change		0.10	0.10
C. Results			
Std. deviation consumption	$std\left[\log C_t\right] \times 100$	0.31	0.13
Average minus Frictionless markup	$\mathbb{E}\left[\mu_{it}\right] - \mu^*$	0.10	0.02

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3. Smaller shocks deliver observed size of price change

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Ave. absolute size of price change		0.10	0.10
C. Results			
Std. deviation consumption	$std[\log C_t] \times 100$	0.31	0.13
Average minus Frictionless markup	$\mathbb{E}\left[\mu_{it}\right] - \mu^*$	0.10	0.02

1. 2.5 times larger output fluctuations (Data: US 1969-2016, $std[c_t] \times 100 = 1.01$)
2. 10 ppt larger markups than frictionless economy $\rightarrow$ 10% Lower output
3. Smaller shocks deliver observed size of price change
4. 25 percent smaller menu costs deliver same flex. (0.07 vs. 0.10% rev)

▸ Figure - (i) ξ comp. stats., (ii) IRF of C_t ▸ Table - Alternative calibrations ▸ Figure - Comp. stats η

Quantification - Parameters and results

		Duopoly	MC	MC′
A. Parameter				
Cross-sector demand elasticity	θ	1.5	1.5	1.5
Within-sector demand elasticity	η	**10.5**	4.5	↑ **10.5**
Size of menu cost	$\bar{\xi}$	**0.17**	0.21	↓ **0.17**
Size of idiosyncratic shocks (%)	σ_z	**3.80**	4.00	↓ **3.80**
B. Moments matched				
Average markup	$\mathbb{E}\left[\mu_{it}\right]$	1.30	1.30	↓ 1.12
Frequency of price change		0.13	0.13	↑ 0.19
Ave. absolute size of price change		0.10	0.10	↓ 0.05
C. Results				
Std. deviation consumption	$std[\log C_t] \times 100$	0.31	0.13	⇓ 0.06
Average minus Frictionless markup	$\mathbb{E}\left[\mu_{it}\right] - \mu^*$	0.10	0.02	↓ 0.01

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Quantification - Accounting for inflation

$$\pi_t \approx \sum_{i=1}^{N} \omega_i \left[\underbrace{\bar{\gamma}_{it}\left(x_{it} - \bar{x}_{it}\right)}_{\text{1. Intensive}} + \underbrace{\bar{x}_{it}\left(\gamma_{it} - \bar{\gamma}_{it}\right)}_{\text{2. Extensive}} + \underbrace{\left(\gamma_{it} - \bar{\gamma}_{it}\right)\left(x_{it} - \bar{x}_{it}\right)}_{\text{3. Covariance}} \right]$$

where $x_{it} = \log p^*_{it} - \log p_{it-1}$, is the desired price change

		Intensive %	Extensive %
Fraction of the difference: $\pi_t^{Mon} - \pi_t^{Duo}$		36	45
Fraction of each margin accounted for by different sectors (μ_{1j}, μ_{2j})			
Case I	Low-Low	-90	-73
Case II	Low-High / High-Low	181	165
Case III	High-High	9	8

Results

1. Extensive and intensive margin components dampened $\approx$ equally
2. Case I sectors are 'special cases'. Many fewer than Case II.

Relation to some of the literature

The duopoly mechanism does not

- Deliver amplification through changing the kurtosis of the distribution of price changes (Alvarez Bihan Lippi 2016) +
- Create excess curvature in profits, causing excess sensitivity of firm level prices to idiosyncratic shocks (Klenow Willis, 2016; Burstein and Hellwig 2007) +

The duopoly mechanism does

- Depend on the price setting technology: firms choose when to change prices. Under Calvo, dynamic complementarity is weaker. +

The duopoly mechanism is qualitatively consistent with previous work

- Strategic complementarities in pricing (Amiti, Itskhoki, Konings (2016)
- Counter-cyclical μ's and conc. (Barro Tenreyo, '06; Rotemburg Woodford, '91)
- Prices stickier for differentiated (final) goods (Bils Klenow, 2004)

Additional results

1. Positive menu costs are preferred by firms

   Results

2. Menu costs lead to large first order output losses

   Results

3. Strategic complementarities in the literature

   Results

4. Empirics: More concentrated markets do have less flexible prices

   Results

Conclusion

Market structure quantitatively important for understanding

1. Aggregate price flexibility following nominal spending shocks
2. Firm level price flexibility following idiosyncratic shocks
3. Cross-sectional heterogeneity in price flexibility

Market structure empirically important

- More concentrated labor markets have lower wages

  Berger, Herkenhoff, Mongey (2019)
- Increasing concentration and weakening Tobin's Q $\leftrightarrow$ Investment

  Philippon Gutierrez (2016)

This paper presents a framework for assessing these issues

- Relabel $p_{it} \rightarrow k_{it}$ delivers an oligopolistic Khan-Thomas model
- Exchange rate shocks
- Oligopsony in labor markets

THANK YOU!

Household - Solution

Preferences - $\downarrow z_{ij}, \uparrow Cost, \uparrow Demand$

$$C = \left[\int_0^1 C_j^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \quad , \quad C_j = \left[\left(\frac{c_{1j}}{z_{1j}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{c_{2j}}{z_{2j}}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

Demand

$$d_{ij} = z_{ij}^{\eta-1}\left(\frac{p_{ij}}{P_j}\right)^{-\eta}\left(\frac{P_j}{P}\right)^{-\theta} C\left(p_{ij} - \frac{W}{z_{ij}}\right)$$

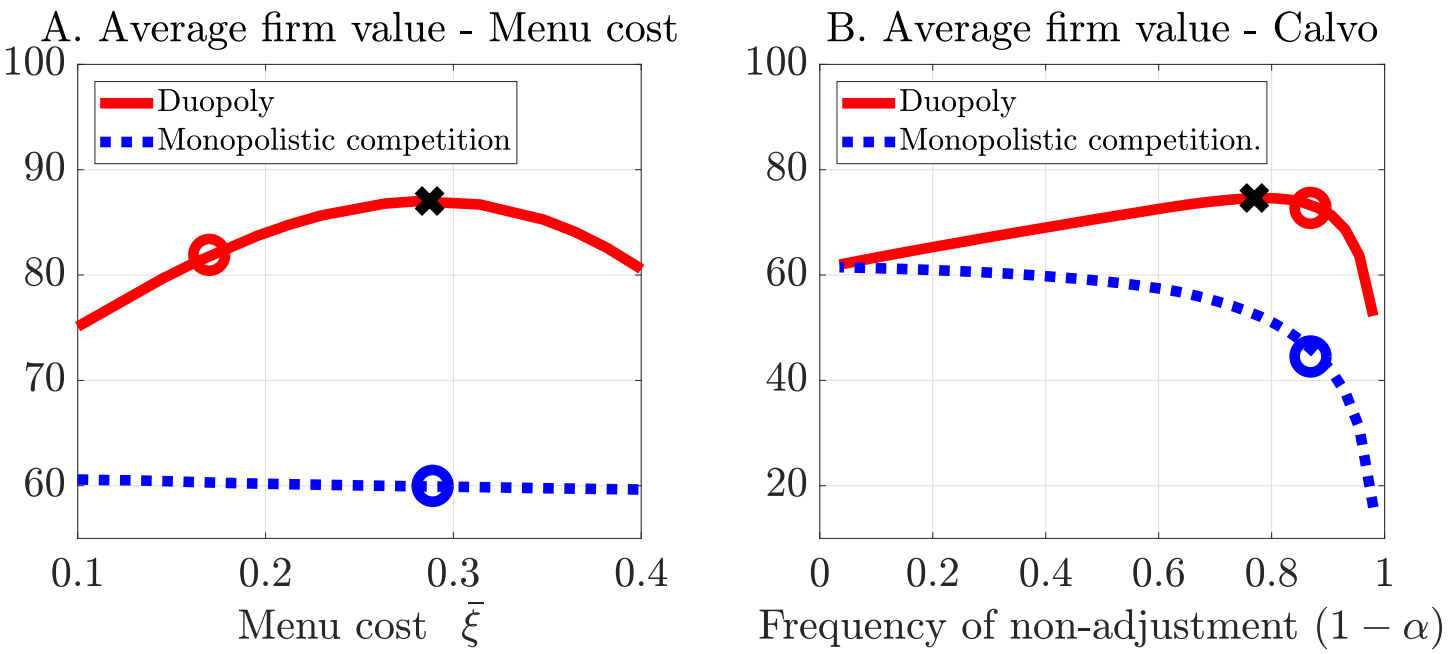
where

$$P_j = \left[\left(z_{1j}p_{1j}\right)^{1-\eta} + \left(z_{2j}p_{2j}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

$$P = \left[\int_0^1 P_j^{1-\theta} dj\right]^{\frac{1}{1-\theta}}$$

Back - Household solution

1. Firms value pricing frictions



✓ More frictions → Higher markups

✗ More frictions → Costly to respond to Δz_{ijt}

- 23% larger firm value in menu-cost model, 16% larger in Calvo
  - Rationalizes why firms create pricing frictions
  - e.g. Apple announces on Sep 24 price of new iPhone on sale Nov 3

Back - Additional results

2. First order output loss due to nominal rigidity

$$Y = \frac{1}{\mu} \quad , \quad \mu = \left[\int_0^1 {\mu_j}^{1-\theta} dj \right]^{\frac{1}{1-\theta}} \quad , \quad \mu_j = \left[{\mu_{1j}}^{1-\eta} + {\mu_{2j}}^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

			Mon. Comp.	Duopoly
(1)	Output		0.76	0.75
(2)	... under no dispersion	$\mu_{it} = \mathbb{E}[\mu_{it}]$	0.77	0.77
(3)	... with no menu costs	$\mu_{it} = \mu^*$	0.78	0.83
(3)-(1)	Output loss due to nominal rigidity		2.4%	9.7%

Result

- Nearly 10% output losses due to nominal rigidity in oligopoly
- 1st order $\sim$ 80% due to higher markups
- 2nd order $\sim$ 20% due to price dispersion

Back - Additional results

3. Strategic complementarities in MC models

Strategic complementarities

"Substantial nominal rigidity can arise from a combination of strategic complementarities and nominal frictions" - Ball Romer (1990)

Klenow Willis (2016), Burstein Hellwig (2007)

