THE ELUSIVE COSTS OF INFLATION: PRICE DISPERSION DURING THE U.S. GREAT INFLATION

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Optimal Level of Inflation

What level of inflation should central banks target?

- Pre-crisis policy consensus to target roughly 2% inflation per year
- Academic studies argued for still lower rates
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- Great Recession has lead to increasing calls for higher inflation targets
  - Blanchard, Dell'Ariccia, Mauro (2010), Ball (2014), Krugman (2014)
  - Blanco (2015)

Price Dispersion and the Costs of Inflation

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  - Prices will drift further from optimum between times of adjustment
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Price Dispersion and the Costs of Inflation

- Higher inflation will lead to higher price dispersion
  - Prices will drift further from optimum between times of adjustment
  - Distorts allocative role of the price system
- In standard New Keynesian models, these costs are very large
  - Going from 0% to 12% inflation per year yields a 10% loss of welfare
- Much more costly than business cycle fluctuations in output in these same models

THIS PAPER

- Measure sensitivity of inefficient price dispersion to changes in inflation

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    - We extend BLS micro-data on consumer prices back to 1977
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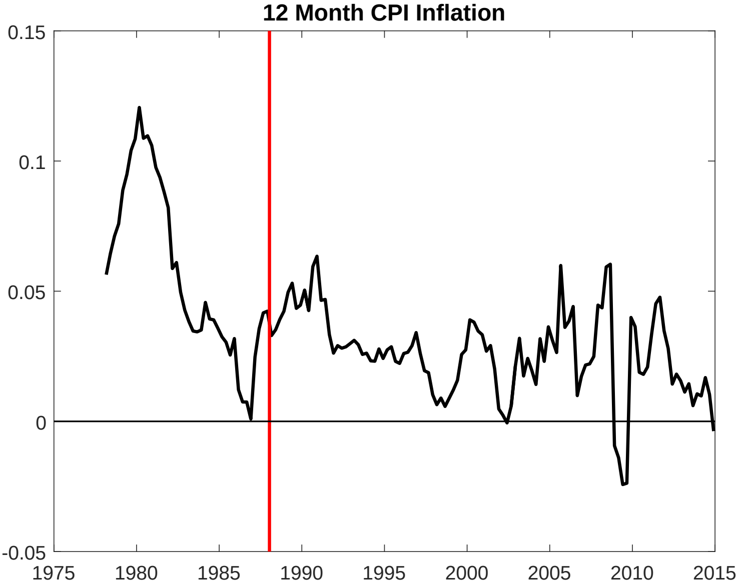

FIGURE: CPI Inflation in the U.S. (excluding shelter)

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    - We extend BLS micro-data on consumer prices back to 1977
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2. Difficulty in interpreting raw price dispersion
    - Product heterogeneity (e.g., quality and size)
    - Absolute size of price changes informative about inefficient price dispersion

Elusive Costs of Inflation

- No evidence of increased price dispersion in Great Inflation period:
  - Average absolute size of price change is completely flat over 1978-2014
  - Even standard deviation of absolute size is completely flat

ELUSIVE COSTS OF INFLATION

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- Main cost of inflation in New Keynesian models completely elusive
- Optimality of low inflation based on these models needs to be reassessed

(Other costs of inflation may be important)

PRICE FLEXIBILITY OVER TIME

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  - Tremendous technological change
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- Frequency of price change very sensitive to inflation
- Both absolute size and frequency facts favor menu cost model over Calvo model

Existing Empirical Evidence

Earlier work on standard deviation of sectoral inflation:

- Vining and Elwertowski 76, Parks 78, Fisher 81

Earlier work on price **change** dispersion:

- Van Hoomissen 88, Lach and Tsiddon 92, Vavra 14;

Very limited literature on price dispersion:

- Reinsdorf 94 (US BLS data, 1980-1982),
  Sheremirov 13 (US IRI data 2002-2009)
- Alverez et al. 16 (Argentine hyperinflation)

Why Is Inflation so Costly
in Standard Sticky Price Models?

