Market structure and monetary non-neutrality

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Introduction

Key question in macroeconomics

- How do changes in nominal spending affect output vs. inflation?
- Nominal rigidity + Firms are ‘small’ in their market (competitive)

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Motivation

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

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

2. Increasing concentration - Philippon Gutierrez (2017), Autor et al. (2017)

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Question

- How does market structure affect transmission of monetary shocks?

Approach

Quantitative model

- Firm heterogeneity - Idiosyncratic productivity shocks
- Nominal rigidity - Menu cost of changing prices
- Exogenous changes in nominal spending - Shocks to money supply
- New - Two ‘large’ firms in each sector. Dynamic oligopoly. ▸ Literature

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- 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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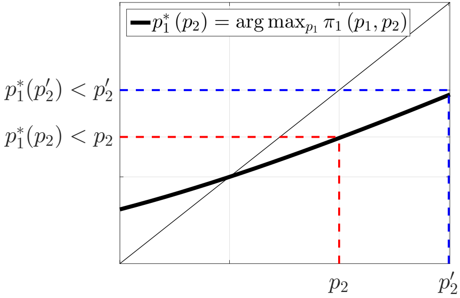
Main finding

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

Dynamic complementarity

Dynamic complementarity

Static complementarity



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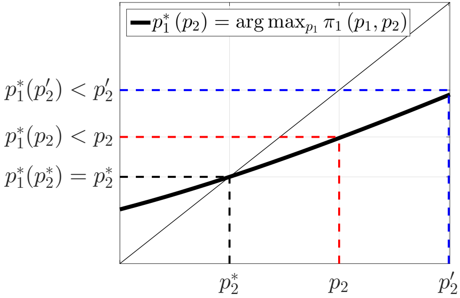

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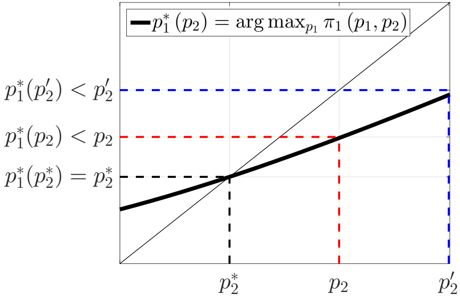

+ Menu costs $\rightarrow$ Wipe out small gains from best responses

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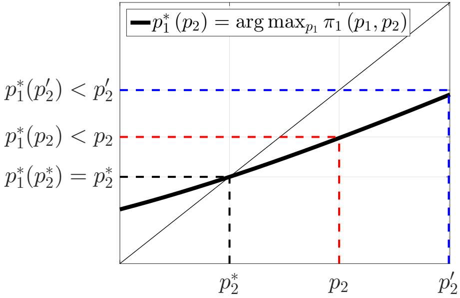

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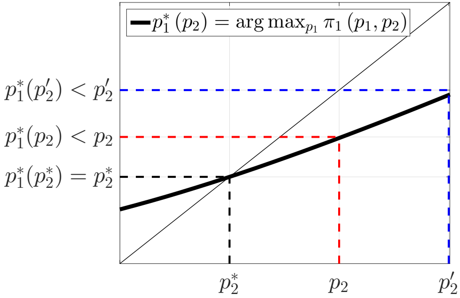

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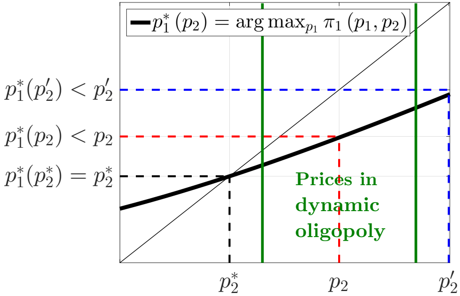

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Dynamic complementarity $\rightarrow$ Slow response of P

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Monopolistic competition

- Increase in money $\rightarrow$ Firm's relative price falls

1. Extensive
   - Firms with low prices more likely to change their price
2. Intensive
   - Price increases are larger to make up for increase in agg. prices

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Duopoly

- Increase in money $\rightarrow$ Competitor's relative price falls

1. Reduces desired price increase $\rightarrow$ $\downarrow$ Intensive
2. Reduces value of a price increase $\rightarrow$ $\downarrow$ Extensive

Three additional results

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1. Welfare

- Output is 10 ppt higher with no menu costs
- 75% due to higher markups, only 25% due to price dispersion
- Suggests a different focus for welfare analysis

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- MC menu cost models with SC can generate large real effects
- But implausible parameter values to match good-level data
- Addresses a challenge in the literature (Nakamura Steinsson '10)

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3. Empirical relationship (Carlton '86, Bils Klenow '04)

- Lower menu costs needed in the duopoly model
- *Across-region Within-product* correlations support model (IRI data)
- Better understand heterogeneity in price flexibility

Outline

Environment

Representative household

- **Preferences** Nested CES: Sectors $j \in [0,1]$, goods $i \in \{1,2\}$

Heterogeneous Firms

- **Technology** Good ij is produced by firm i in sector j using labor
- **Productivity** Firm-specific z_{ij}. Evolves stochastically.
- **Menu cost** Pay a cost ξ to change price

Monetary policy

- Money M grows at rate $g' = M'/M$

$$\log g' = (1-\rho_g)\log \overline{g} + \rho_g \log g + \sigma_g \varepsilon'_g$$

Household

Flow utility

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

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

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

Total nominal expenditure

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

▸ 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 problem - Solution

Markups

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

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

Household problem - Solution

Markups

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

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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 — $X = (\lambda, g)$

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Timing and Information (Doraszelski Satterthwaite, 2007)

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

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Competitor's policies

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

Firm problem

Value

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

Firm problem

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Value of adjusting price

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

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

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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 $\mu_i^*(x, X)$