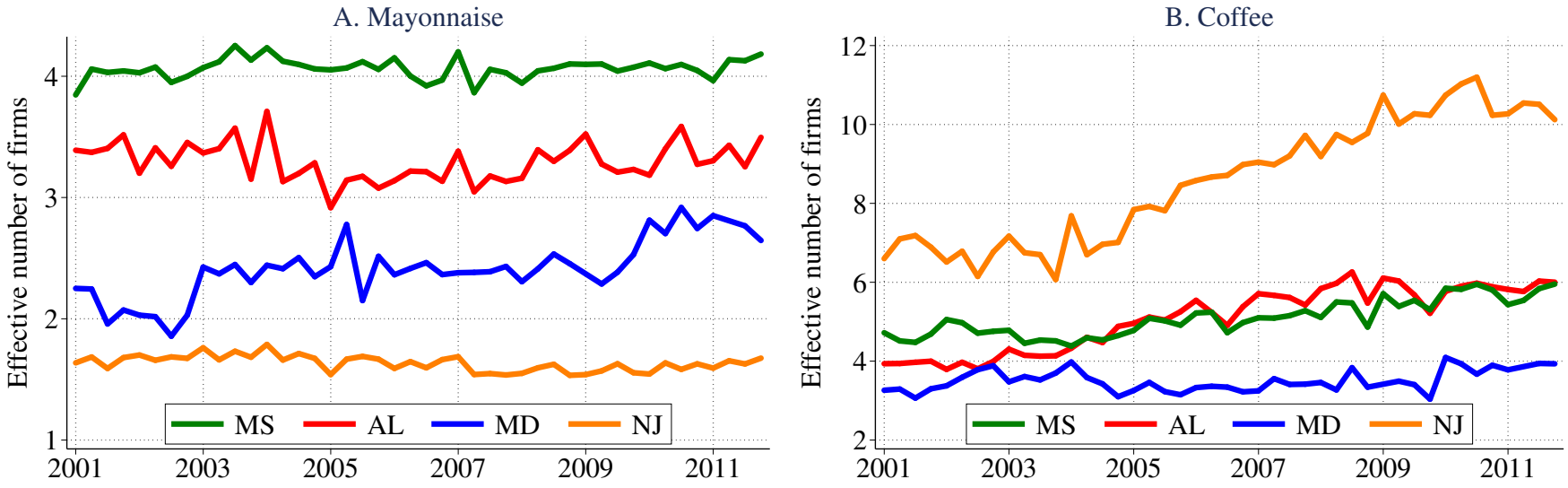
"Recent work has cast doubt on SC as a source of amplification in menu cost models, by showing that introducing SC's can make it difficult match size, freq. for plausible values of $\bar{\xi}$ and σ_z...this challenge is a serious one" - Nakamura Steinsson (2010)

This paper

- Smaller $\bar{\xi}$ and σ_z under duopoly
- Larger $\uparrow$ $std[c_t]$ due to strategic complementarity
- How? Complementarity due to μ_{1jt}/μ_{2jt}, not μ_{it}/μ_t

Back - Additional results Profit functions

4. More concentrated markets, Less flexible prices



1. Variation across states, within product categories
2. Market concentration is not region specific

   See: Bronnenburg Dhar Dubé (JPE '09), Bronnenburg Dubé Gentzkow (AER '12)

3. Most variation in price flex. is within product-p, across states-s

$$\text{std}\left[\log freq_{spt} \middle| \; t\right] = 0.65$$
$$\text{std}\left[\log freq_{spt} \middle| pt\right] = 0.54.$$

4. More concentrated markets, Less flexible prices

$$
\begin{aligned}
X_{spt} &= \hat{\gamma}_{pt} + \hat{\beta}_1 Nfirms_{spt} + \hat{\beta}_2 Rev_{spt} + \hat{e}^X_{spt} \\
\tilde{e}^X_{spt} &= \frac{\hat{e}^X_{spt}}{\text{std}[\hat{e}^X_{spt} | pt]}
\end{aligned}
$$

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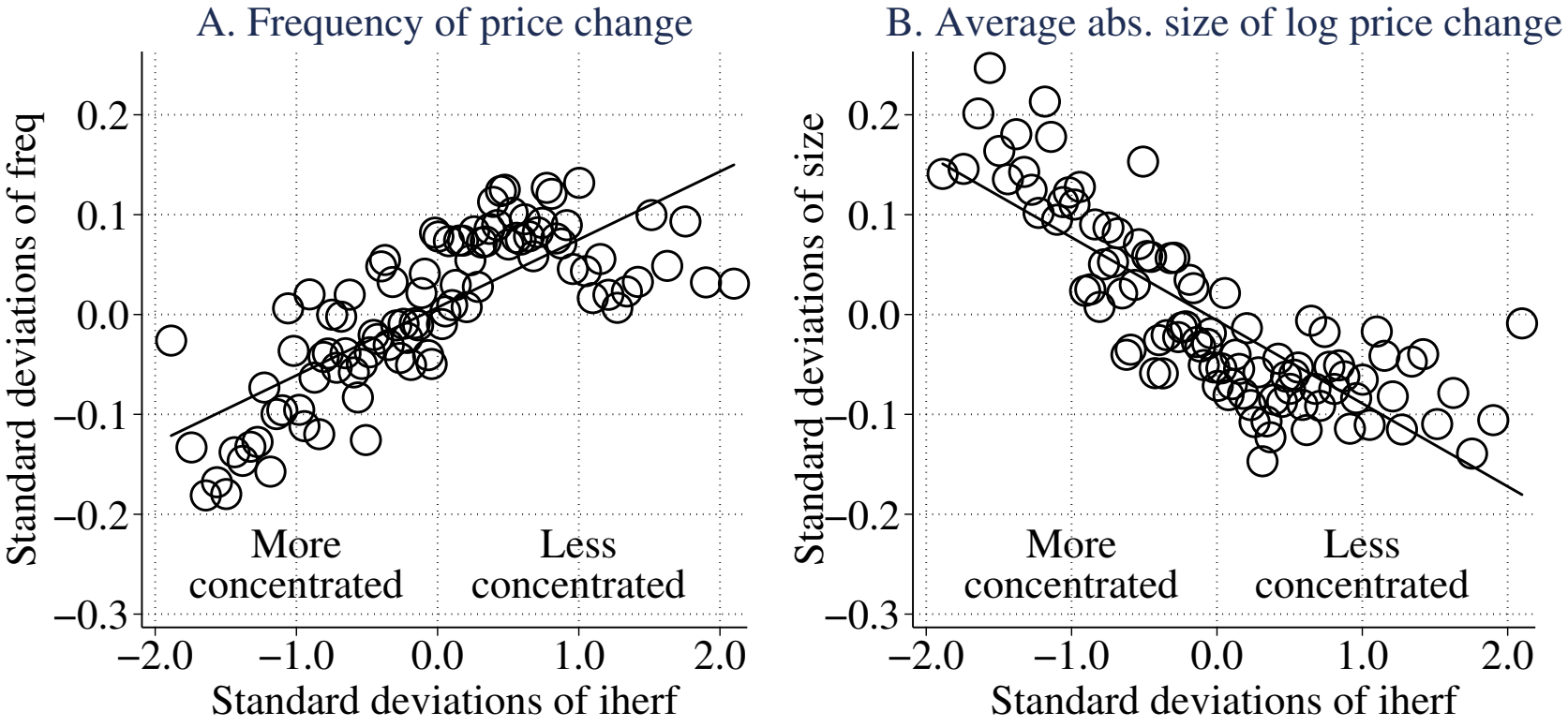

Back - Additional results

Extension - Endogenous entry

Resolve two issues

- Data Many small firms with high turnover
- Theory Threat of entry may affect pricing: $\uparrow M$, $\uparrow \pi$
  - Kokovin Parenti Thisee Zhelobodko (2015)

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1. Preferences

$$C = \left[\gamma^{\frac{1}{\eta}} \left[(z_1 c_1)^{\frac{\eta-1}{\eta}} + (z_2 c_2)^{\frac{\eta-1}{\eta}} \right] + (1-\gamma)^{\frac{1}{\eta}} C_f^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

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2. Endogenous measure δ of atomistic, one-period firms $k \in [0, \delta]$

$$C_f = \left[\int_0^{\delta} c_{fk}^{\frac{\rho-1}{\rho}} dk \right]^{\frac{\rho}{\rho-1}}, \quad p_{fk}^* = \frac{\rho}{\rho-1} M, \quad P_f = \delta^{-\frac{1}{\rho-1}} \frac{\rho}{\rho-1} M$$

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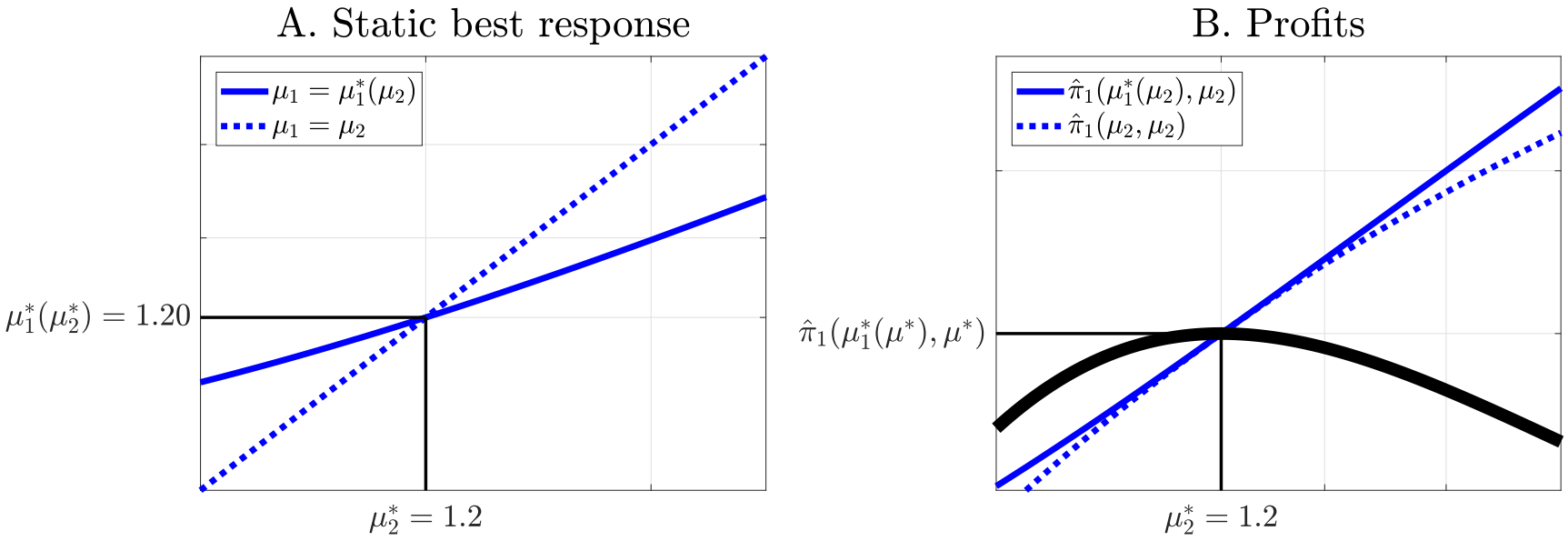
3. Free-entry determines size of fringe $\pi^f \left(p_1, p_2, z_1, z_2, M, \delta \right) - \phi = 0$