Costs of Inflation in Sticky Price Models

Households maximize

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\log C_{t+j} - L_{t+j}\right]$$

where

$$C_t = \left[\int_0^1 c_{it}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}},$$

subject to

$$P_t C_t + Q_{it} B_{it} \leq W_t L_t + (D_{it} + Q_{it}) B_{it-1}.$$

Costs of Inflation in Sticky Price Models

Household optimization implies demand curves for individual products:

$$c_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\theta} C_t,$$

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a labor supply equation

$$\frac{W_t}{P_t} = C_t$$

and asset (dividend strip) valuation equation:

$$V_{it}^j = E_t\left[\beta^j \left(\frac{C_{t+j}}{C_t}\right)^{-1} D_{t+j}\right]$$

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- Implies that marginal costs are

$$MC_{it} = \frac{W_t}{A_{it}}$$

Costs of Inflation in Sticky Price Models

- Monetary policy controls nominal aggregate demand $S_t = P_t Y_t$
- Nominal aggregate demand follows a random walk with drift:

$$\log S_t = \mu + \log S_{t-1} + \eta_t$$

Flexible Price Benchmark

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- Aggregation of production function yields:

$$Y_t = A_f L_t$$

Flexible Price Benchmark

Output, labor supply and real wage determined by:

Labor Supply:	$\frac{W_t}{P_t} = Y_t$
Production Function:	$Y_t = A_f L_t$
Markup:	$P_t = \Omega_f \frac{W_t}{A_f}.$

FLEXIBLE PRICE BENCHMARK

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Production Function: $Y_t = A_f L_t$

Markup: $P_t = \Omega_f \frac{W_t}{A_f}$.

Solution:

$$Y_t = \Omega_f^{-1} A_f$$

$$L_t = \Omega_f^{-1}.$$

Notice that solution is independent of inflation.

Equilibrium with Sticky Prices

Useful to consider analogous set of equations to flex price case:

Labor Supply: $$\frac{W_t}{P_t} = Y_t$$

Production Function: $$Y_t = A_t(\bar{\pi})(L_t - L_t^{pc})$$

Price Setting: $$P_t = \Omega_t(\bar{\pi})\frac{W_t}{A_t(\bar{\pi})}$$

where

$$A_t(\bar{\pi}) = \left[\int_0^1 \left(\frac{p_{it}}{P_t}\right)^{-\theta} A_{it}^{-1} di\right]^{-1}$$

and the last equations is simply definition of “aggregate markup” ($\Omega_t(\bar{\pi})$)

Equilibrium with Sticky Prices

Solution:

$$Y_t = \Omega_t(\bar{\pi})^{-1} A_t(\bar{\pi})$$
$$L_t = \Omega_t(\bar{\pi})^{-1} + L_t^{pc}$$

EQUILIBRIUM WITH STICKY PRICES

Solution:

$$Y_t = \Omega_t(\bar{\pi})^{-1} A_t(\bar{\pi})$$

$$L_t = \Omega_t(\bar{\pi})^{-1} + L_t^{pc}$$

Three potential sources of welfare loss from inflation:

- Labor needed to change prices: L_t^{pc}
- Lower labor productivity: $A_t(\bar{\pi}) < A_f$
- Aggregate markup different: $\Omega_t(\bar{\pi}) \neq \Omega_f$

Welfare with Sticky Prices

- Measure of welfare (consumption equivalent loss):

$$E\left[\log\left((1+\Lambda)C_t^A\right) - L^A\right] = E\left[\log\left(C_t^B\right) - L^B\right].$$

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  - Menu cost model (constant fixed cost of price change)
  - Calvo model (randomly infinite or zero cost of price change)

