Search, Competition, and Monetary Non-Neutrality

13th NYU Search Theory Workshop

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April 19, 2019

Introduction

Motivation:

- Important feature of product markets is ability to search for prices

In this project:

- Show evidence of product market frictions
- Incorporate these frictions into a menu cost model
- Study how they affect monetary non–neutrality

Main result:

- Product market frictions increase monetary non–neutrality

Outline

Empirically document price dispersion:

- Cross–sectional dispersion is large: $\sigma = 16\%$
- Most of this cannot be explained by store or product differences

Incorporate frictional product markets into a menu cost model:

- Burdett–Judd search frictions
- Heterogeneous productivity
- Menu cost

Study implications for monetary non–neutrality:

- Compare to Golosov & Lucas
- Application: cyclicality of monetary non–neutrality

Price dispersion decomposition

Why are prices different?

- **Good differences:** Hansen's is more expensive than Coca–Cola
- **Store differences:** Coca–Cola at Whole Foods is more expensive than at Safeway

Today:

- The extent of price dispersion is large
- Large component of dispersion is **not** due to store or good differences
- $\Rightarrow$ Heterogeneity in the price of the same good at similar stores

Data: Kilts–Nielsen RMS

- Weekly price and quantity data at 35,000 stores across the U.S.
- Product = barcode

Price decomposition

Following Kaplan and Menzio (2015):

$$\log p_{jst} = \mu_{jt} + y_{st} + z_{jst}$$

- Good component:

$$\mu_{jt} = \frac{1}{S} \sum_{s=1}^{S} \log p_{jst}$$

- Normalized price

$$x_{jst} = \log p_{jst} - \mu_{jt}$$

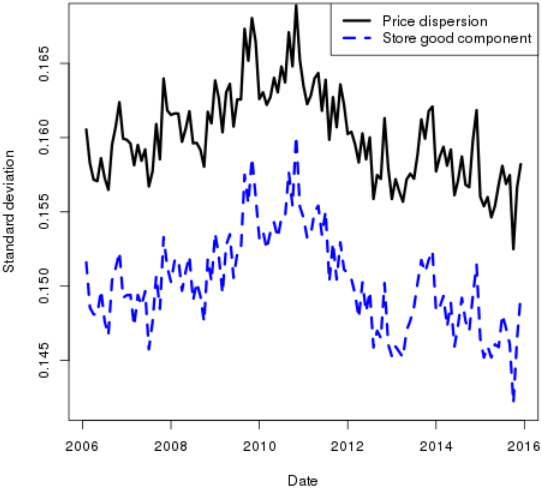
- Store component:

$$y_{st} = \frac{1}{J} \sum_{j=1}^{J} x_{jst}$$

- Store–good component:

$$z_{jst} = x_{jst} - y_{st}$$

Motivating fact



weighted

Modeling store–good dispersion

Burdett–Judd (1983):

- Informational frictions
- Firms face a tradeoff between high and low prices
- Indifference leads firms to set heterogeneous prices

Price dispersion also arises from:

- Menu costs
- Productivity differences and product differentiation

Today's model:

1. Frictional product market
2. Menu cost
3. Productivity heterogeneity + product differentiation

A quantitative model

Environment:

- Discrete time
- A single market for a homogeneous good y
- Background inflation π
- Nominal wage W tracks inflation

Each period, a measure one of households:

- Enters the market and seeks to purchase the good
- May face heterogeneous prices
- A household facing real price p will purchase

$$d(p) = p^{-1/\gamma}$$

A quantitative model

A measure one of sellers:

- Maximize present discounted value of future profits
- Produce homogeneous good using CRTS production function:

$$y_i = z_i \ell_i \quad z' \sim \Gamma(z'|z)$$

- $\Gamma(z'|z)$ a persistent productivity process:

$$z' = \begin{cases} \rho z + \epsilon & \text{with probability } \lambda \\ z & \text{with probability } 1 - \lambda \end{cases}$$

- Real input cost fixed at ω
- Each posts nominal price d, faces real menu cost ϕ
- Inflation erodes their real price by π each period

A quantitative model

Firms meet buyers in a Burdett–Judd (1983) market:

- Distribution of real prices $F(p)$
- Each consumer encounters either one or two firms
- Measure α meet only one firm, $1-\alpha$ meet two
- If buyer encounters two firms, purchases good from firm with a lower price
- Profit for a firm with a real price p is then

$$R(p,z;F) = \Big[\underbrace{\alpha}_{\text{captive}} + \underbrace{2(1-\alpha)(1-F(p))}_{\text{non–captive}}\Big] \underbrace{\left(p - \frac{\omega}{z}\right)}_{\text{per–unit profit}} \underbrace{p^{-1/\gamma}}_{\text{intensive margin}}$$

A quantitative model

A firm must pay menu cost ϕ to change its price

The value of a firm with real price p and productivity z:

$$V(p,z) = \max\left\{V^{NA}(p,z), V^{A}(z) - \phi\right\}$$

where

$$V^{NA}(p,z) = R(p,z;F) + \mathbb{E}_{z'}\left[V\left(\frac{p}{1+\pi}, z'\right)\right]$$

$$V^{A}(z) = \max_{p'}\left\{R(p',z;F) + \mathbb{E}_{z'}\left[V\left(\frac{p'}{1+\pi}, z'\right)\right]\right\}$$

Equilibrium

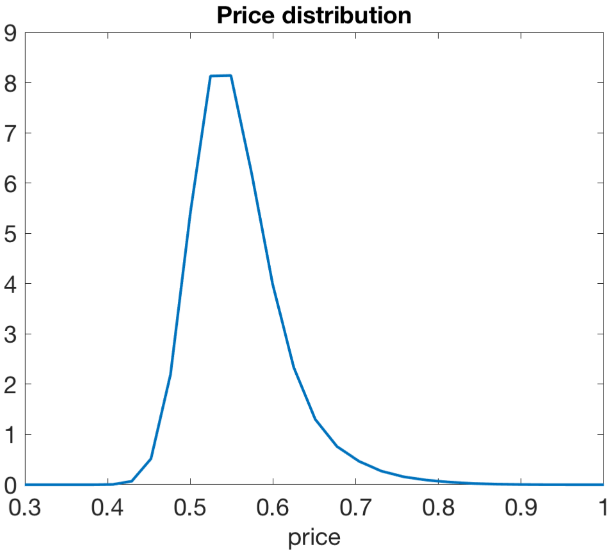
A steady–state equilibrium is:

- A distribution of real prices, $F(p)$
- Policy rules and value functions

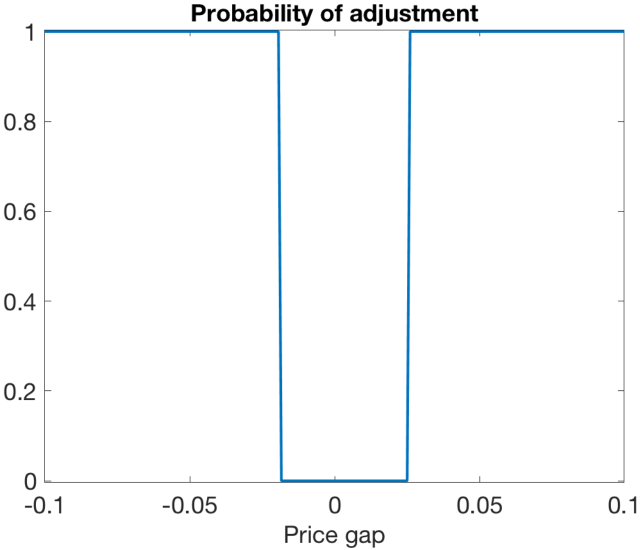
such that:

- Conditional on the distribution of prices, the policy rules maximize the value functions
- The value functions satisfy their recursive definitions
- The steady–state distribution implied by the policy rules is consistent with the distribution of real prices