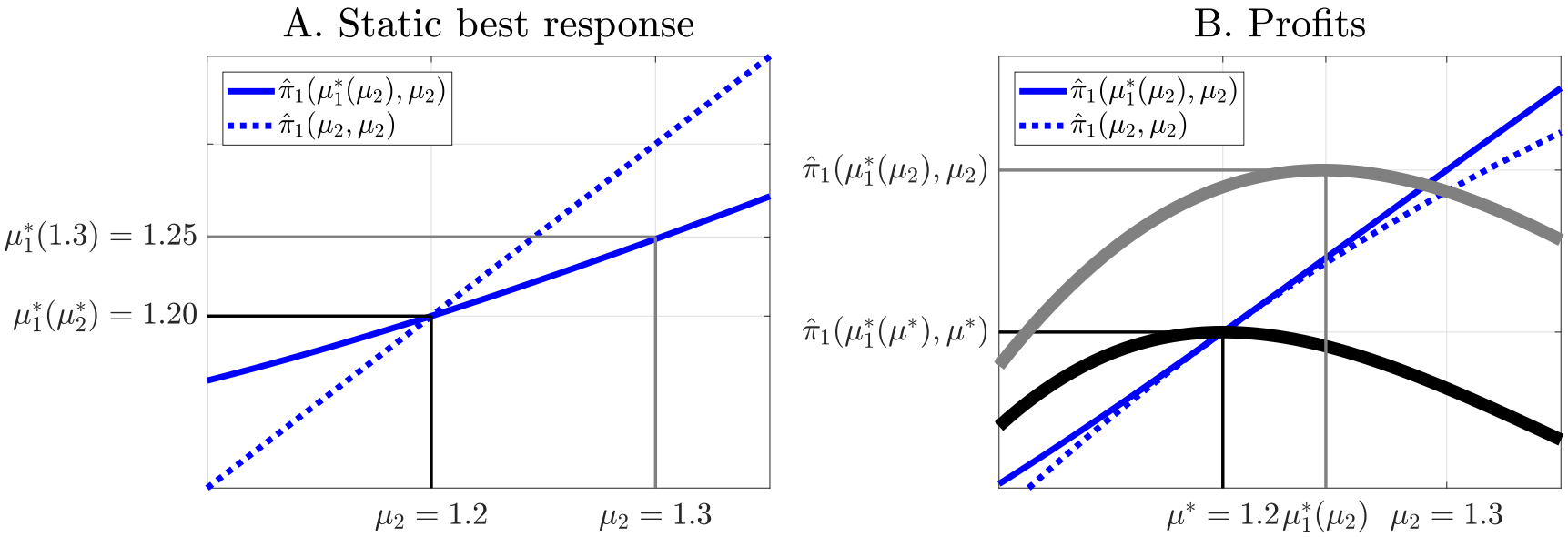
Household problem - Solution - Profits



$$\frac{\pi_{ij}}{W} = \left(\frac{\mu_{ij}}{\mu_j}\right)^{-\eta} \left(\frac{\mu_j}{\mu}\right)^{-\theta} \frac{1}{\mu}\left(\mu_{ij} - 1\right) = \hat{\pi}_i\left(\mu_{ij}, \mu_{-ij}\right) \mu^{\theta-1}$$

Back - Household solution

Household problem - Solution - Profits



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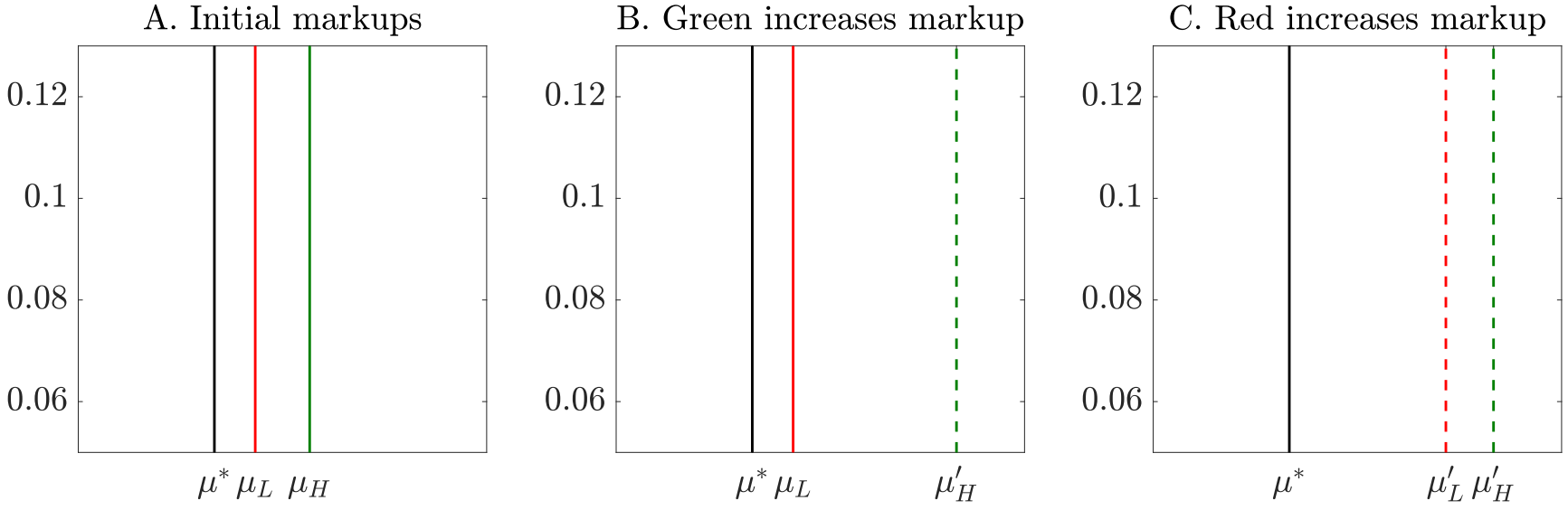
Back - Household solution

Duopoly - Case I - Profit functions



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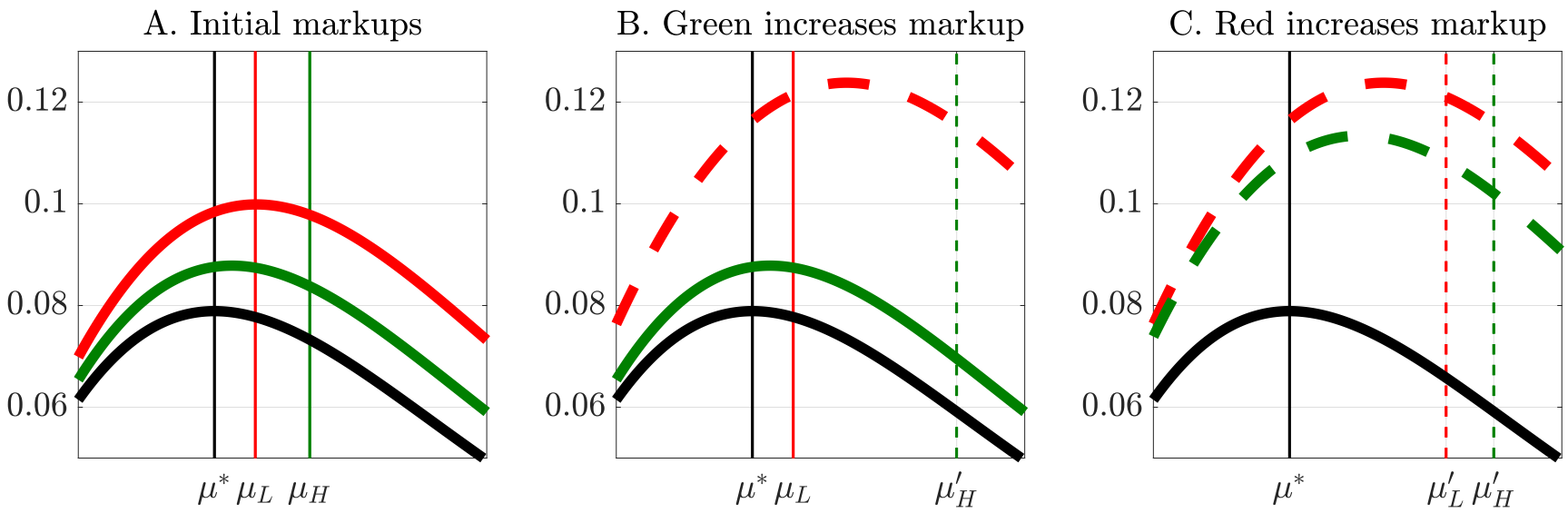
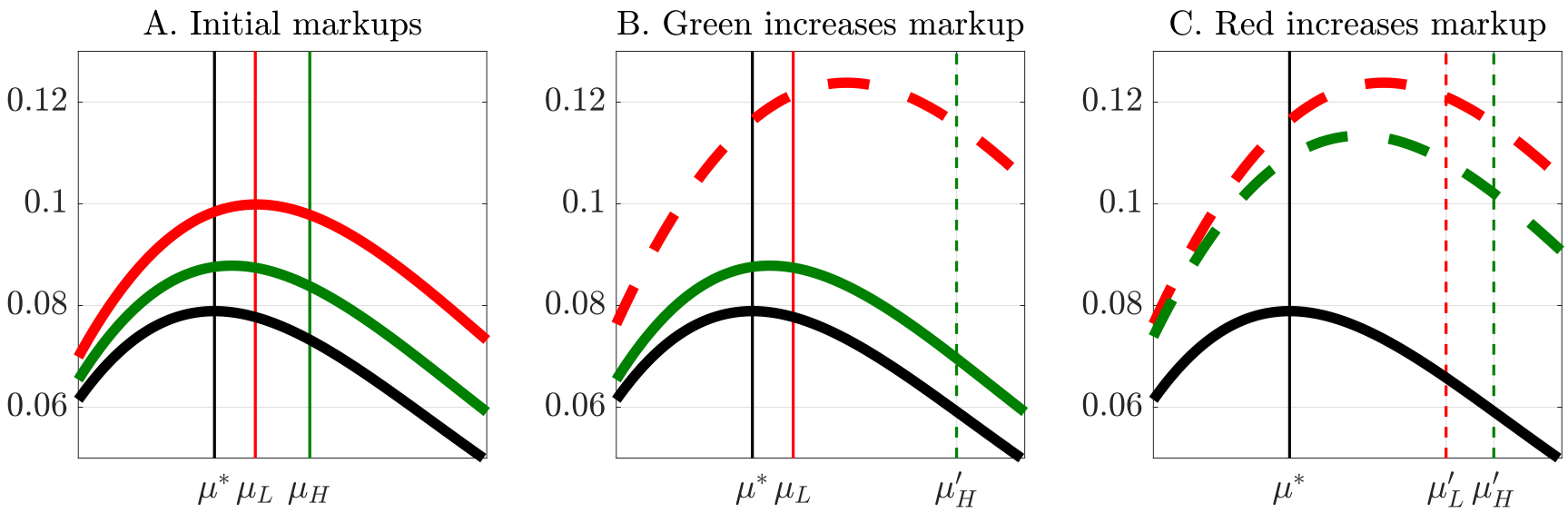