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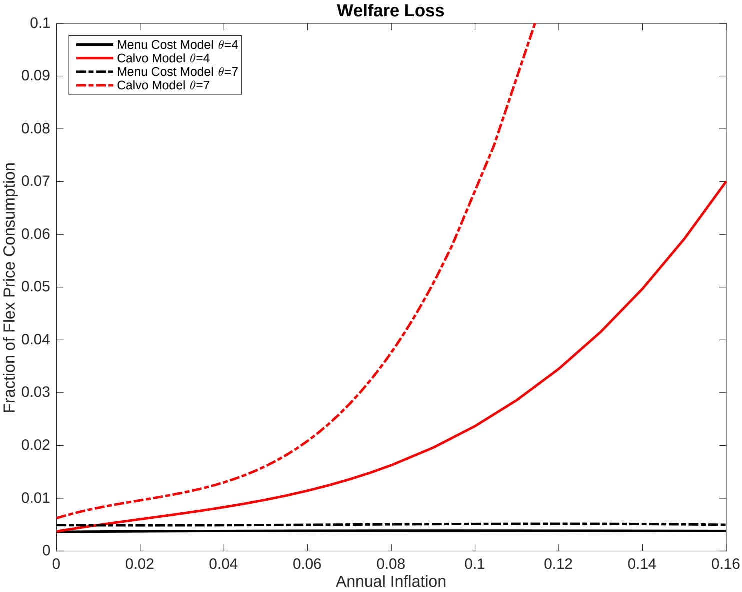
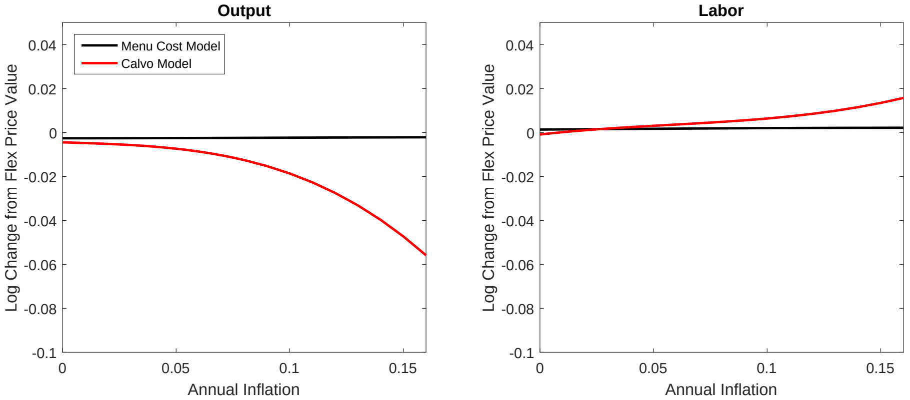
- Calculate equilibrium numerically using methods described in Nakamura and Steinsson (2010)

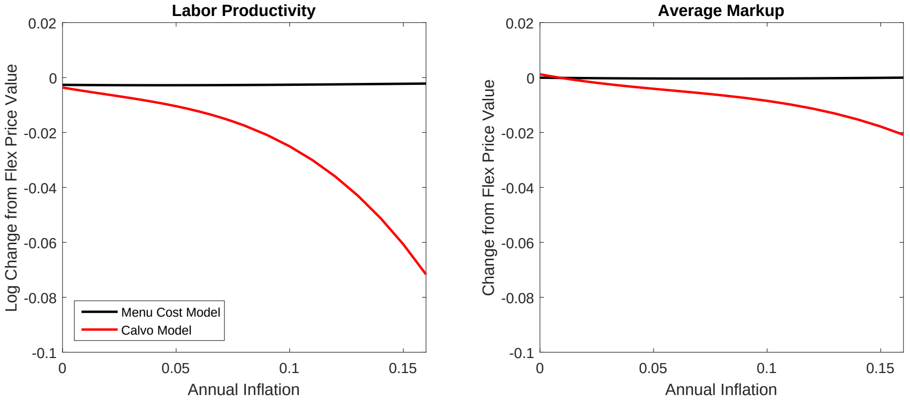
Calibration

- Already made several "calibration choices":
  - Log utility in consumption
  - Linear disutility of labor
  - Linear production function
- Subjective discount factor: $\beta = 0.96^{1/12}$
- Elasticity of substitution between individual goods: $\theta = 4$
- Menu cost and standard deviation of idiosyncratic shocks set to match frequency and size of price changes
- Persistence of idiosyncratic shocks set to 0.7
- Standard deviation of aggregate shocks calibrated based on standard deviation of US nominal GDP from 1988-2014.



Calvo Varying


Output
Menu Cost Model
Calvo Model
Log Change from Flex Price Value
Annual Inflation
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.05
0.1
0.15
Labor
Log Change from Flex Price Value
Annual Inflation


Labor Productivity
Log Change from Flex Price Value
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.05
0.1
0.15
Annual Inflation
Menu Cost Model
Calvo Model
Average Markup
Change from Flex Price Value
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.05
0.1
0.15
Annual Inflation