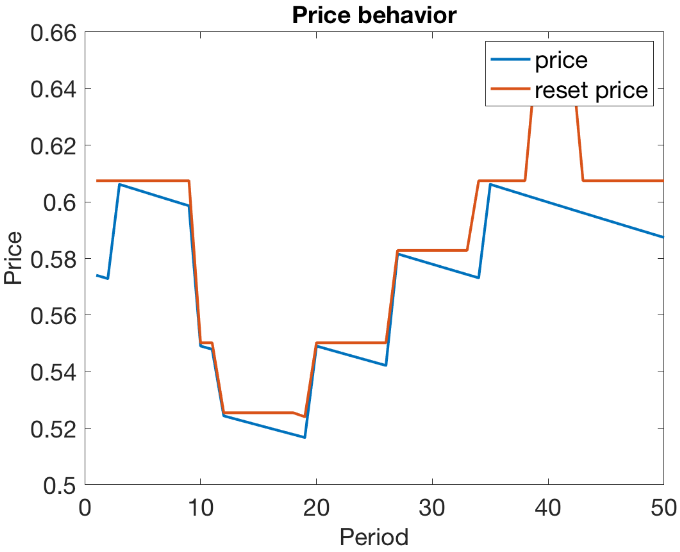
The equilibrium distribution of prices



(s,S) policy


Probability of adjustment
1
0.8
0.6
0.4
0.2
0
-0.1
-0.05
0
0.05
0.1
Price gap

Simulated firm policy



Product market frictions and price stickiness

How does introducing product market frictions impact price stickiness?

Exercise: Compare response of output to a monetary shock in Golosov–Lucas and search economies calibrated to same moments

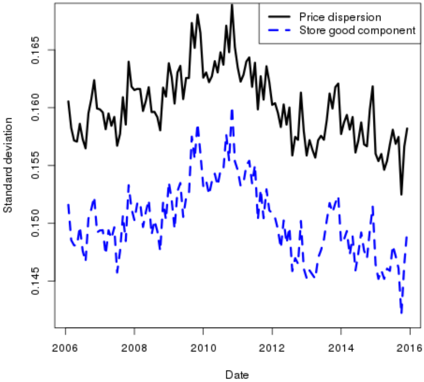
Flow profits:

$$R(p, z; F) = \Big[\alpha + 2(1-\alpha)(1-F(p))\Big]\left(p - \frac{\omega}{z}\right)p^{-1/\gamma}$$

Golosov–Lucas a special case ($\alpha = 1$):

$$R(p, z; F) = \left(p - \frac{\omega}{z}\right)p^{-1/\gamma}$$

Calibrating the model



- Kaplan et al (2015): 36% of the variance is persistent
- Target: $\sqrt{.36 \times 14.2^2\%} = 8.5\%$

Calibration

Targets:

- Frequency of price adjustment: 11%
- Average size of price change: 7.5%
- Price dispersion: 8.5%

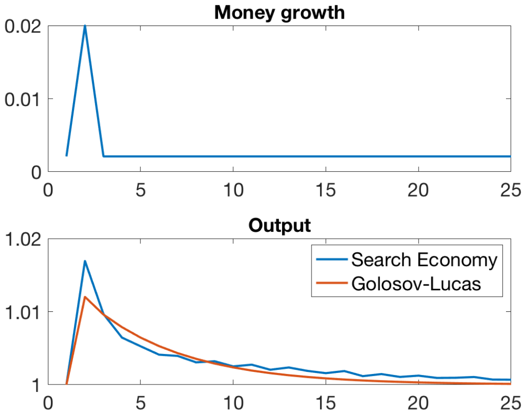
Calibrations

	Search economy	Golosov–Lucas
Variance of productivity shock	5%	5.2%
Menu cost	0.135	0.02
Measure of captive customers	13%	100%
Frequency of price change	11.2%	11.1%
Average size	7.1%	7.6%
Price dispersion	8.5%	8.6%

Externally calibrated parameters

Output response

Experiment: Unanticipated 2% shock to the growth rate of money



Output response

Response of output to a monetary shock

Statistic	Search economy	GL economy	% difference
Peak response	1.69%	1.20%	41%
Total response	7.70%	6.45%	19%

- Introducing search implies stronger monetary non–neutrality
- Peak and total response is larger in the search economy
- Total response is larger partly due to persistence in prices

What's going on?

A monetary shock moves firms' optimal prices and pushes them toward adjustment bands.