A. Static best response is to undercut: $\mu_H^*(\mu_L) < \mu_L$.

Duopoly - Case I - Profit functions



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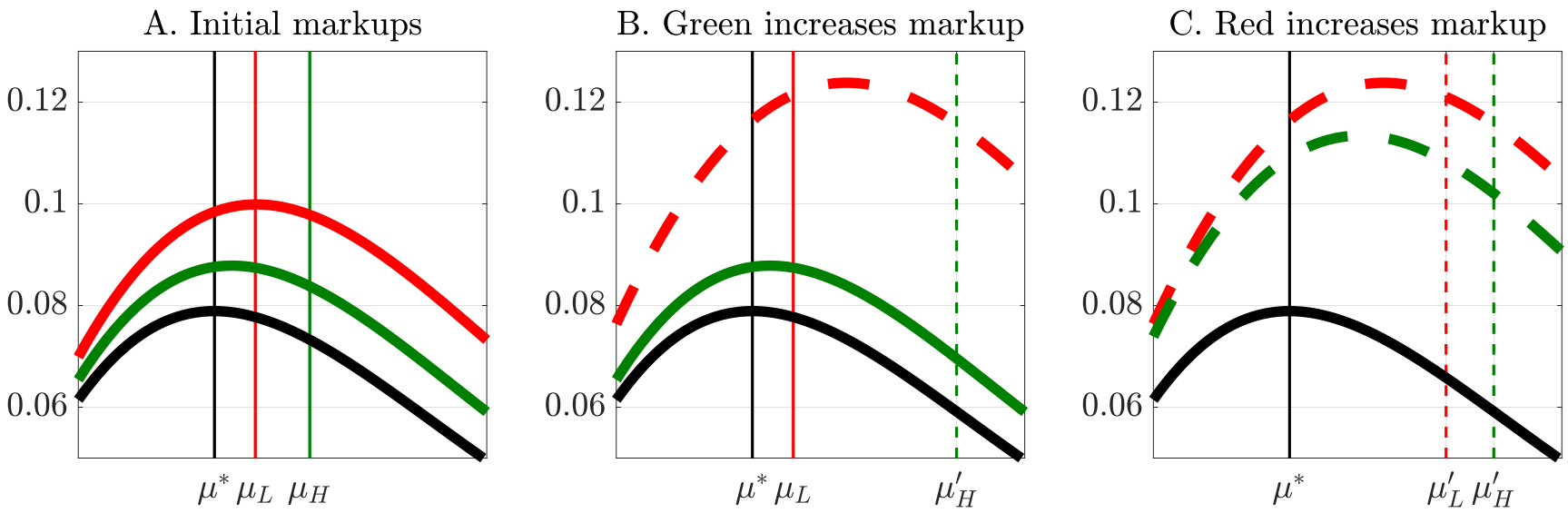

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C. $\mu_L \to \mu'_L$ such $\pi_H(\mu'_H, \mu'_L) > \pi_H(\mu_H^*(\mu'_L), \mu'_L) + \xi$

Back - Household solution
Back - Case I

Extension - Exchange-rate pass-through

Question in trade literature

- Question — Euro devalues $10c$, BMW reduces US prices by $2.5c$?
- Answer — BMW competes with Ford, Ford unaffected by shock

Extension - Exchange-rate pass-through

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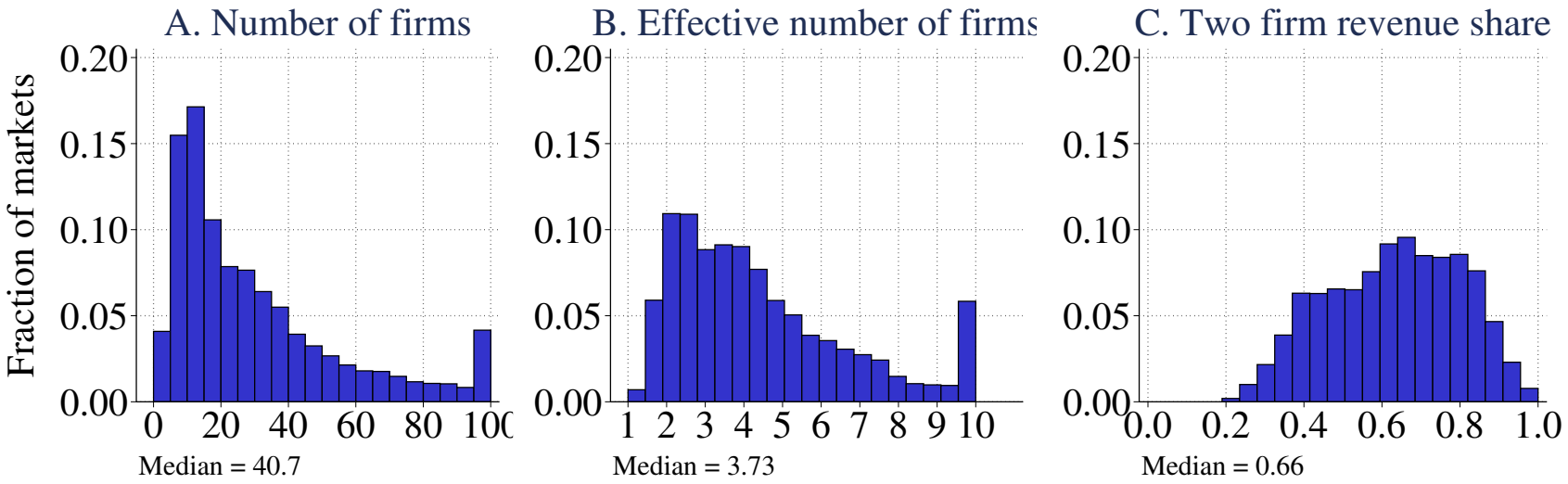
2. Marginal cost

$$mc_i = \frac{W^{1-\alpha_i} (W^*)^{\alpha_i}}{z} \quad + \quad E = \log\left(\frac{W}{W^*}\right) \quad \rightarrow \quad mc_i = \frac{W}{\exp(\alpha_i E)}$$

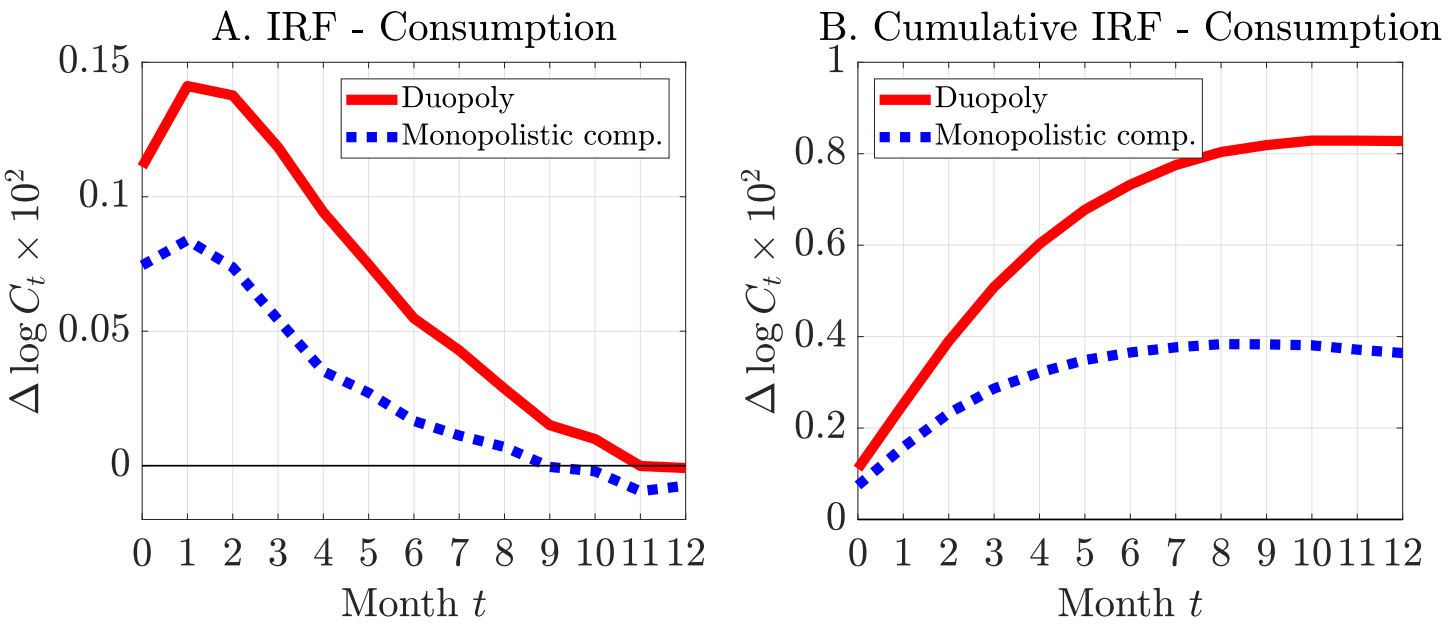
Data - Markets are highly concentrated

- Market 31 IRI product cat. (p) $\times$ 46 states (s) $\times$ 132 months (t)
- Firm First 6 digits of barcode (within a product category)
- Example In the market for Mayonnaise in Ohio, 2005:Q1, of 14 firms, Hellmann's had a 45% revenue share
- Example Herfindahl index of 0.43, Inverse herfindahl index of 2.3



Back - Introduction
Comparison to 6 digit NAICS

Market structure and monetary non-neutrality



Results

- Consumption fluctuations are 2.5 times as large
- Cumulative response of output is 2.4 times as large

Back - Calibration

Literature

1. Monopolistic competition, menu-costs

   Monetary Golosov Lucas (2007), Nakamura Steinsson (2010), Midrigan (2011), Vavra (2014)
   Alvarez et al. (2016 $\times 5$), Klenow Willis (2016), Burstein Hellwig (2007)

   Inter'l Itskhoki Gopinath (2010), Itskhoki Mukhin (2016), Berger Vavra (2016)

   New - Dynamic oligopoly

2. Oligopoly, flexible prices

   Trade Atkeson Burstein (2008), Edmond Midrigan Xu (2015), Pennings (2015)

   IO Hottman Redding Weinstein (2016)

   New - Nominal rigidity

3. Dynamic oligopoly, nominal rigidity

   Maskin-Tirole '88, Jun Vives '04, Einav Somaini '13, Nakamura Zerom '10, Neiman '11

   New - Equilibrium macroeconomic model

Back - Approach

Literature - Existing results

(1)	(2)	Ref. (3)	Peak IRF $\frac{\Delta \log \hat{Y}_t}{\Delta \log \hat{M}_t}$ (4)	P.C. slope $\lambda = \frac{\partial \pi_t}{\partial \widehat{mc}_t}$ (5)	Freq. α (6)	Dur. $1/\alpha$ (7)
Panel A.						
Golosov-Lucas	Menu cost	Fig. 4a	**0.42**	1.36	0.67	1.49
Nakamura-Steinsson	14-sector	Fig. VIII	**0.50**	1.00	0.62	1.62
	+ Round-a-bout*	Fig. IX	**0.80**	0.25	0.39	2.56
Gertler-Leahy	Baseline	Fig. 2	**0.45**	1.22	0.65	1.53
	+ sectoral labor**	Fig. 3	**0.75**	0.33	0.43	2.30
Burstein-Hellwig	Baseline	Fig. 5	**0.34**	1.94	0.73	1.37
	+ DRS**	Fig. 5	**0.56**	0.79	0.58	1.73
	+ Wage rigidity*	Fig. 5	**0.70**	0.43	0.47	2.11
Klenow-Willis	Baseline	Fig. 4	-	**0.51**	0.50	1.99
	+ Kimball**	Fig. 4	-	**0.40**	0.46	2.16
This paper	Monopolistic comp.	Fig. 5	**0.42**	1.38	0.67	1.49
	Duopoly**	Fig. 5	**0.74**	0.36	0.45	2.25
Forms of pricing complementarity: $*$ = 'macro'-complementarity, $**$ = 'micro'-complementarity						
Panel B.						
Calvo model	Bils-Klenow	Tab. 1	0.931	0.167	0.22	**4.55**
	CET (RANK)		0.992	0.008	0.08	**12**
Rotemburg	MKV (HANK)	Tab. D2	0.909	**0.100**	0.27	3.70