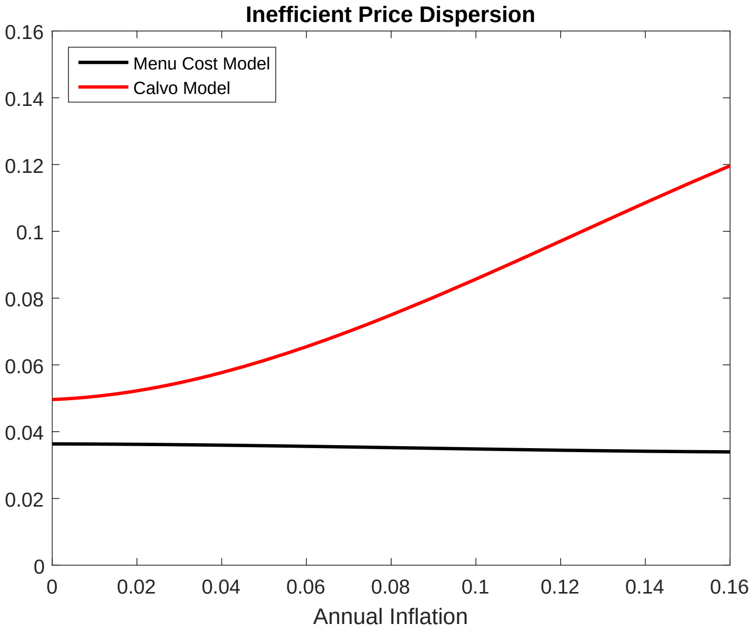
Bottom Line

Menu Cost Model:

- Welfare costs are small
- Welfare costs are unresponsive to moderate inflation

Calvo Model:

- Welfare costs rise rapidly with inflation
- Welfare costs arise from a drop in labor productivity



Inefficient Price Dispersion
Menu Cost Model
Calvo Model
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Annual Inflation

New Micro Data on Consumer Prices During the U.S. Great Inflation

NEW MICRO DATA ON CONSUMER PRICES

- We digitized micro data underlying the U.S. CPI for period May 1977 to October 1986
  - Contains Great Inflation and Volcker disinflation periods
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- Existing CPI Research Database has sample period from 1988 onward

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- Full sample 1978 to 2014
    - Drop 1977 data (quality concerns)
    - 6 month gap in 1986-1987

Information in Dataset

- Product category (ELI) (e.g., toothpaste)
- Location (e.g., Chicago)
- Outlet (e.g., Pathmark at corner of 125th St. and Lex Ave)
- Product (e.g., 2L bottle of Diet Coke)
- Price
- Sales flag, imputation flag

- Sample size: Varies from 80k to 100k per month

DATA CONSTRUCTION

Two phases:

- Scanning of microfilm images
  - Obsolete cartridges which don't fit modern scanners
- Conversion of scanned images to machine readable form
  - Customer optical character recognition software

```
PSU/HS/POPS/CL     BASE PR                                                                                                  EF PR
OUTLET/QTE/VER     BP W/TX          8001     8002     8003     8004     8005     8006     8007     8008     8009     8010     8011  FFFSCCF
O-T/CHAIN/POP      QL ADJ                                                                                                    % CH
A101/B/118105C     3.423R              -    3.500    3.500    3.500    3.500    3.500    3.500    3.500    2.990    2.990    2.884        -
0054853/001/009    3.697R              - RN1         AA1      AA1      AA1      AA1      AA1      AA1      RA1   AA1       T  RN1I   X      1
012/      /B                  -        -        -        0        0        0        0        0        0      -15        0       -4
A101/B/118/05C                -        -        -        -        -        -        -        -        -        -        -        -    5.500
0054853/001/010               -                                                                                                    RN1
012/       /B                 -        -        -        -        -        -        -        -        -        -        -        -        -
A101/B/118/05C     3.874R          3.990    3.990    3.868    3.990    3.990    3.990    3.990    3.990    3.990    3.990    3.990    3.990
0054853/002/006    4.197R            AA1      AA1    T  RN1I     RA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1
012/       /B                 -        -        0       -3        3        0        0        0        0        0        0        0        0
A101/A/118/01D     37.055C             -        -   41.400   41.400   41.865   41.884   41.541   36.000   36.000   39.381   36.000        -
0055222/001/010    40.020C             -          H  RC1      AA9    A  RN91  A  RN91  A  RN91     RA1      AA1     AA1I      AA1
016/       /B                 -        -        -        -        0        1        0       -1      -13        0        9       -9        -
A101/A/118/01D                -        -        -        -        -        -        -        -        -        -        -        -     44.9
0055222/001/011               -                                                                                                    RN1
016/      /B                  -        -        -        -        -        -        -        -        -        -        -        -        -
A101/B/118/01D     18.907C        25.000   25.000   23.000   23.000   23.000   23.000   23.000   23.000   23.000   23.000   23.000   23.000
0055765/001/004    20.280C           RA1      RA1      RA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1
001/       /U                 -        -        0       -8        0        0        0        0        0        0        0        0        0
A101/8/118/02D     58.484R        60.000   60.000   60.000   60.000   60.000   60.000   60.000   60.000   60.000   60.000   60.000   60.000
0055765/002/007    62.583R           AA1      RA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1
001/       /U                 -        -        0        0        0        0        0        0        0        0        0        0        0
A101/8/118/01D     13.448C        13.990   13.990   13.990   13.990   13.990   13.990   13.990   13.990        -        -        -        -
0055958/001/005    14.432C           RA1      AA1      AA1      AA1      AA1      AA1      AA1      AA1    X      1
018/       /B                 -        -        0        0        0        0        0        0        0        -        -        -        -
A101/8/118/01D     13.448C             -        -        -        -        -        -        -        -   14.990   14.990   14.990   14.990
0055958/001/006    14.432C                                                                        RC1      AA1      AA1      AA1
018/       /B                 -        -        -        -        -        -        -        -        -        0        0        0
A101/8/118/05C     3.990C          5.990    5.990    5.990    5.990    6.057        -        -        -        -        -        -        -
0055958/002/005    4.309C            AA1      AA1      AA1      AA1    T  RN1I  X      1
018/       /B                 -        -        0        0        0        1        -        -        -        -        -        -        -
A101/8/118/05C     5.049R              -        -        -        -        -    4.990    4.990    4.990    4.990        -        -        -
0055958/002/006    5.403R                                                RN1      AA1      AA1      AA1    X      1
018/       /B                 -        -        -        -        -        -        -        0        0        0        -        -        -
A101/8/118/05C     5.049C              -        -        -        -        -        -        -        -        -    5.990    5.990    5.990
0055958/002/007    5.403C                                                                                  RC1      AA1      AA1
018/       /B                 -        -        -        -        -        -        -        -        -        -        -        0        0
A101/8/118/02D     42.266C             -        -        -   58.000   58.000   58.000   39.990   24.990        -        -        -        -
0057534/004/012    45.644C                          RC1      AA1      AA1      B  RA1  B  RA1    X      1
001/       /W                 -        -        -        -        -        0        0      -31      -38        -        -        -        -
```

ELIMINATING OCR ERRORS

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- Only use prices accepted by one of two algorithms
- Similar procedures for sales flag, imputations flag

Empirical Results

Measuring Price Dispersion

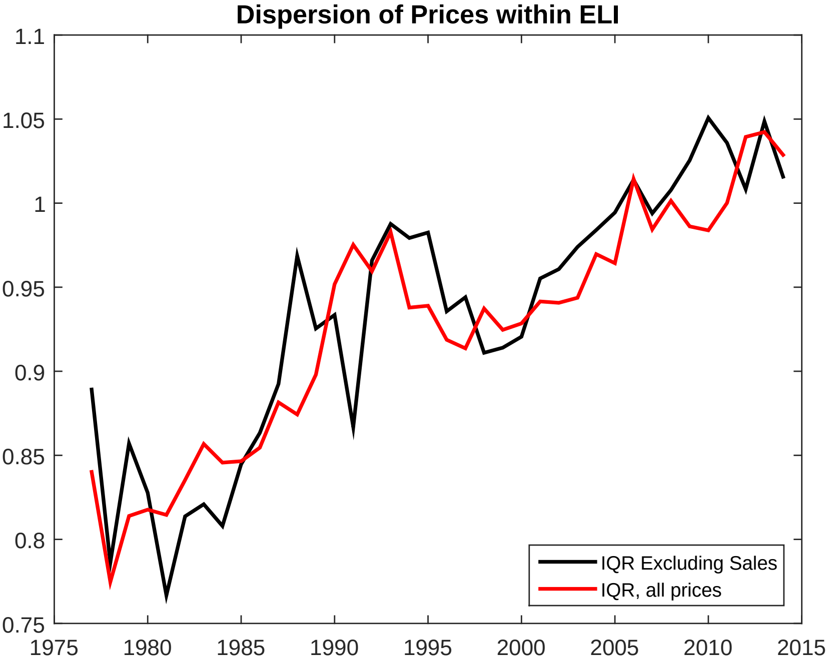
- If all products were homogenous within product category ...