Recursive equilibrium

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

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

- Transition function for the distribution of sectors $\lambda' = \Gamma_\lambda(X,\lambda)$
- Aggregate markup function $\mu(X)$

such that

1. $W = PC = M$ + Markup definitions $\leftrightarrow \mu(X) = \frac{1}{C(X)}$
2. Firm policies and values are Markov-Perfect at the sectoral level
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 $i \in [0,1]$

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

- Competitive equilibrium
- Same
  - Household problem
  - Shocks
  - Parameters: $\bar{\xi}$, σ_z, η, θ

Illustrative simulation

Show

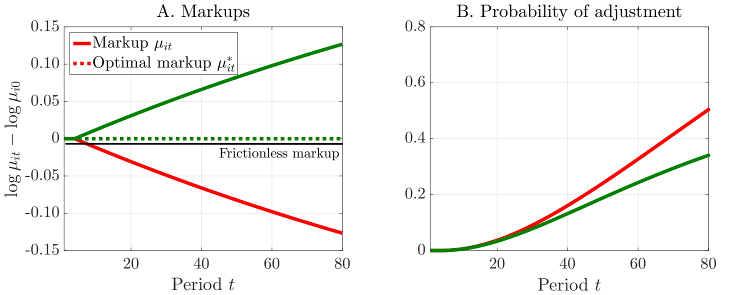
- Micro MPE policies attain high markups in equilibrium
- Macro Weaker intensive and extensive response to $\uparrow M$

Setup

- Fix paths for shocks $z_{it} \to \bar{\mu}_{it}$
- Fix paths for menu costs $\xi_{it} = \bar{\xi}$
- No aggregate shocks or inflation $g_t = 0$
- Show paths for equilibrium policies
  (i) Optimal markup $\mu^* \left(\bar{\mu}_{1t}, \bar{\mu}_{2t}\right)$
  (ii) Probability of adjustment $\gamma \left(\bar{\mu}_{1t}, \bar{\mu}_{2t}\right)$

Note: Using estimated parameters (next)

Monopolistic competition



Markups

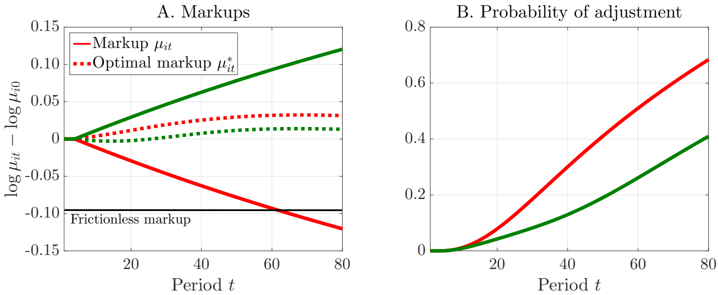
- Same optimal price $\mu^*_L = \mu^*_H$

Adjustment

- Precautionary motive $\gamma_L > \gamma_H$

Profit functions

Duopoly



Markups

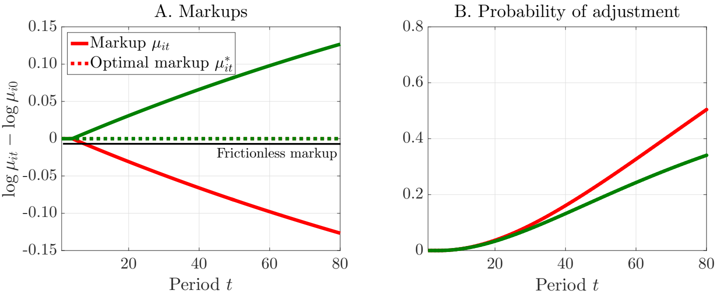
- Dynamic complementarity
- Policies support high markups

Adjustment

- High γ_L to incentivize low γ_H

▸ Profit functions

Monopolistic competition - $\uparrow M$



Intensive margin

Extensive margin

▸ Profit functions

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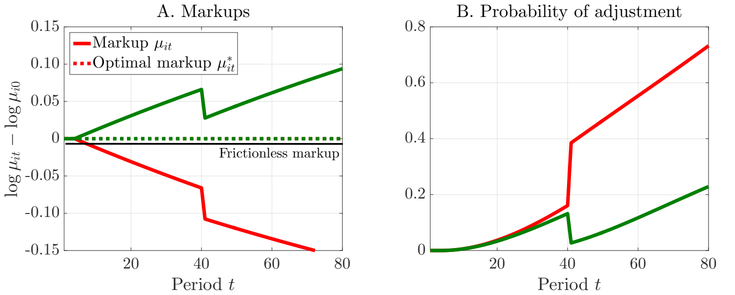


Intensive margin

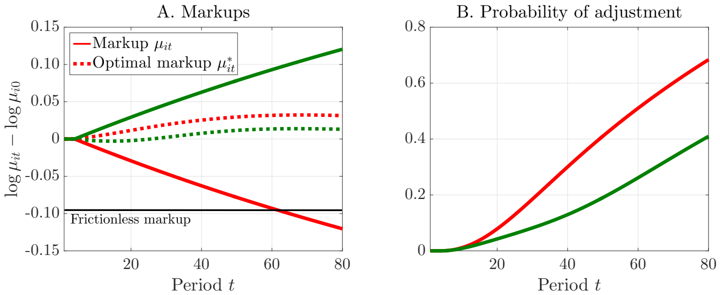
- Optimal price adjustment $\Delta p_L = \mu^*_L / \mu_L$ increases by ΔM