Back - Approach

Household

$$\mathbf{W}(S,B) = \max_{\{c_{ij}\},N,\{B(S')\}} \log C - N + \beta\mathbb{E}\left[\mathbf{W}\left(S', B(S')\right)\right]$$

where

$$C = \left[\int_0^1 C_j^{\frac{\theta-1}{\theta}} dj\right]^{\frac{1-\theta}{\theta}} \quad , \quad \theta > 1$$

$$C_j = \left[c_{1j}^{\frac{1-\eta}{\eta}} + c_{2j}^{\frac{1-\eta}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad , \quad \eta > \theta$$

subject to a nominal budget constraint

$$\underbrace{\int_0^1 \left[p_{1j}c_{1j} + p_{2j}c_{2j}\right] dj}_{=M(S)} + \sum_{S'} Q(S,S')B(S') \leq B(S) + W(S)N + \Pi(S)$$

Back - Household preferences

Calibration - Identification

Increasing ξ

- Costly to adjust. Adjust less often. Widen bounds.
- $\uparrow$ Size, $\downarrow$ Frequency

Increasing σ_z

(i) Given bounds. Hit bounds more often. $\uparrow$ Frequency

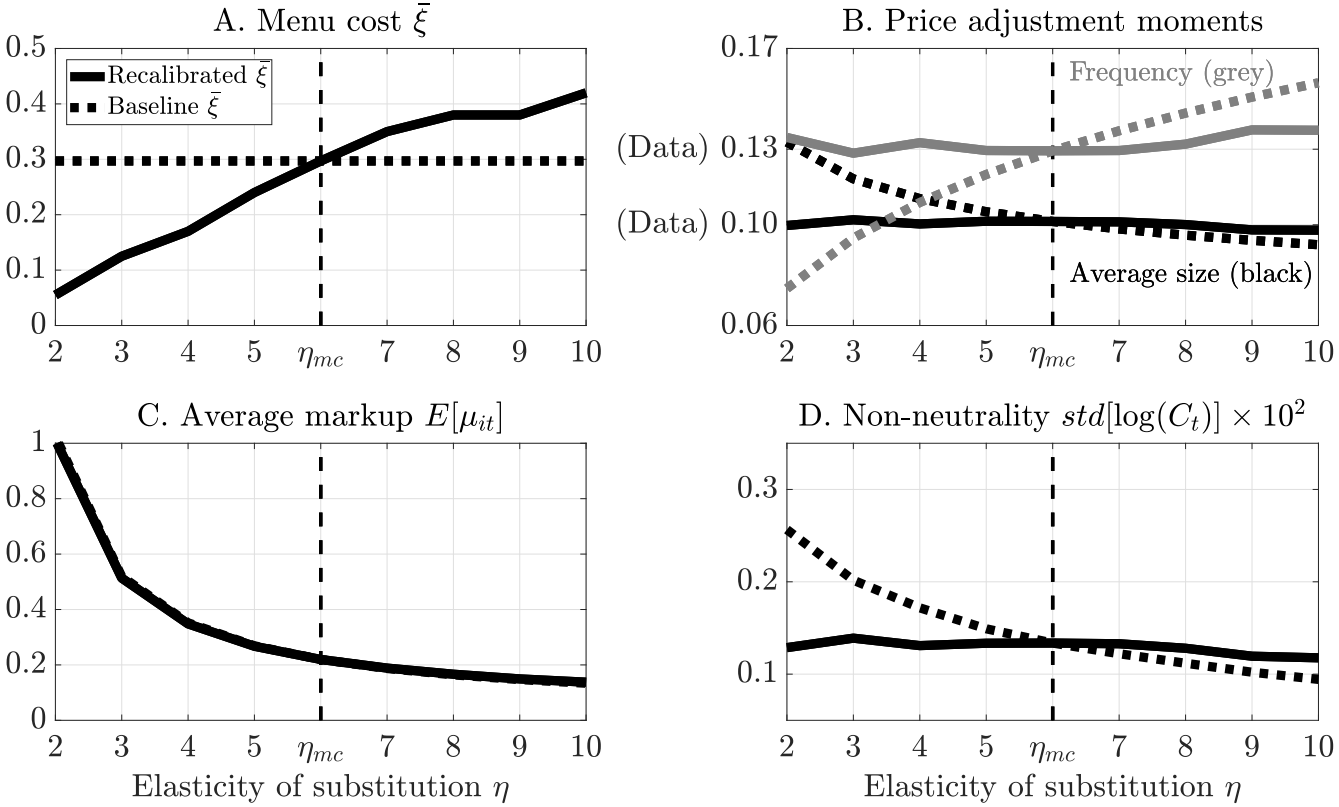
(ii) Hit bounds more often $\rightarrow$ Widen bounds $\uparrow$ Size

Increasing η

- Increase average markup

Back - Calibration strategy

Benchmarking models - Robustness



(A) For each η, choose $\bar{\xi}$ and σ_z to match the data.

(B) Lower $\downarrow \eta \rightarrow$ Profits less sensitive to prices $\rightarrow$ Require lower $\downarrow \bar{\xi}$

(C) Can match $\mathbb{E}[\mu_{it}] = 1.30$ from duopoly model with $\eta^* = 4.5$

(D) **Result** When $\bar{\xi}$ and σ_z are recalibrated $\sigma(C_t)$ is unaffected

Back - Calibration strategy

Recursive equilibrium - Computation

Krussel-Smith

- Conjecture price function for $\mu(S)$

$$\log \mu(S) - \log \bar{\mu} = \alpha_g \left(\log g(S) - \log \bar{g}\right) + \alpha_\mu \left(\log \mu(S_{-1}) - \log \bar{\mu}\right)$$

- Reduces aggregate state to $S = (\mu_{-1}, g)$

MPE policy functions

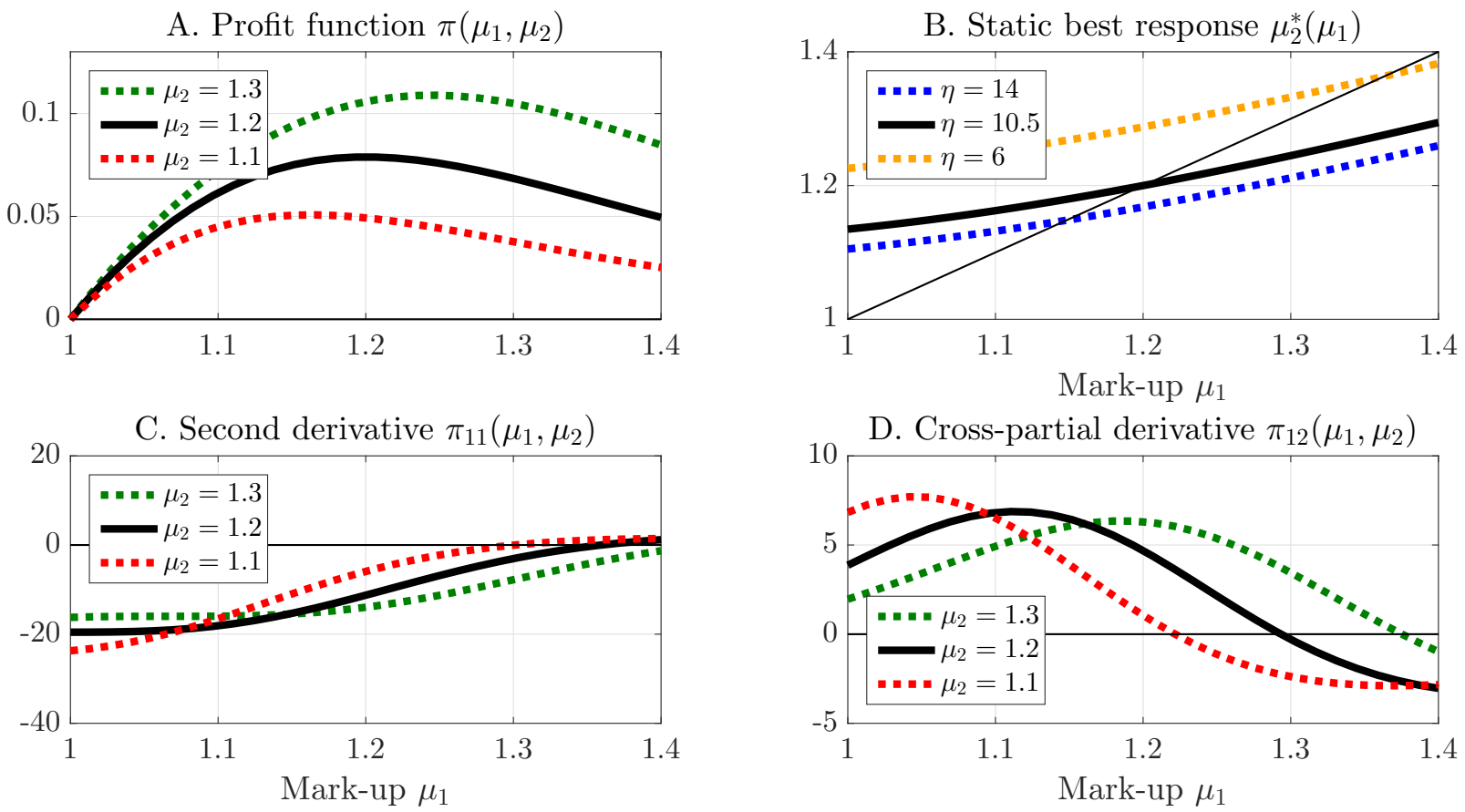
- Approximate expected value function $V^e\left(\mu_1, \mu_2, \mu, g\right)$

$$V^e(\mu_1, \mu_2, \mu, g) = \int V\left(\frac{\mu_1}{e^{\varepsilon_1' + g'(g, \varepsilon_g')}}, \frac{\mu_2}{e^{\varepsilon_2' + g'(g, \varepsilon_g')}}, \mu, g'(g, \varepsilon_g')\right) dF(\varepsilon_1', \varepsilon_2', \varepsilon_g')$$

- Cubic splines in μ_1, μ_2. Linear splines in μ, g
- Guess initial pricing policies $\mu_{-i}^{(0)\prime}(\mu_i, \mu_{-i}, S)$ and $\gamma_{-i}^{(0)\prime}(\mu_i, \mu_{-i}, S)$
- Given competitor policies, use collocation algorithm to solve for value functions
- Determines new $\mu_{-i}^{(1)\prime}(\mu_i, \mu_{-i})$ and $\gamma_{-i}^{(1)\prime}(\mu_i, \mu_{-i})$
- Continue, until $\mu_{-i}^{(k+1)\prime} = \mu_{-i}^{(k)\prime}$ and $\gamma_{-i}^{(k+1)\prime} = \gamma_{-i}^{(k)\prime}$

Back - Recursive equilibrium

Profit function properties



- Panel B - Best response slope between 0 and 1
- More elastic demand $\uparrow \eta \rightarrow$ (i) $\downarrow \mu^*$, (ii) $\uparrow$ *slope*