  ... simply calculate cross-sectional variance

MEASURING PRICE DISPERSION

- If all products were homogenous within product category ...

  ... simply calculate cross-sectional variance
- In practice, large amount of product heterogeneity (e.g., quality and size) within product category
- This creates “efficient” dispersion in prices
- “Efficient” dispersion may dwarf “inefficient” dispersion



Dispersion of Prices within ELI
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
1975
1980
1985
1990
1995
2000
2005
2010
2015
IQR Excluding Sales
IQR, all prices

DIFFERENCING OUT DESIRED PRICES

- Could we difference out desired prices by looking at prices relative to a long-term average real price?

Differencing Out Desired Prices

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- Consider the following statistic:

$$x_{ijt} = \log p_{ijt} - \log P_{jt} - \sum_{\tau=t_0^{ij}}^{T^{ij}} [\log p_{ij\tau} - \log P_{j\tau}]$$

We call it the "fixed-effects price gap"

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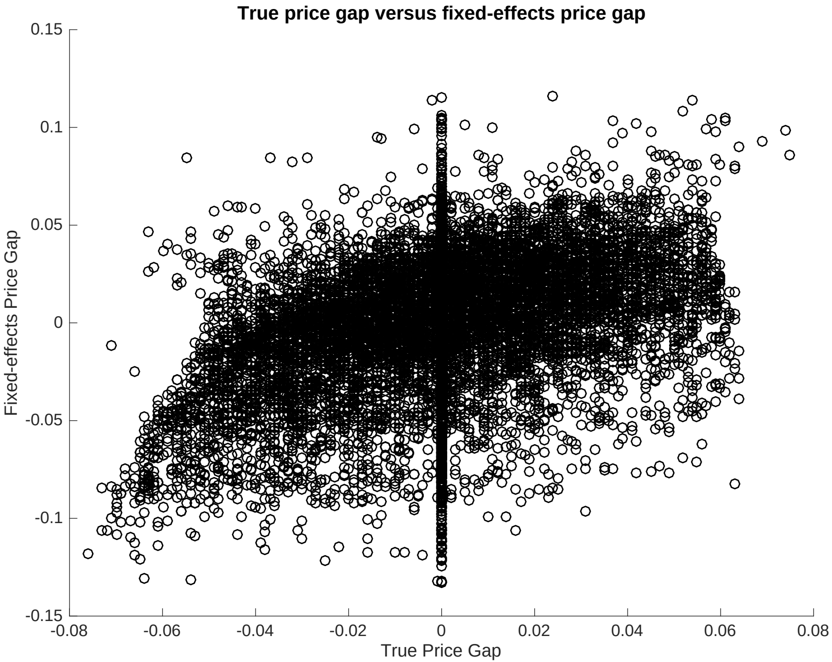
  We call it the “fixed-effects price gap”
- Is this a model-free measure of inefficient price dispersion?
  - Let’s simulate data from our model to check?


True price gap versus fixed-effects price gap
Fixed-effects Price Gap
True Price Gap
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08

Fixed-Effects Price Gap Vs. True Price Gap

Why doesn't it work?

- Basic problem is unobserved idiosyncratic variation in desired prices
  - Large idiosyncratic variation needed match size of price changes

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  - Prices that change are those that have idiosyncratic shocks making adjustment more profitable
  - There is a reason why a price hasn't change for a long time

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  - There is a reason why a price hasn't change for a long time
- Earlier literature used price **change** dispersion (Lach-Tsiddon 92)
  - This also doesn't work