Extensive margin

- Jump in γ_L shifts price change dist. to price increases

▸ Profit functions

Duopoly - $\uparrow M$



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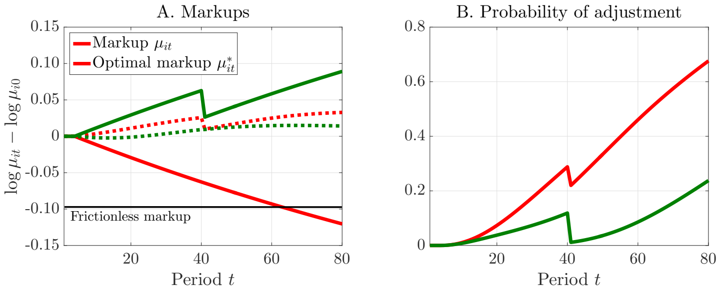


Intensive margin

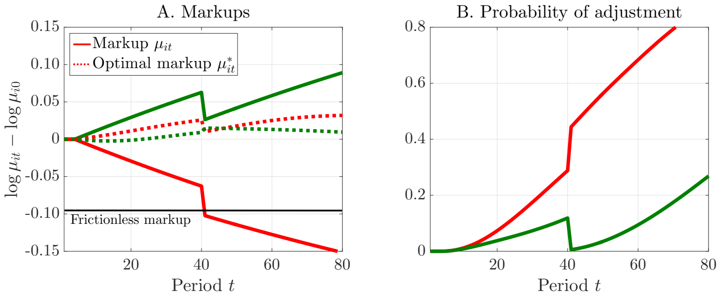
- Dynamic complementarities: Falling μ_H reduces μ^*_L

Extensive margin

- Lower value of adjustment $V_L^{adj} - V_L^{stay}$ reduces γ_L

▸ Profit functions

Duopoly - $\uparrow M$



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

Calibration - What contributes to larger output effects?

Static complementarity

- More substitutable within sectors η, less across sectors θ

Dynamic complementarity

- *Which features help firms to track each other's prices in the MPE?*
- Larger menu costs $\bar{\xi}$
- Smaller idiosyncratic shocks σ_z
- Lower trend money growth $\bar{g}$?
- Lower volatility of money growth σ_g?
- State-dependent (menu cost), rather than Calvo

Calibration - Strategy (monthly)

Parameters chosen externally

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

Parameters calibrated internally

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

Quantifying the real effects of monetary shocks

- Money supply and nominal demand

$$M_t = P_t C_t$$

- Log deviation from steady-state trend $(\bar{g} > 0)$

$$m_t \quad = \quad p_t + c_t$$

- Exogenous $\quad std\left[m_t\right]$

- Endogenous $\quad std\left[c_t\right], std\left[p_t\right]$

- Model: Aggregate demand $\rightarrow$ Price and Output responses

Calibration - Parameters and results

		Duopoly	MC
A. Parameter			
Across 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	0.04	0.04
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	$std\left[c_t\right]$	0.31	0.13
Average - Frictionless markup	$\mathbb{E}\left[\mu_{it}\right] - \mu_f$	0.10	0.02

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* 2.5 times larger output fluctuations (Data: US 1969-2016, $std[c_t] = 1.01$)

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3. 25 percent smaller menu costs deliver same frequency of price change

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

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Size of menu cost	$\bar{\xi}$	0.17	0.21	0.17
Size of idiosyncratic shocks	σ_z	0.04	0.04	0.04
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	$std[c_t]$	0.31	0.13	0.06
Average - Frictionless markup	$\mathbb{E}\left[\mu_{it}\right] - \mu_f$	0.10	0.02	0.01

∗ 2.5 times larger output fluctuations (Data: US 1969-2016, $std[c_t] = 1.01$)

1. 10 ppt larger markups than frictionless economy → Lower output
2. Same size shocks deliver observed size of price change
3. 25 percent smaller menu costs deliver same frequency of price change

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

Accounting for inflation

Questions

1. Lower price response due to smaller extensive or intensive margin?
2. Which sectors (μ_{1j}, μ_{2j}) dampen each margin the most?

Decomposition *à la* Caballero-Engel (2007)

- One-time unforeseen $\Delta M_t > 0$

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

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

Accounting for inflation

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

	Intensive %	**Extensive %**
Fraction of the difference: $\pi_t^{Mon} - \pi_t^{Duo}$	36	45
Fraction of each margin by (μ_{1j}, μ_{2j})		
Low-Low	-90	-73
Low-High / High-Low	142	122
High-High	48	51

Result

- Extensive and intensive margin components dampened $\approx$ equally
- Low markup sectors become more flexible

Relation to some of the literature

The duopoly mechanism does not deliver amplification through

- More kurtosis in dist. of price changes (Alvarez Bihan Lippi, 2016) ▸ +
- Excess curvature in demand as under Kimball (Klenow Willis, 2016) ▸ +

... but does depend on firm's ability to choose when to change prices

- Dynamic complementarities weaker under Calvo ▸ +

... and is qualitatively consistent with previous empirical work

- Strategic complementarities in pricing (Gopinath Itskhoki, 2010)
- Counter-cyclical μ's and conc. (Barro Tenreyo, '06; Rotemburg Woodford, '91)
- Prices stickier for differentiated (final) goods (Bils Klenow, 2004)

Additional results

1. Large output losses; menu costs lead to higher markups

   ▸ Results

2. Strategic complementarities in the literature

   ▸ Results

3. Empirical relationship between concentration and flexibility

   ▸ Results

Conclusion

Market structure quantitatively important for understanding

- Aggregate price flexibility following nominal spending shocks
- Firm level price flexibility following idiosyncratic shocks
- Cross-sectional heterogeneity in price flexibility

Market structure important for macroeconomics

- Increasing concentration and falling labor share
  Autor, Dorn, Katz, Patterson, Van Reenen (2016)
- Increasing concentration and weakening Tobin's $Q \leftrightarrow$ Investment
  Philippon Gutierrez (2016)

Need macroeconomic models that can speak to these changes!