Back - Strategic complementarities

Calibration and results

		Baseline		Alternative MC models		
		Duo_I	MC_I	MC_{II}	MC_{III}	MC_{IV}
A. Parameters						
Within-sector elasticity of substitution	η	10.5	4.5	10.5	6	10.5
Upper bound of menu cost distribution	$\xi \sim U[0, \bar{\xi}]$	0.17	0.21	0.17	0.29	0.42
Size of shocks (percent)	σ_z	3.8	4.0	3.8	4.1	4.3
B. Moments						
Markup	$\mathbb{E}[\mu_{it}]$	1.30	1.30	1.12	1.22	1.13
Frequency of price change	$\mathbb{E}[\mathbf{1}\{p_{it} \neq p_{it-1}\}]$	0.13	0.13	0.19	0.13	0.13
Log abs. price change	$\mathbb{E}[\lvert \log(p_{it}/p_{it-1}) \rvert]$	0.10	0.10	0.05	0.10	0.10
C. Results						
Std. deviation consumption (percent)	$\sigma(\log C_t)$	0.31	0.13	0.06	0.13	0.13
Average minus frictionless markup	$\mathbb{E}[\mu_{it}] - \mu^*$	0.10	0.02	0.01	0.02	0.02

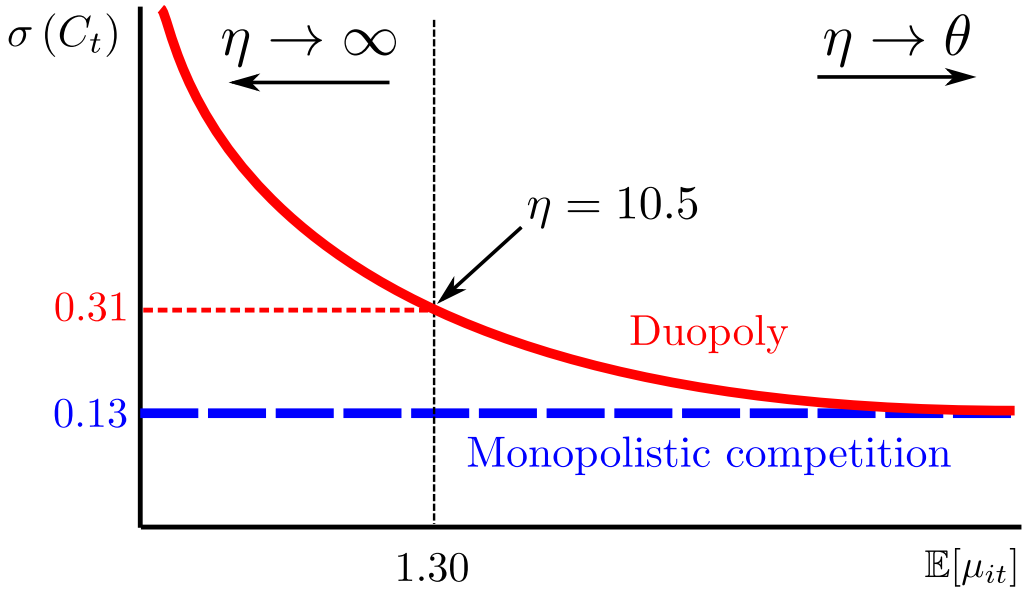
I Parameters same as estimated duopoly model

II Same $\eta_m = \eta_d$ re-calibrated $\bar{\xi}_m$, $\sigma_{z,m}$

III Both models have flexible price markup of 1.20

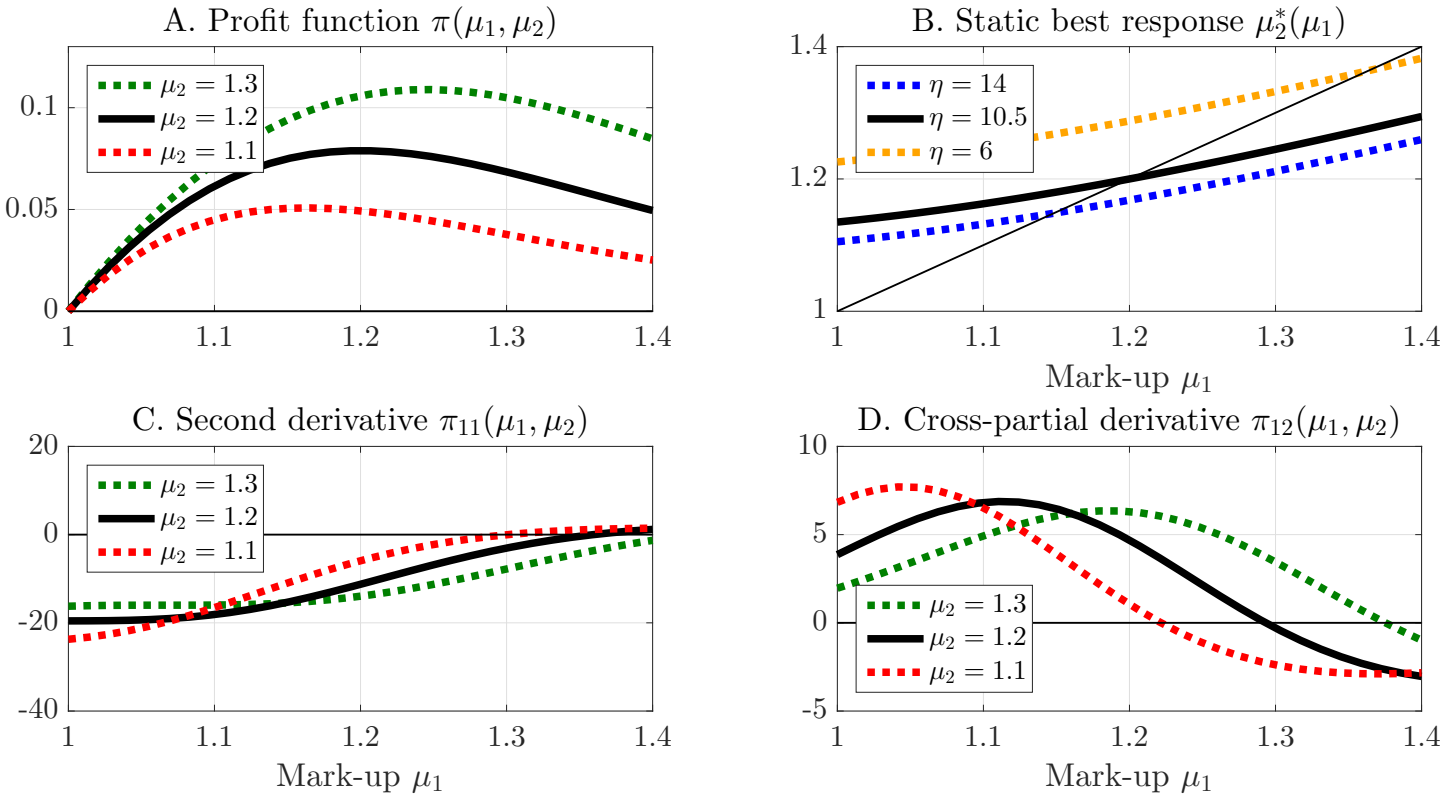
Back - Calibration

Robustness to target $\mathbb{E}\left[\mu_{it}\right]$



Back - Calibration

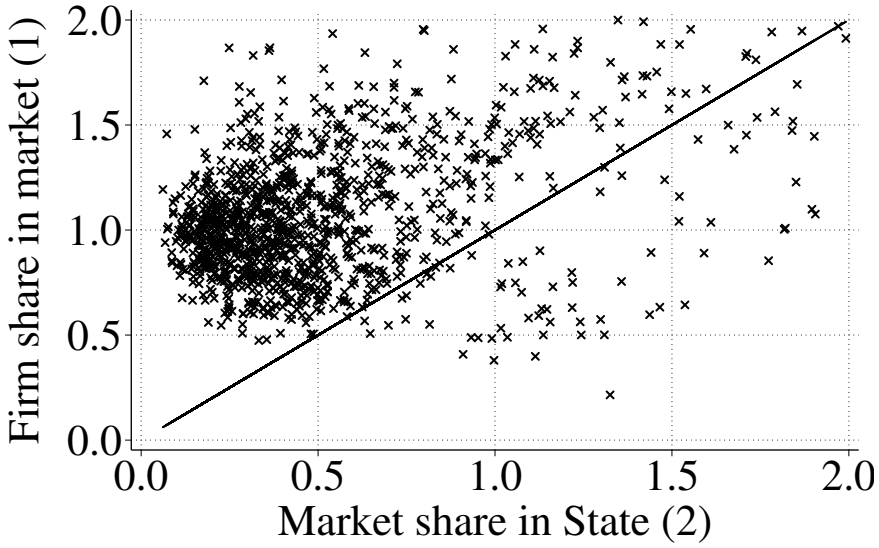
Profit function properties

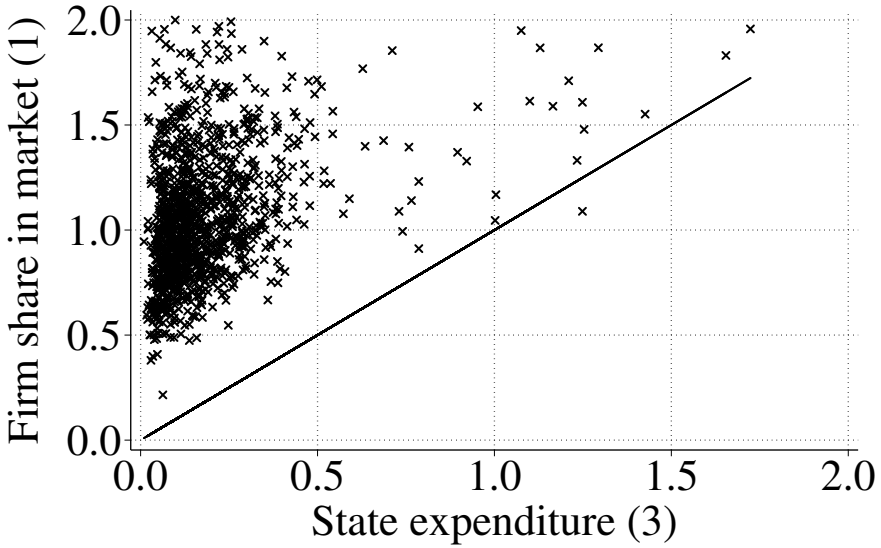


- Strategic complementarity driven by $\pi_{12} > 0$
- Weird property of CES demand functions - Panel D
- As markups increase, π_{12} falls, then becomes negative