How much do reset prices move?

- Real rigidities

How likely are firms to adjust and by how much?

- Caballero–Engel (2007) decomposition
- Alvarez–Le Bihan–Lippi (2016) statistic

Elasticity of demand

The demand of a firm with price p is:

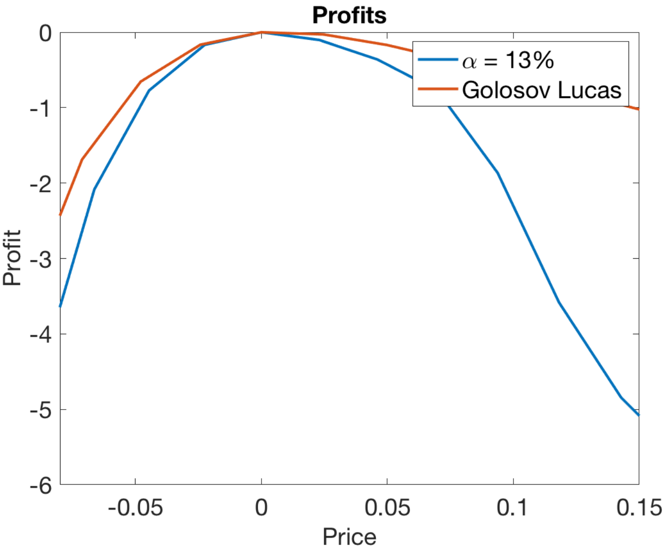
$$D(p, z; F) = \Big[\alpha + 2(1-\alpha)(1-F(p))\Big] p^{-\frac{1}{\gamma}}$$

The elasticity of demand is:

$$\frac{\partial \log D}{\partial \log p} = -\frac{2(1-\alpha)f(p)p}{\alpha + 2(1-\alpha)(1-F(p))} - \frac{1}{\gamma}$$

- Elasticity is $-1/\gamma$ when $f(p) = 0$ or when $\alpha = 1$
- For high $f(p)$, demand is more elastic

Real rigidities



Real rigidities

Golosov–Lucas ignores an extra margin of consumer adjustment:

- Consumers are entirely captive in GL
- In search economy, some consumers can switch to other stores
- This penalizes firms for setting high prices

Profit curvature + coordination failure makes prices stickier:

- A monetary shock lowers all real prices
- Because of menu cost, not all firms adjust
- Those that do adjust face sharp penalty for high relative price

How likely are firms to adjust and by how much?

Caballero–Engel decomposition:

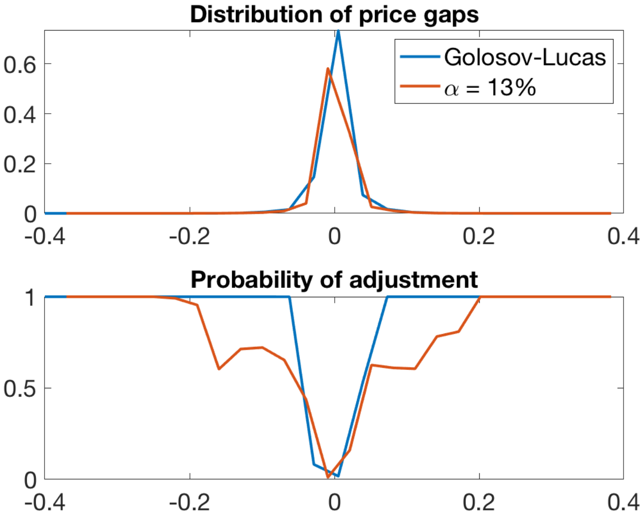
- Price gap $x \equiv \log p^* / \log p$
- Distribution of price gaps $f(x)$
- Probability of adjustment $\Lambda(x)$

A first order Taylor approximation implies:

$$\lim_{\Delta S \to 0} \frac{\Delta \pi}{\Delta S} = \underbrace{\int \Lambda(x) f(x) dx}_{\text{Intensive Margin (Frequency)}} + \underbrace{\int x \Lambda'(x) f(x) dx}_{\text{Extensive Margin}}$$