THANK YOU!

Household - Solution

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

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

Demand

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

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. 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	$\mu_{ij} = \mathbb{E}[\mu_{ij}]$	0.77	0.77
(3)	... with no menu costs	$\mu_{ij} = \mu_f$	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 - 75% accounted for by higher markups
- 2nd order - 25% accounted for by price dispersion

Back - Additional results

2. 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
- And $\uparrow std[c_t]$ through strategic complementarity
- How? Complementarity is between μ_{1jt} and μ_{2jt}, not μ_{it} and μ_t

▸ Back - Additional results

3. Market concentration and price flexibility

3. Market concentration and price flexibility

1. Oligopoly

- Lower menu cost in duopoly model
- Prices change less when firms behave strategically
- Here   1 firm = Non-strategic, 2 firms = Strategic, ∞ firms = Non-strategic

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2. Elasticity

- More competition $\rightarrow$ More elastic demand $\rightarrow$ More price changes

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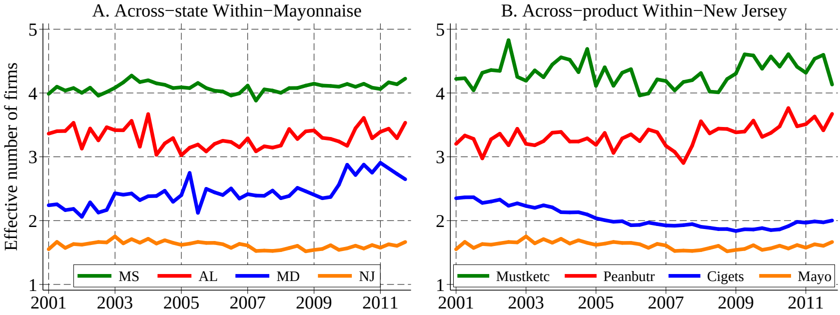
Examine correlation structure of IRI data

- U-shaped r'ship between freq of price change and concentration
- Hump-shaped r'ship between size of price change and concentration

3. Heterogeneity in market concentration



- Effective number of firms = Inverse Herfindahl Index

✓ Variation across states, within product categories

✓ Variation across product categories, within states

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

▸ Robust - Revenue share of top firm   ▸ Fig. Cross/within region variation in (i) frequency, (ii) size of price changes

3. Regression

	Across-state w/in product		Across-product w/in state	
	Size (%)	Frequency	Size (%)	Frequency
Eff. number of firms	0.244***	-0.912***	0.201***	-0.900***
	(0.037)	(0.161)	(0.043)	(0.181)
Eff. number of firms^2	**-0.048*** **	**0.171*** **	**-0.038*****	**0.228*****
	(0.010)	(0.043)	(0.012)	(0.072)
Observations	32,016	32,016	32,016	32,016
R-squared	0.100	0.106	0.036	0.031
Quarter FE	✓	✓	✓	✓
Rev_{pst} control	✓	✓	✓	✓

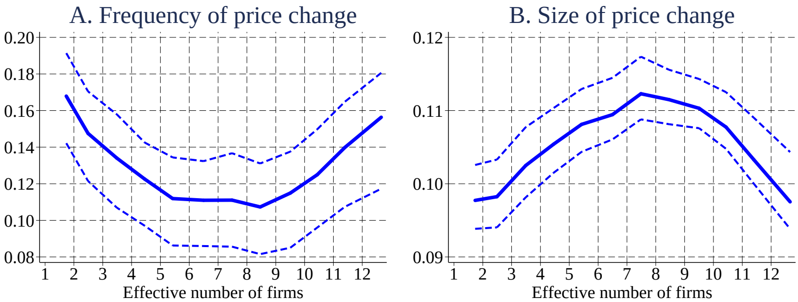
- Standard errors clustered at State × Product level

Result

- Hump-shaped profiles of price flexibility by market concentration
- Robust to either specification

▸ Estimating equations ▸ Unweighted ▸ Number of goods weighted ▸ No rev. control ▸ Revenue share

3. Average predicted values: Across-state w/in product



Note Solid lines plot the revenue weighted mean of predicted (A.) frequency (B) size of price change from across-state within-product regression. Means are computed within *Effective number of firms* bins of width one. Dashed lines give $25^{th}/75^{th}$ percentiles.

Model has a causal interpretation of correlations in the data

- Oligopoly forces strong at a small handful of firms, then weaken
- Market structure important for understanding price flexibility

▸ 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

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

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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 $\pi^f \left(p_1, p_2, z_1, z_2, M, \delta \right) - \phi = 0$

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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1. Preferences

$$C = \left[\omega_h^{\frac{1}{\sigma}} \left(z_h c_h \right)^{\frac{\sigma-1}{\sigma}} + \left(1 - \omega_h\right)^{\frac{1}{\sigma}} \left(z_f c_f \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

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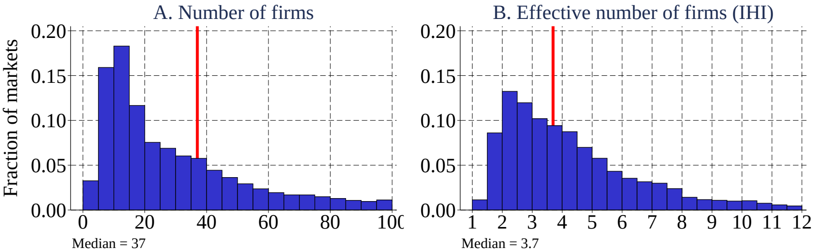
2. Marginal cost