Back - Markups ad Values

Decomposing revenue changes at large firms



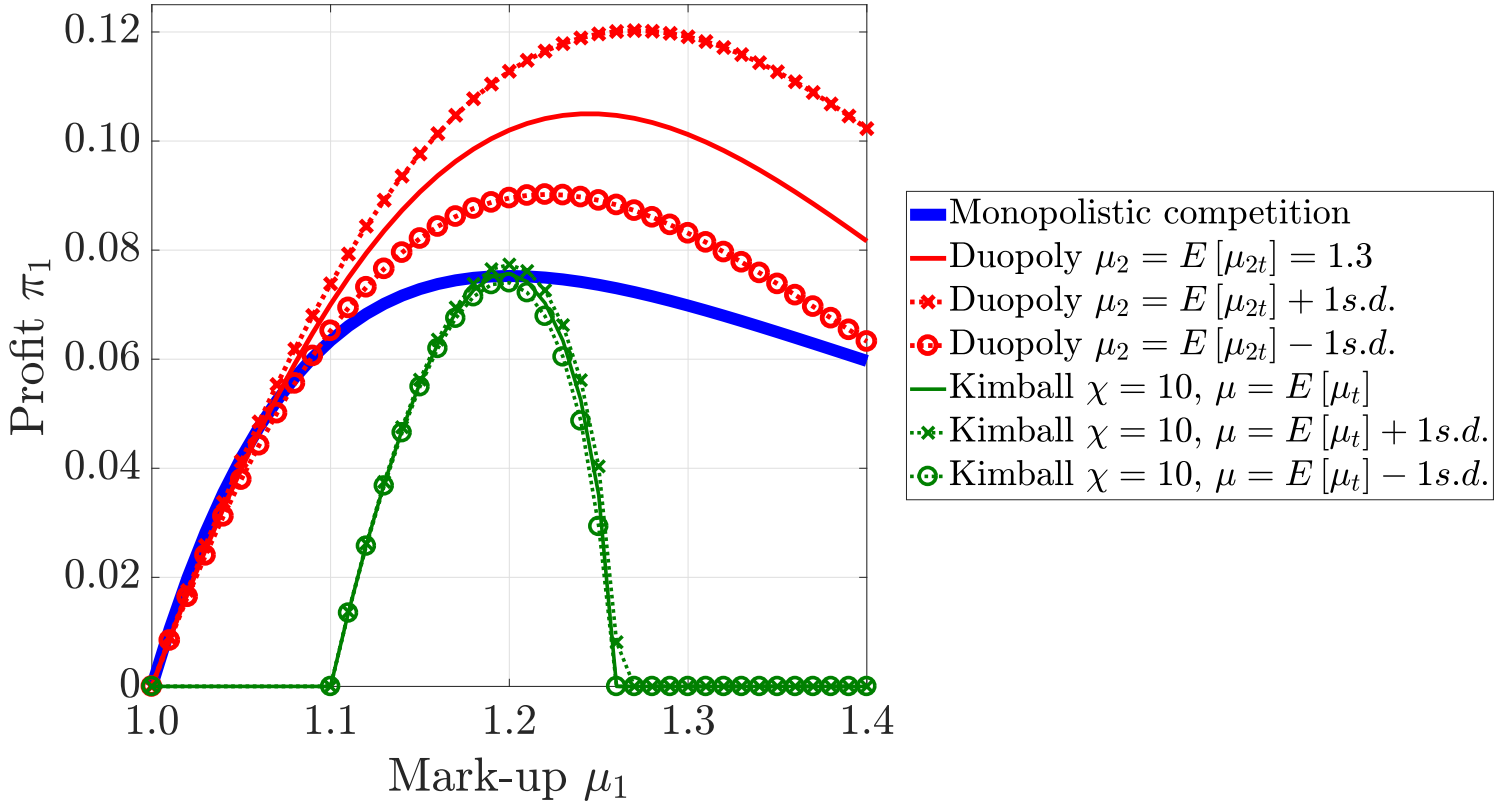


For each state s, product category p, decompose time-series variance in $\Delta \log r_{ipst}$

$$var\left(\Delta \log r_{ipst}\right) = \underbrace{var\left(\Delta \log\left(\frac{r_{ipst}}{r_{pst}}\right)\right)}_{\text{(1) Firm share in market}} + \underbrace{var\left(\Delta \log\left(\frac{r_{pst}}{r_{st}}\right)\right)}_{\text{(2) Market share in state}} + \underbrace{var\left(\Delta \log r_{st}\right)}_{\text{(3) State expenditure}} + \text{Covariances}$$

Back - Calibration strategy

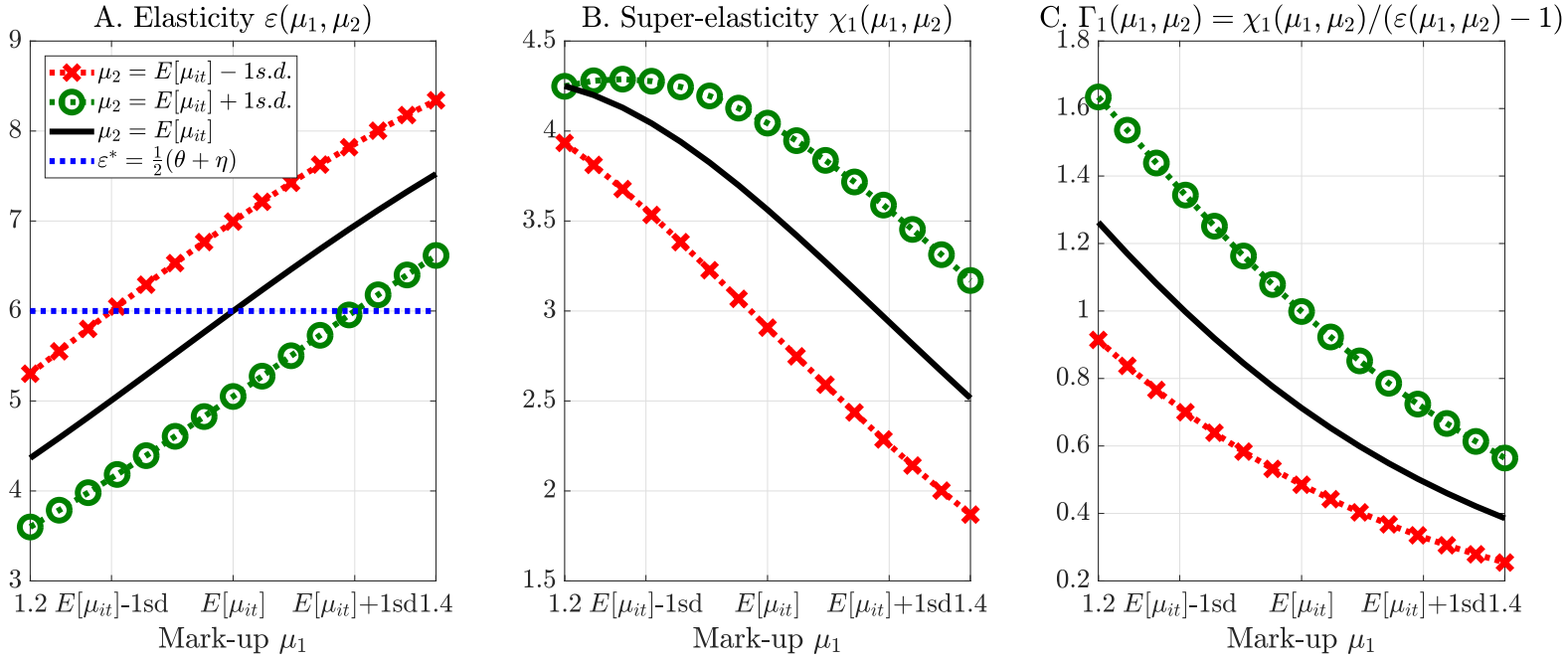
Relation to Kimball-style strategic complementarity



- Duopoly demand function super-elasticity $\varepsilon \approx 3$
- Literature Klenow Willis - $\varepsilon = 10$, Gopinath Itskhoki - $\varepsilon = 4$

Back - Additional results
Back - Example μ policies

Relation to Kimball-style strategic complementarity



- Duopoly demand function super-elasticity $\varepsilon \approx 3.5$

  Literature - Berger Vavra (2.4), Gopinath Itskhoki (4), Klenow Willis (10),

- 'Responsiveness' measure $\varepsilon/\sigma \approx 0.58$

  Literature - EMX (0.19), Berger Vavra (0.47), Gopinath Itskhoki (0.80)

Back - Additional results
Back - Example μ policies

Empirical - Data details

- IRI data
  - An observation is at the UPC $\times$ Category $\times$ Store level
  - Stores: 2,000, Years: 2001-2012, Categories: 31
  - e.g. Mayonnaise, 2001. Firms: 72, UPCs: 402
- Observations removed
  - Absolute size of price change greater than 99th percentile
  - Data missing at $t-1$
- Regular price changes
  - Price change set to zero $\Delta \log p_{ict} = 0$
  - Possible measurement error: $\Delta|\log p_{ict}| < 0.001$
  - Promotional flag $Promo_{ict} = 1$
  - Items coming off promotion $Promo_{ict-1} = 1$ & $Promo_{ict} = 0$
- Statistics
  - All statistics computed monthly for each product category c
  - Data is weekly, statistics reported monthly using week three of each month
  - e.g. Frequency $freq_{ct}$ is fraction of c goods changing price at t

$$freq_{ct} = \sum_{i \in c} \mathbf{1}\left[d \log p_{ict} \neq 0\right] / N_{ct}$$

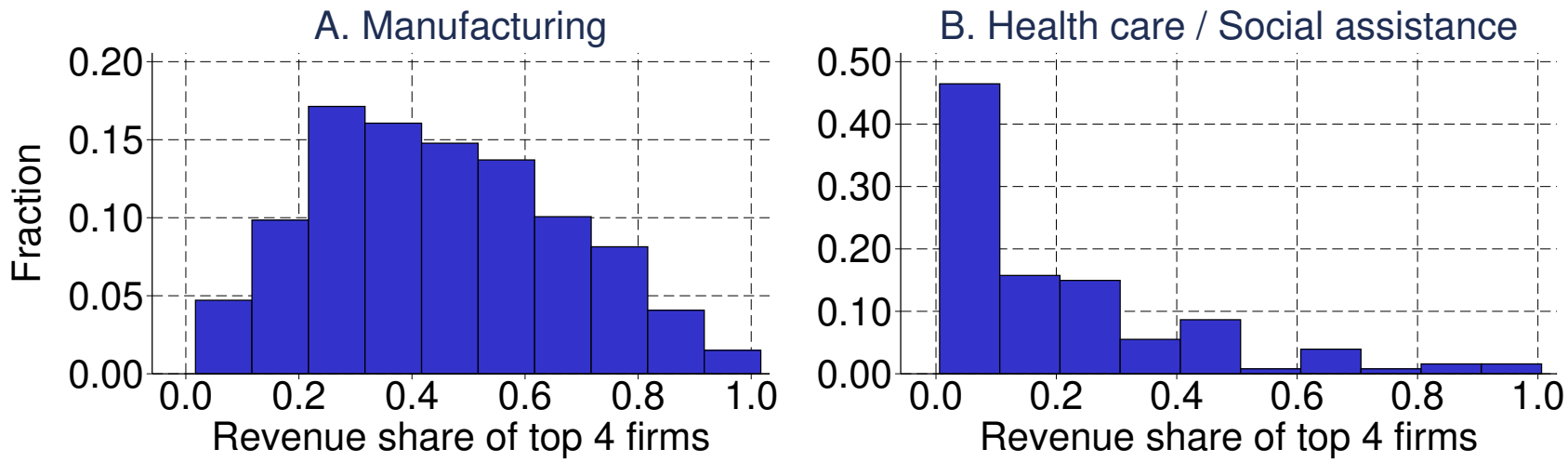
Back - Empirical - Size of price changes
Back - Regression specification
Back - Calibration