Details

The distribution of price gaps matters



The distribution of price gaps matters

Table: Caballero Engel (2007) Decomposition

Calibration	Intensive	Extensive	Total
Search	11.2%	14.4%	25.6%
GL	11.1%	17.8%	29.0%

- Search economy has stickier prices
- Intensive margin pinned down by frequency of adjustment
- So, difference is due to the extensive margin:

$$\int x \Lambda'(x) f(x) dx$$

- High menu cost + heterogeneous penalty

The distribution of price gaps matters

Alvarez et. al (2016) sufficient statistic:

$$\mathcal{M} \propto \frac{Kur(\Delta p_i)}{N(\Delta p_i)}$$

- Summarizes the selection effect
- Calvo: High kurtosis (lots of small price changes)
- Golosov–Lucas: Low kurtosis (most price changes are large)

Caveats:

- Sufficient statistic holds in Golosov Lucas (in GE)
- Requires that p^* moves one–for–one with ΔM
- So does not hold in model with $\alpha < 1$

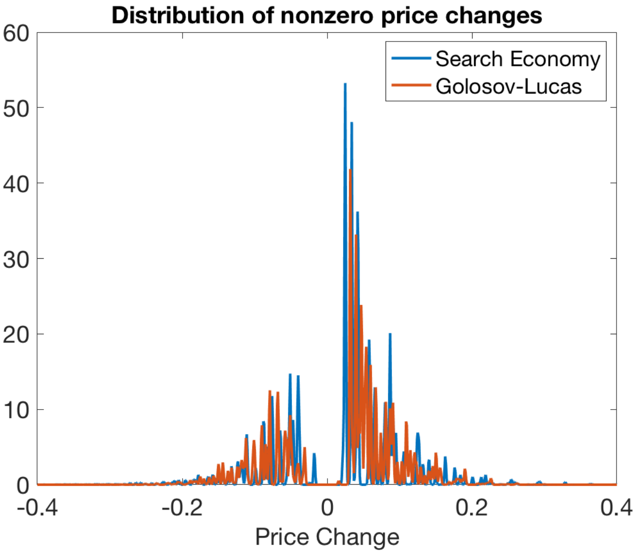
Alvarez–Le Bihan–Lippi statistic

Table: Alvarez, Le Bihan & Lippi (2016) statistics

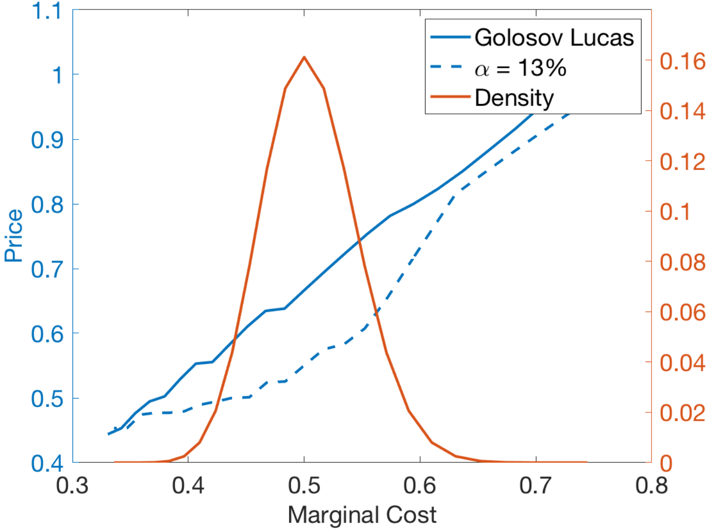
Calibration	Frequency	Kurtosis	Kurtosis/Frequency
Search	1.31	4.32	3.20
GL	1.34	2.76	2.07

- Frequency pinned down by calibration
- Higher kurtosis of price changes in search economy
- More mass of large and small price changes in search economy