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

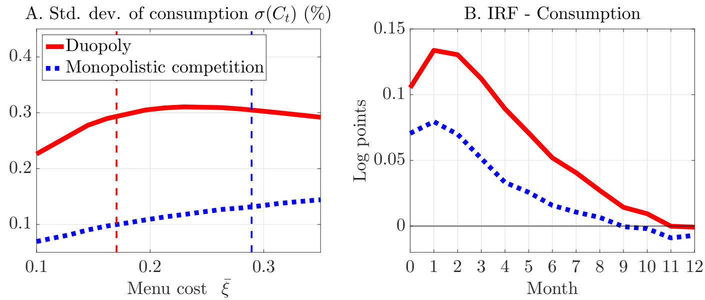
Data - Markets are highly concentrated

- **Market** 31 IRI product cat. (p) $\times$ 46 states (s) $\times$ 40 quarters (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

Household

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

where

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

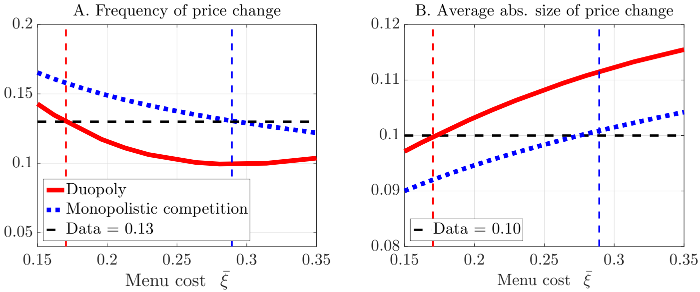
$$C_j \;=\; \left[c_{1j}{}^{\frac{\eta-1}{\eta}} + c_{2j}{}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad , \quad \eta > \theta$$

subject to a nominal budget constraint

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

Back - Household preferences

Menu cost comparative statics



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

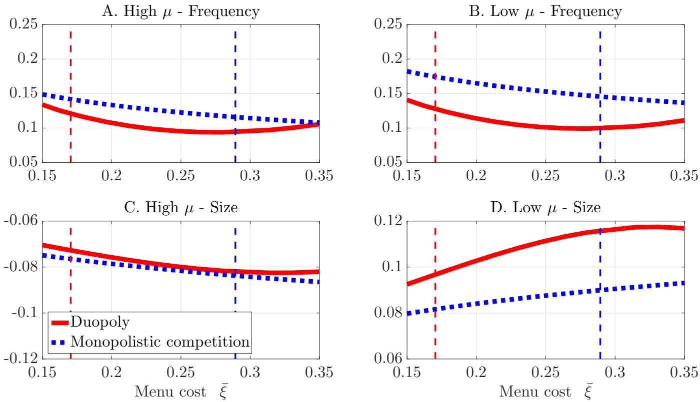
- But... Wider bounds $\rightarrow$ $\downarrow$ Frequency
- Turns out, direct effect dominates

Increasing η

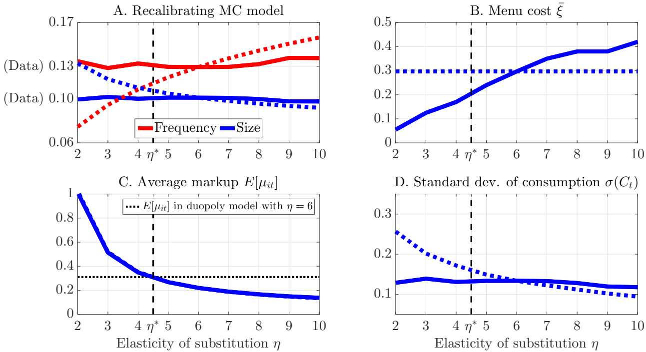
- Increase average markup

Back - Calibration strategy

Menu cost comparative statics



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 $\mathbb{E}\left[\mu_{it}\right] = 1.30$ 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

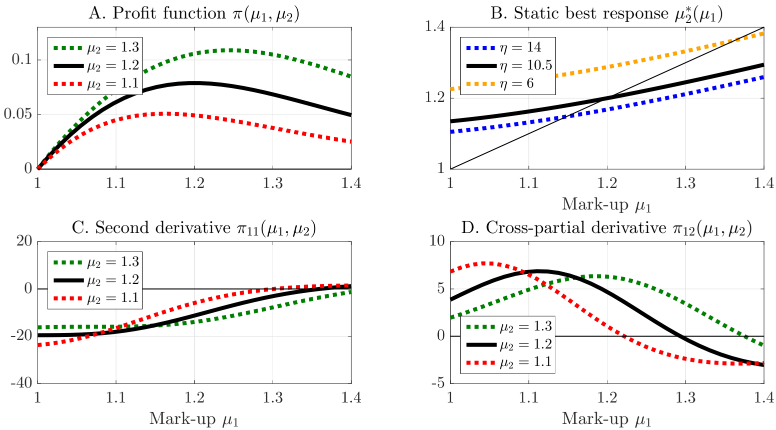
- Approximate expected value function $V^e\left(\mu_1, \mu_2, \mu, g\right)$

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

- 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

		Duopoly	Monopolistic competition			
			Base	Alt. I	Alt. II	Alt. III
A. Parameter						
Elasticity of demand	η	**10.5**	4.5	**10.5**	**10.5**	**6**
Size of menu cost	$\bar{\xi}$	**0.17**	0.21	**0.17**	0.42	0.29
Size of shocks	σ_z	**0.04**	0.04	**0.04**	0.04	0.04
B. Moments matched						
Average markup	$\mathbb{E}[\mu_{it}]$	**1.30**	**1.30**	1.12	1.13	1.22
Frequency of price change		**0.13**	**0.13**	0.19	**0.13**	**0.13**
Size of price change		**0.10**	**0.10**	0.05	**0.10**	**0.10**
C. Results						
Std. deviation consumption	$\sigma(C_t)$	0.31	0.13	0.06	0.13	0.13
Average - Frictionless markup	$\mathbb{E}[\mu_{it}] - \mu^*$	0.10	0.02	0.01	0.02	0.02