Comparison to Census Manufacturing

- Data National NAICS 6-digit revenue share of 4 largest firms

✓ Few industries are national, e.g. Manufacturing

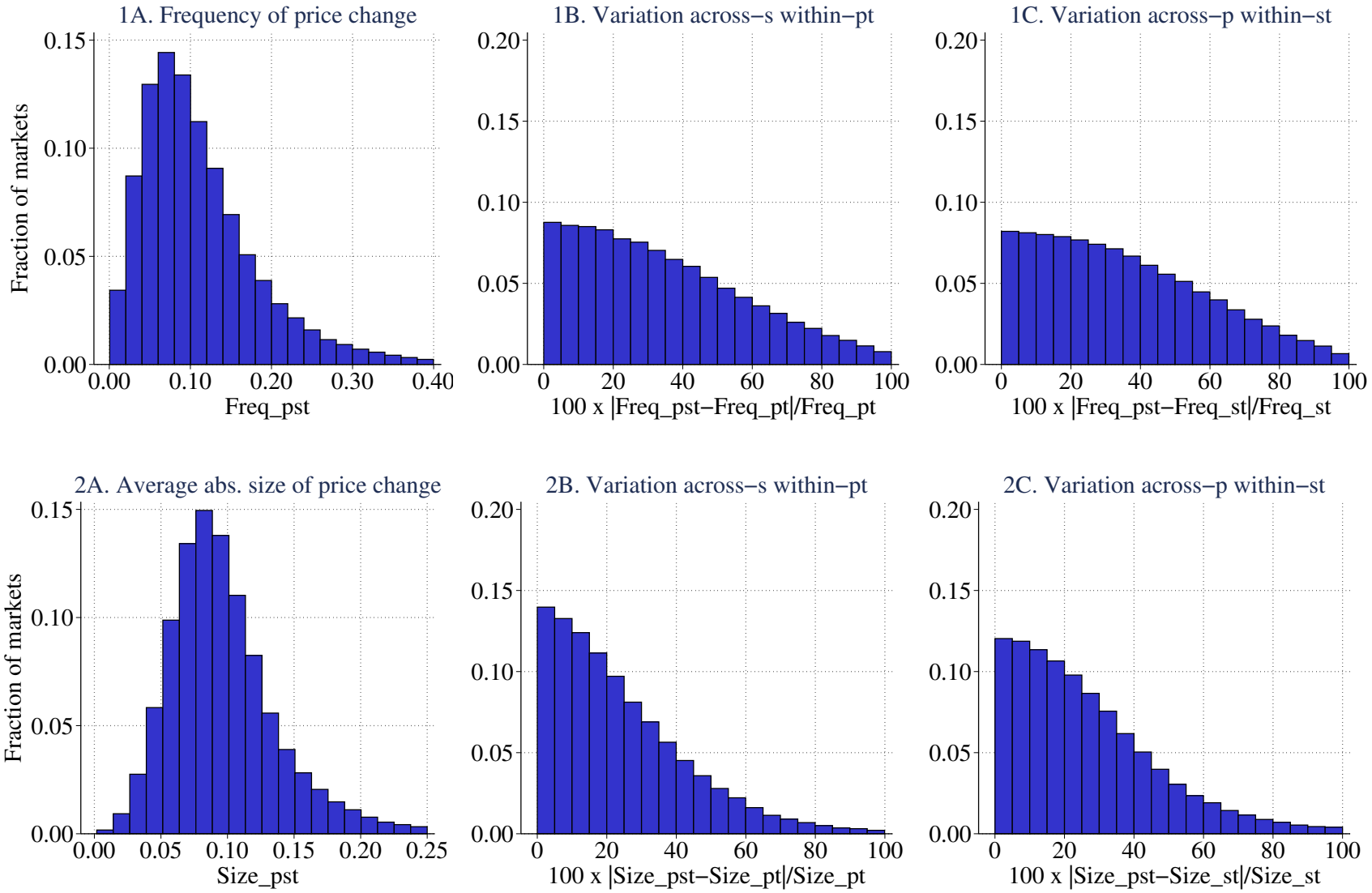
✗ Most industries are local, e.g. Health care



Source: 2007 Economic Census, 6–digit NAICS classification, national level

Back - Inverse herfindahl

3. Variation in price flexibility



Back - Variation in concentration

Time- vs State-dependent pricing

	Fixed menu cost	Random menu cost		Calvo	
	MC	Duo	**MC**	Duo	**MC**
$\sigma(\log(C_t)) \times 100$	**0.08**	0.31	**0.13**	0.41	**0.38**
Relative $\sigma(\log(C_t))$					
Duopoly vs Mon.Comp		2.38	-	1.07	-
Calvo vs Menu Cost		-	-	1.32	**2.92**

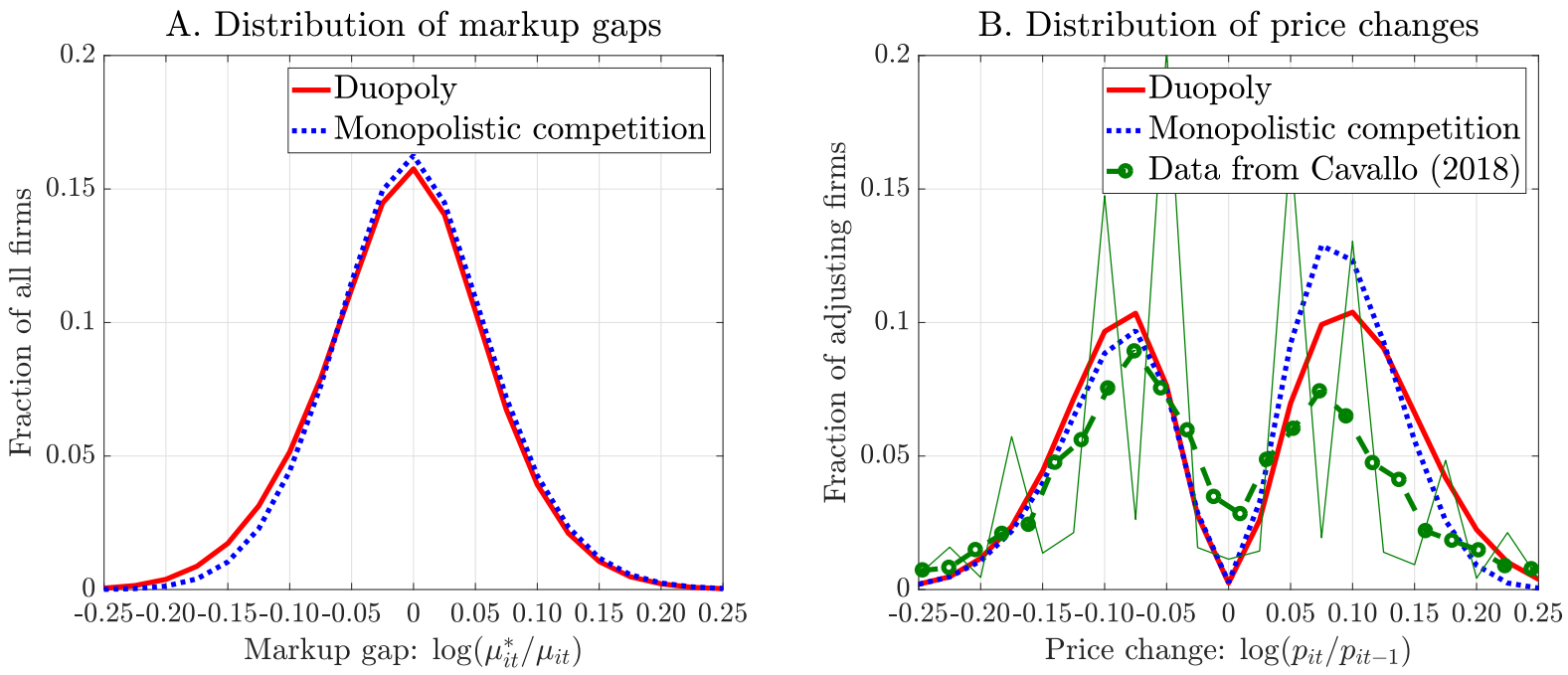
Oligopoly under Calvo

+ Lose selection effect $\rightarrow$ Larger output responses
- Weaker dynamic complementarity $\rightarrow$ Smaller output response
= Slightly larger output responses

Calvo: 30% larger under Duopoly vs 200% larger under M.C.

Back - Additional results

Distribution of price gaps [solid] and changes [dotted]



Back - Additional results

Firm problem

Markov states

- Sector — Markups $\bar{\mu}_i$, $\bar{\mu}_{-i}$ — $x = (\bar{\mu}_i, \bar{\mu}_{-i})$
- Aggregate — Distribution $\lambda(x)$, money growth g — $X = (\lambda, g)$

Equilibrium functions

- Aggregate markup $\mu(X)$

Timing and Information (Doraszelski Satterthwaite, 2007)

$$\underbrace{(x, X) \text{ determined}}_{\text{Public}} \rightarrow \underbrace{\text{Draw menu cost } \xi_i \sim U\left[0, \bar{\xi}\right]}_{iid \text{ + Private}} \rightarrow \underbrace{\text{Pricing decisions}}_{\text{Simultaneous}}$$

Competitor's policies

- Markup adjustment — $\mathbf{1}^{adj}_{-i}(x, X, \xi_{-i}) \in \{0, 1\}$
- Markup conditional on adjustment — $\mu^*_{-i}(x, X) \in \mathbb{R}_+$

Back - Recursive equilibrium

Firm problem

Value

$$V_i\left(x, X, \xi_i\right) = \max_{\mathbf{1}_i^{adj} \in \{0,1\}} \mathbf{1}_i^{adj}\left[V_i^{adj}\left(x, X\right) - \xi_i\right] + \left(1 - \mathbf{1}_i^{adj}\right) V_i^{stay}\left(x, X\right)$$

Value of adjusting price

$$V_i^{adj}\left(x, X\right) = \max_{\mu_i^* \in \mathbb{R}_+} \int_0^{\bar{\xi}} \left[\pi\left(\mu_i^*, \mu_{-i}(x, X, \xi_{-i}), \mu(X)\right) + \beta \mathbb{E}\left[V_i\left(x', X', \xi_i'\right)\right]\right] dF\left(\xi_{-i}\right)$$

$$\mu_{-i}(x, X, \xi_{-i}) = \underbrace{\mathbf{1}_{-i}^{adj}(x, X, \xi_{-i})\mu_{-i}^*(x, X)}_{\text{Competitor adjusts}} + \underbrace{\left(1 - \mathbf{1}_{-i}^{adj}(x, X, \xi_{-i})\right)\bar{\mu}_{-i}}_{\text{Competitor stays}}$$

Solution

- Probability of price adjustment $\gamma_i(x, X) = \int_0^{\bar{\xi}} \mathbf{1}_i^{adj}(x, X, \xi_i) dF(\xi_i)$
- Markup conditional on adjustment $\mu_i^*(x, X)$

Back - Recursive equilibrium