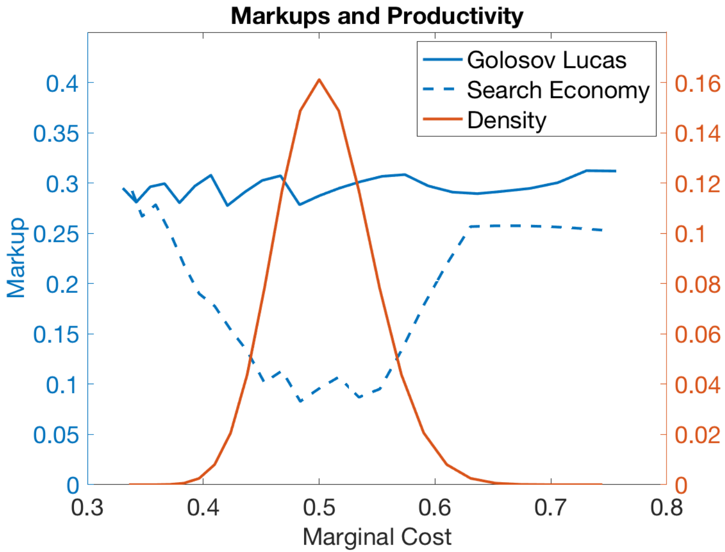
Kurtosis is higher in the search economy



Why is kurtosis higher in the search economy?



Non–constant markups



How does introducing search affect monetary non–neutrality?

How much do reset prices move?

- Firms in search economy are penalized for high relative prices

How likely are firms to adjust and by how much?

- Lots of firms with low incentive to change price
- This lowers probability of adjustment
- Have higher kurtosis of price changes

To do

- Calibrate both models to match ALL statistics
- Match the productivity dispersion between stores of same productivity

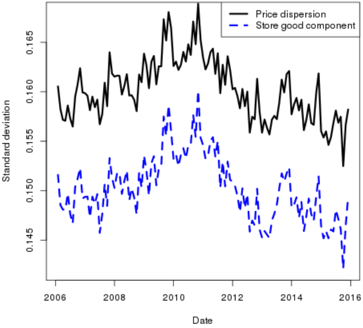
Application: monetary non–neutrality in booms and busts

How to rationalize countercyclical price dispersion?

- Vavra (2014): countercyclical productivity dispersion
- What about counter–cyclical pricing power?
- An increase in α might lead firms to set more dispersed prices

Question: What could cyclical variation in α imply for monetary non–neutrality over the business cycle?

Monetary policy in recessions



- Kaplan et al (2015): 36% of the variance is persistent
- Target: $\sqrt{.36 \times 16^2\%} = 9.6\%$ and $\sqrt{.36 * 14.2^2\%} = 8.5\%$

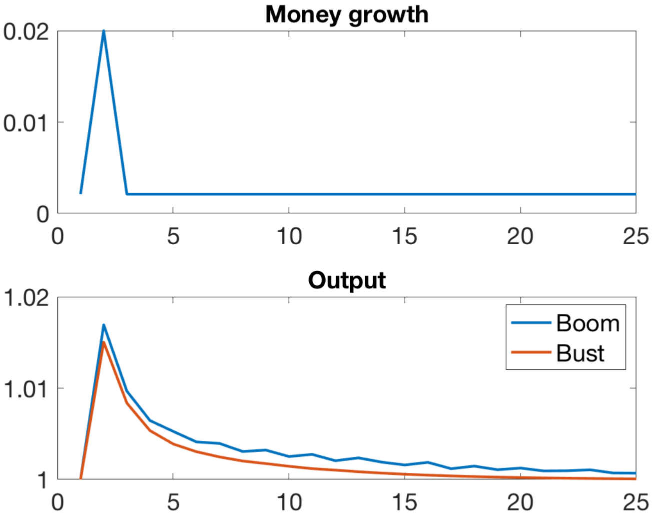
Calibrating the model over the business cycle

The model in normal times and in a recession

	Normal times	Recession	Data
Variance of productivity shock	0.05	–	–
Menu cost	0.135	–	–
Measure of captive customers	13%	25%	–
Frequency of price change	11.2%	10.4%	11%
Average size	7.1%	8.3%	7.5%
Price dispersion	8.5%	9.7%	(8.5%, 9.6%)

Externally calibrated parameters

Effects of a monetary shock



Effects of a monetary shock

In response to a 2% shock to money growth:

Response of output to a monetary shock

Statistic	Boom	Bust	% difference
Peak response	1.69%	1.5%	12%
Total response	7.70%	5.0%	50%

- The peak response is 12% of the initial change in the money supply
- Total response is much larger due to persistence in prices
- Monetary policy is much more effective at stimulating output in the boom than in the bust

What's going on?