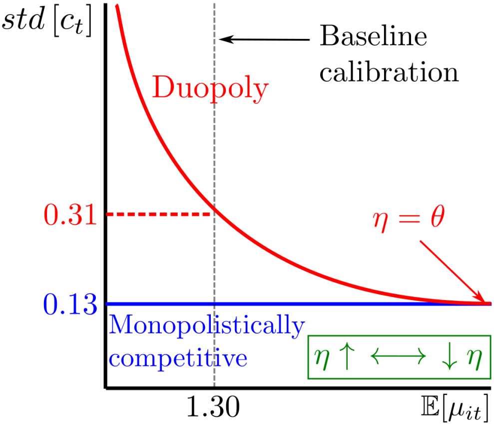
I Parameters same as estimated duopoly model

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

III Both models have flexible price markup of 1.20

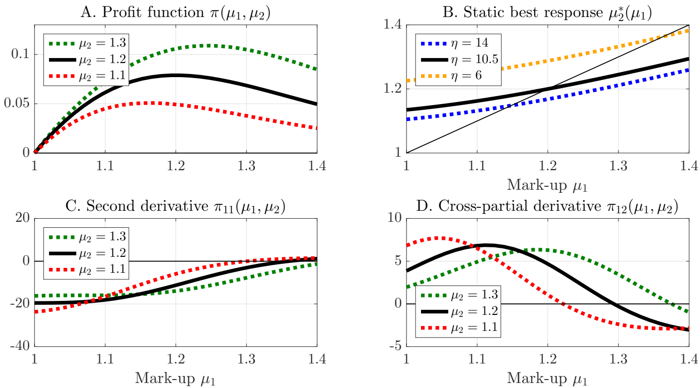
▸ Back - Calibration

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



Back - Calibration

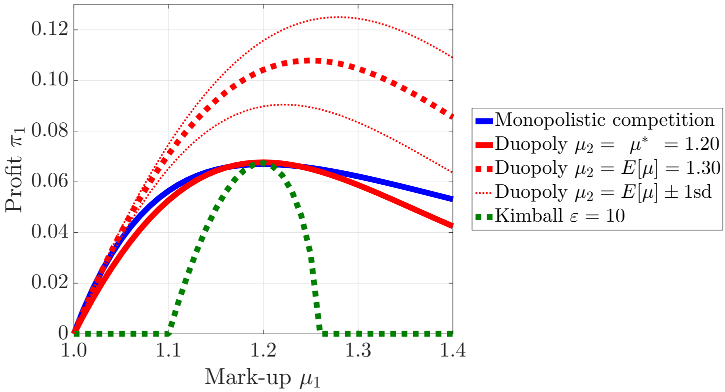
Profit function properties



- 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

Relation to Kimball-style strategic complementarity



- Duopoly demand function super-elasticity $\varepsilon \in [0.3, 0.7]$
- Literature Klenow Willis - $\varepsilon = 10$, Gopinath Itskhoki - $\varepsilon = 4$

▸ 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 99^{th} 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

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

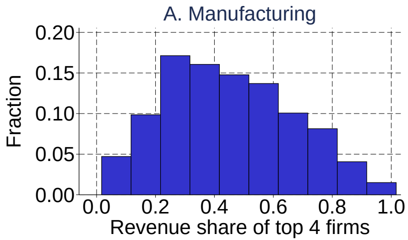
▸ Back - Empirical - Size of price changes ▸ Back - Regression specification ▸ Back - Calibration

Comparison to Census Manufacturing

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

✓ Few industries are national, e.g. Manufacturing

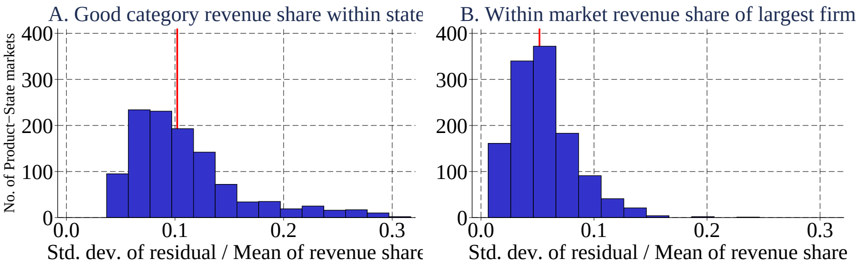
✗ Most industries are local, e.g. Health care



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

▸ Back - Introduction ▸ Back - Inverse herfindahl

Category vs. Firm Revenue Share Fluctuations



- For each state s, product category p, take

A. Revenue share of product category r_{pst} / r_{st}

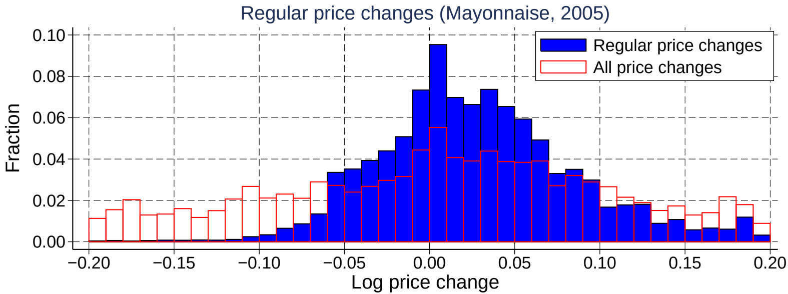
B. Within product category revenue share of largest firm r^1_{pst} / r_{pst}