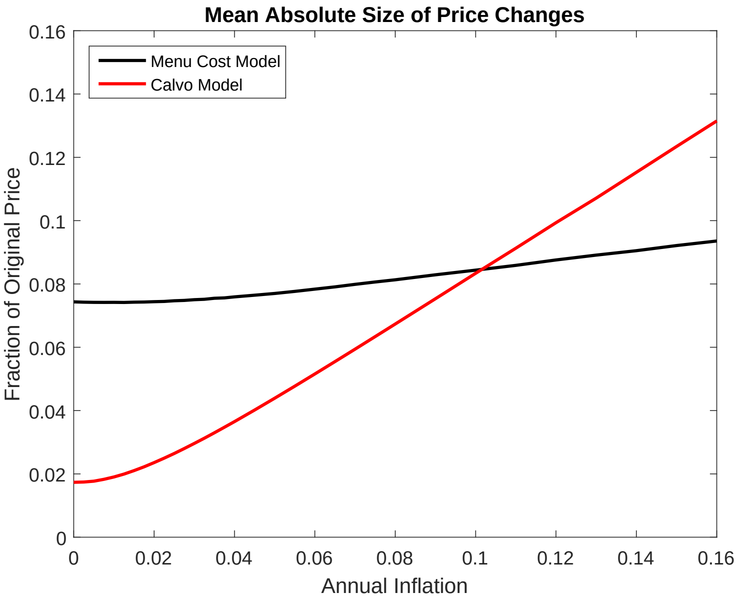
Dispersion and Absolute Size

Alternative approach: Focus on *absolute size* of price changes

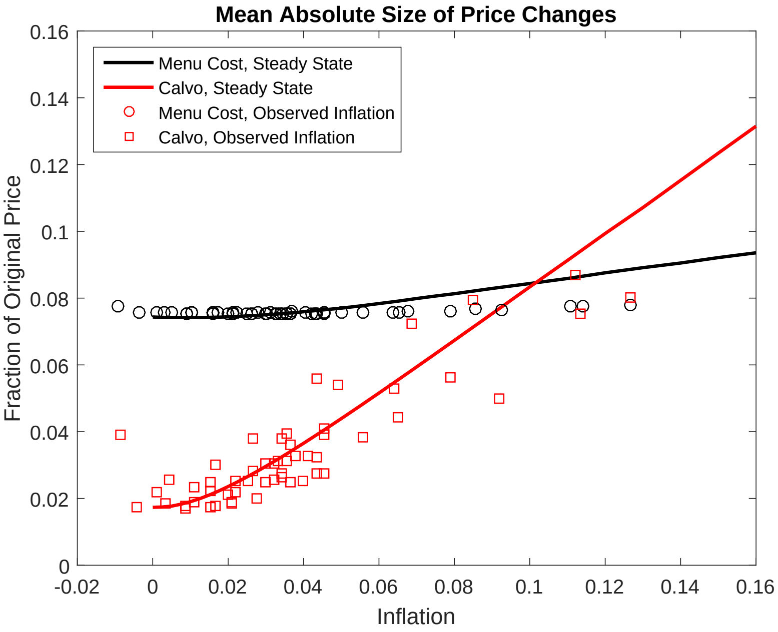
DISPERSION AND ABSOLUTE SIZE

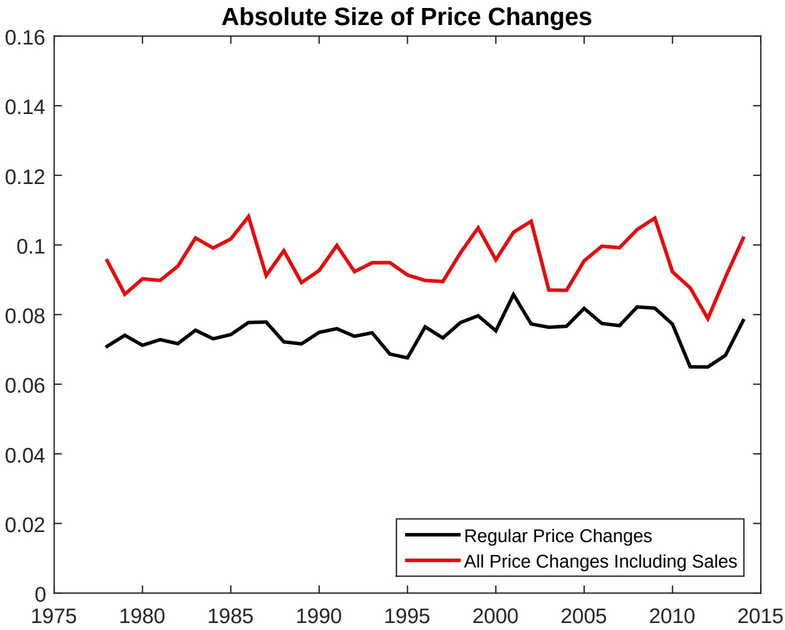
Alternative approach: Focus on *absolute size* of price changes

- Absolute size reveals distance of prices from desired prices
- If prices are drifting further from desired level due to inflation should change by more when they change