Prices are stickier in booms

Real rigidities

- Lower α in booms makes profit function have more curvature
- Makes prices in booms stickier, increases persistence

Distribution of price gaps

- Lower α in booms penalizes high relative prices
- Pushes firms toward their adjustment bands
- Makes prices in booms more flexible

Kurtosis similar

- Slightly higher in booms
- Makes prices stickier in booms

Detail

Relation to literature

Vavra (2014) also studies time–varying price dispersion

- He accounts for time varying dispersion using time–varying idiosyncratic firm volatility
- Concludes that monetary policy is *less* effective in recessions
- I find the same by accounting for a similar fact in a different way

Responsiveness or uncertainty?

- Berger and Vavra (forthcoming), Bachmann and Moscarini (2012), Ilut et. al (2014), Baley and Blanco (2016), Munro (2016)

Relation to literature

Competition and monetary policy: Klenow and Willis (2016), Mongey (2018), Wang and Werning (2018)

- New: way of modeling competition

Ss model and menu cost literature: Golosov and Lucas (2007), Midrigan (2010), Vavra (2014), Argente and Yeh (2018)

- New: different way of accounting for price dispersion

Frictional search literature: Head et. al (2012), Burdett and Menzio (2017)

- New: quantitative assessment

Conclusion

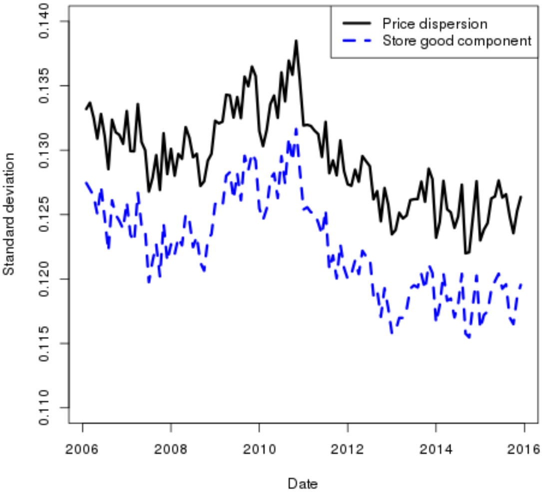
Results:

- Introducing search into a standard menu costs model increases monetary non–neutrality

Future work:

- Klenow and Willis (2016) critique of micro–real rigidities
- Calibrate model to match Alvarez–Le Bihan–Lippi statistic
- Match dispersion in data, controlling for productivity

Weighted dispersion decomposition



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Calibration

Externally calibrated parameters

Parameter		Value	Source
Discount rate	β	$0.95^{\frac{1}{12}}$	Monthly
Demand curve	γ	$1/4$	CES demand[1]
Wage	ω	0.5	Normalization
Money growth	π	0.0021	Mean inflation
Persistence of tfp	ρ_z	0.62	Vavra (2014)
Prob. of shock	λ	0.13	Vavra (2014)