- Compute coefficient of variation

∗ Standard deviation computed after removing cubic time trend

▸ Back - Calibration

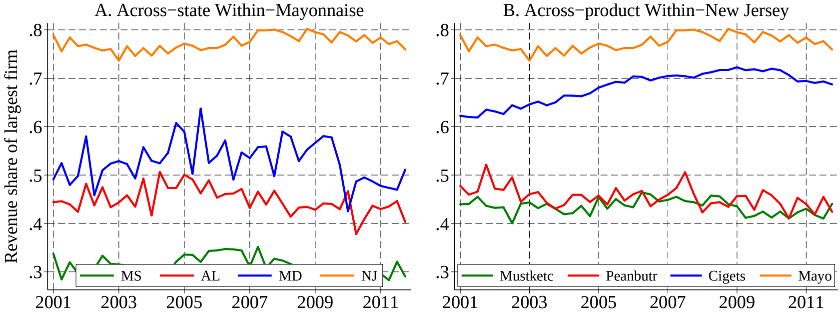
Empirical - Distribution of price changes



− Regular price changes: Mean = .0396, Std dev. = .087, Skew = 1.673, Kurtosis = 11.149
− All price changes: Mean = .0005, Std. dev. = .256, Skew = −.108, Kurtosis = 3.418

▸ Back - Empirical - Size of price changes

3. Variation in market concentration - Share top firm



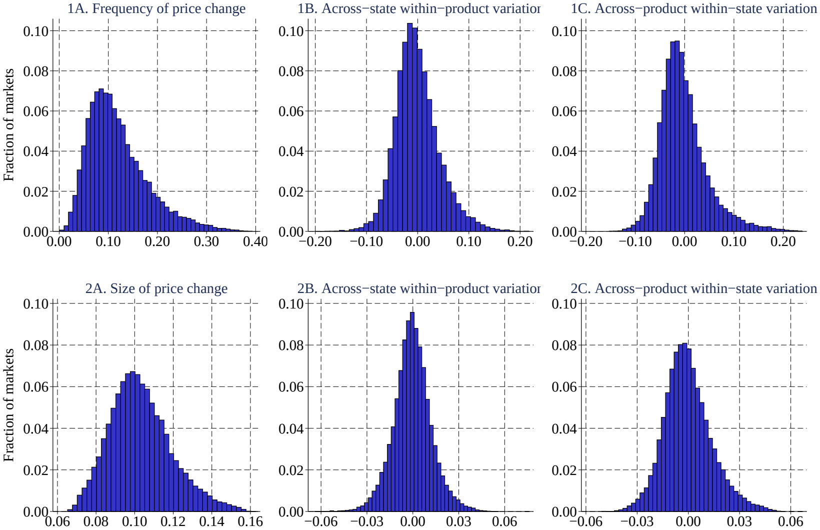
✗ Little time-series variation

✓ Variation across states, within product categories

✓ Variation across product categories, within states

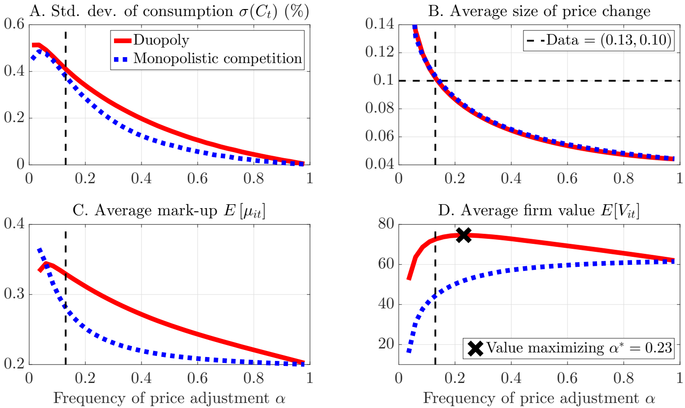
▸ Back - Variation in concentration

3. Variation in price flexibility



▸ Back - Variation in concentration

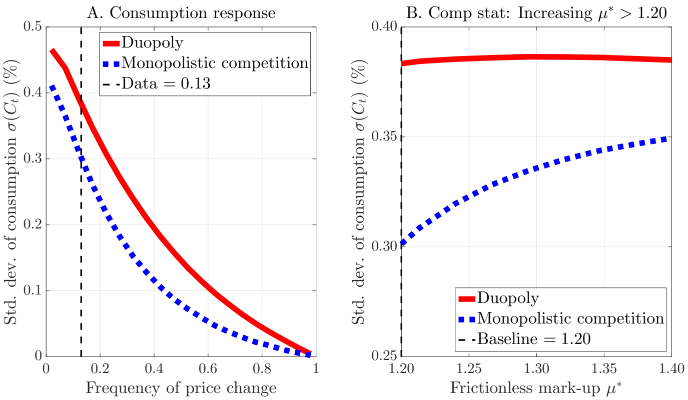
Varying nominal rigidity in a Calvo rigidity α



- DC and MC models converge as $\alpha \to 1$
- Optimal exogenous frequency of price adjustment $\alpha^* = 0.23$

Back - Additional results

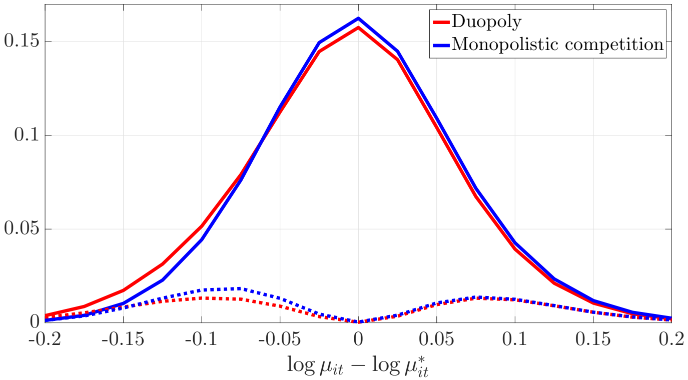
Comparative statics in Calvo model



- MC - Increasing $\uparrow \mu^*$ $\rightarrow$ Less substitutable $\rightarrow$ P responds slowly
- DC - Increasing $\uparrow \mu^*$ $\rightarrow$ Less substitutable $\rightarrow$ p_i more flexible