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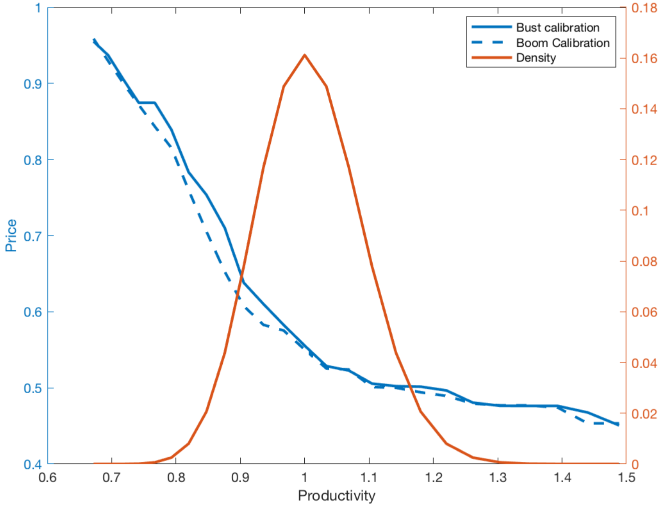
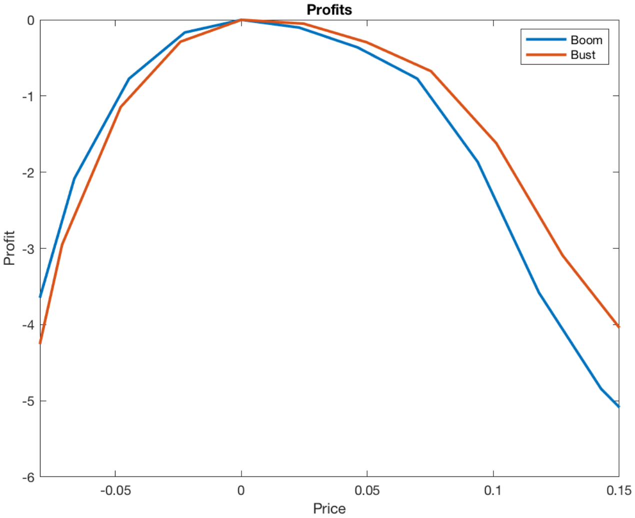
[1] "Standard value" used in Nakamura and Steinnson (2010)

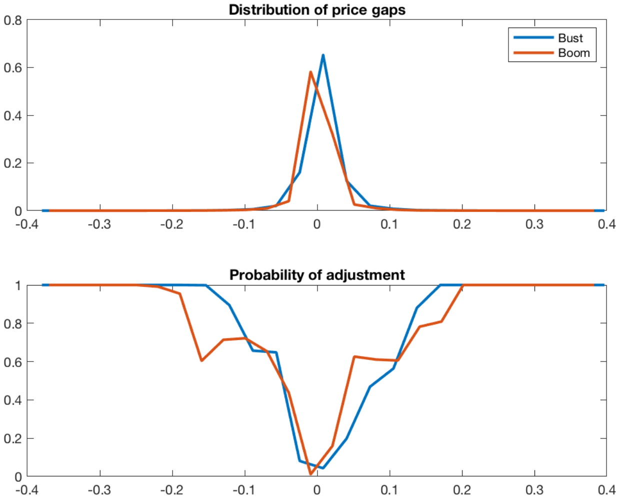
Real rigidities



Real rigidities



Caballero and Engel (2007)



Caballero and Engel (2007)

Table: Caballero Engel (2007) Decomposition

Calibration	Intensive	Extensive	Total
Boom	11.2%	14.4%	25.6%
Bust	10.4%	12.4%	22.8%

- Fall in α in boom drives up frequency of adjustment.
- Pushes firms toward their adjustment bands.
- This increases price flexibility.

Alvarez–Le Bihan–Lippi (2016)

Table: Alvarez, Le Bihan & Lippi (2016) statistics

Calibration	Frequency	Kurtosis	Kurtosis/Frequency
Boom	1.31	4.32	3.20
Bust	1.25	3.73	2.98

- In recessions, measure of captive customers α rises.
- This causes frequency of adjustment to fall.
- Kurtosis also falls because reset prices move toward the GL case.

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How likely are firms to adjust and by how much?

Caballero–Engel decomposition:

- Price gap $x \equiv \log p^* / \log p$
- Distribution of price gaps $f(x)$
- Probability of adjustment $\Lambda(x)$

Inflation is given by

$$\pi = \int x\Lambda(x)f(x)dx$$

If an aggregate shock moves desired prices by ΔS, then inflation is

$$\pi(\Delta S) = \int (x + \Delta S)\Lambda(x + \Delta S)f(x)dx$$

A first order Taylor approximation implies

$$\lim_{\Delta S \to 0} \frac{\Delta \pi}{\Delta S} = \underbrace{\int \Lambda(x)f(x)dx}_{\text{Intensive Margin (Frequency)}} + \underbrace{\int x\Lambda'(x)f(x)dx}_{\text{Extensive Margin}}$$

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