▸ Back - Additional results

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



- MC - Random ξ model is between Golosov-Lucas and Midrigan
- DC - Left skewness due to lower price flexibility at low μ firms

Back - Additional results

Regression - Estimating equations

Across-state, within-product

- Remove quarter t mean for each product category, taken across states

$$\left(y_{pst} - \bar{y}^{s}_{pt}\right) = \alpha_t + \beta_1 \left(x_{pst} - \bar{x}^{s}_{pt}\right) + \beta_2 \left(x_{pst} - \bar{x}^{s}_{pt}\right)^2 + \varepsilon_{pst}$$

Across-product, within-state

- Remove quarter t mean for each state, taken across product categories

$$\left(y_{pst} - \bar{y}^{p}_{st}\right) = \alpha_t + \beta_1 \left(x_{pst} - \bar{x}^{p}_{st}\right) + \beta_2 \left(x_{pst} - \bar{x}^{p}_{st}\right)^2 + \varepsilon_{pst}$$

Additional details

- y_{pst} - Size and frequency of price change
- x_{pst} - Measures of market concentration
- Standard errors clustered at State×Product level

▸ Back - Main regression   ▸ Data details

Regression results - Uniformly weighted

	Across-state w/in product		Across-product w/in state	
	Size (%)	Frequency	Size (%)	Frequency
Eff. number of firms	0.205***	-0.664***	0.138***	-0.667***
	(0.018)	(0.088)	(0.042)	(0.133)
Eff. number of firms^2	-0.018***	0.014	-0.017	0.099
	(0.004)	(0.017)	(0.014)	(0.070)
Observations	32,016	32,016	32,016	32,016
R-squared	0.061	0.078	0.009	0.016
Quarter FE	✓	✓	✓	✓
Rev_{pst} control	✓	✓	✓	✓

- Standard errors clustered at State × Product level

Result

- Hump-shaped profiles of price flexibility by market concentration
- Robust to either source of variation

Back - Main regression

Regression results - Number of goods weighted

	Across-state w/in product		Across-product w/in state	
	Size (%)	Frequency	Size (%)	Frequency
Eff. number of firms	0.186***	-0.516***	0.147***	-0.661***
	(0.034)	(0.134)	(0.051)	(0.176)
Eff. number of firms^2	-0.024***	0.026	-0.030**	0.177**
	(0.007)	(0.031)	(0.015)	(0.074)
Observations	32,016	32,016	32,016	32,016
R-squared	0.061	0.078	0.009	0.016
Quarter FE	✓	✓	✓	✓
Rev_{pst} control	✓	✓	✓	✓

- Standard errors clustered at State × Product level

Result

- Hump-shaped profiles of price flexibility by market concentration
- Robust to either source of variation

Back - Main regression

Regression results - No revenue control

	Across-state w/in product		Across-product w/in state	
	Size (%)	Frequency	Size (%)	Frequency
Eff. number of firms	0.244***	-0.956***	0.220***	-0.894***
	(0.038)	(0.181)	(0.043)	(0.181)
Eff. number of firms^2	-0.048***	0.183***	-0.041***	0.227***
	(0.010)	(0.050)	(0.012)	(0.072)
Observations	32,016	32,016	32,016	32,016
R-squared	0.100	0.095	0.028	0.031
Quarter FE	✓	✓	✓	✓
Rev_{pst} control	✗	✗	✗	✗

- Standard errors clustered at State × Product level

Result

- Hump-shaped profiles of price flexibility by market concentration
- Robust to either source of variation

Back - Main regression

Regression results - Rev. share top firm

	Across-state w/in product		Across-product w/in state	
	Size (%)	Frequency	Size (%)	Frequency
Rev. share top firm	-1.411***	7.727***	-1.436***	6.099***
	(0.428)	(2.015)	(0.392)	(2.286)
Rev. share top firm^2	-9.739***	16.939**	-3.546	13.318
	(1.964)	(7.817)	(3.126)	(17.419)
Observations	32,016	32,016	32,016	32,016
R-squared	0.133	0.107	0.027	0.016
Quarter FE	✓	✓	✓	✓
Rev_{pst} control	✓	✓	✓	✓

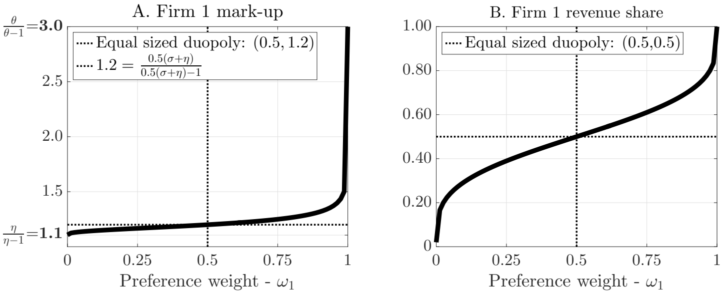
- Standard errors clustered at State $\times$ Product level

Result

- Hump-shaped profiles of price flexibility by market concentration
- Robust to either source of variation

Back - Main regression

Static Nash - Varying ω_1



Preferences

$$C = \left[\int_0^1 c_j^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \qquad c_j = \left[\omega_1 c_{1j}^{\frac{\eta-1}{\eta}} + (1-\omega_1) c_{2j}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

- As $\omega_1 \to 1$, μ_1 converges to monopolistically comp. markup under θ
- As $\omega_1 \to 0$, μ_1 converges to monopolistically comp. markup under η

Back - Nested models