Calvo Varying


Mean Absolute Size of Price Changes
Menu Cost, Steady State
Calvo, Steady State
Menu Cost, Observed Inflation
Calvo, Observed Inflation
Fraction of Original Price
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Inflation



Sectors Quantiles

STANDARD DEVIATION OF ABSOLUTE SIZE

- Welfare losses non-linear in deviation of price from efficient price

$$A_t(\bar{\pi}) = \left[\int_0^1 \left(\frac{p_{it}}{P_t} \right)^{-\theta} A_{it}^{-1} di \right]^{-1}$$

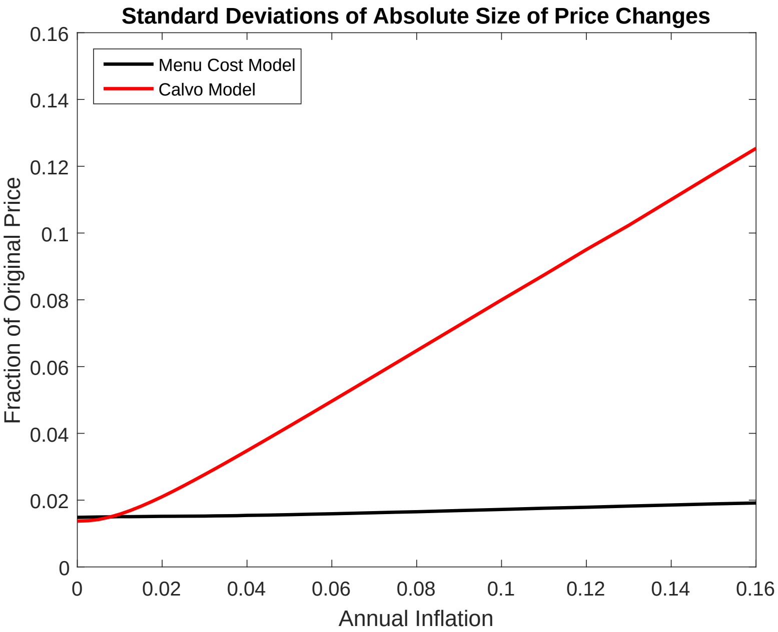
- Largest deviations matter disproportionately

Standard Deviation of Absolute Size

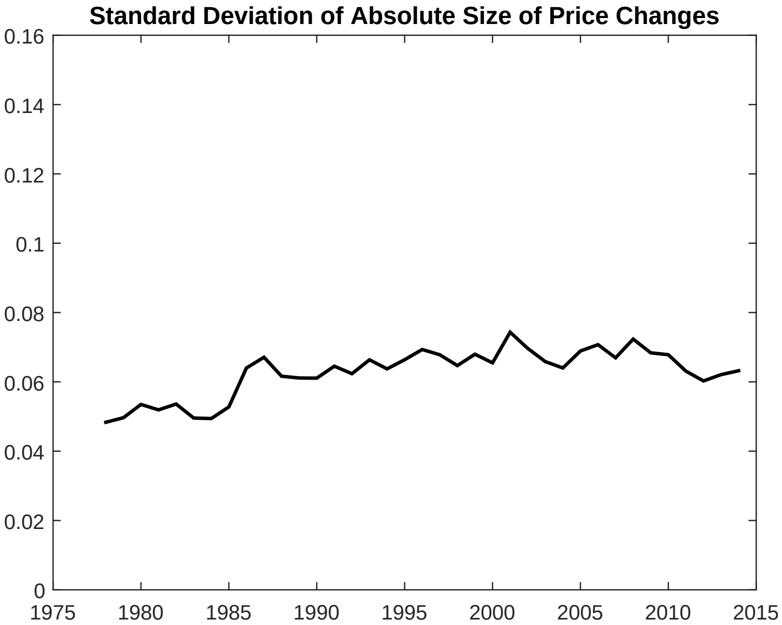
- Welfare losses non-linear in deviation of price from efficient price

$$A_t(\bar{\pi}) = \left[\int_0^1 \left(\frac{p_{it}}{P_t} \right)^{-\theta} A_{it}^{-1} di \right]^{-1}$$

- Largest deviations matter disproportionately
- Conditional on mean absolute size, standard deviation informative about prevalence of very large price changes



Transitory Inflation Calvo Varying



Fixed Effects Price Gap

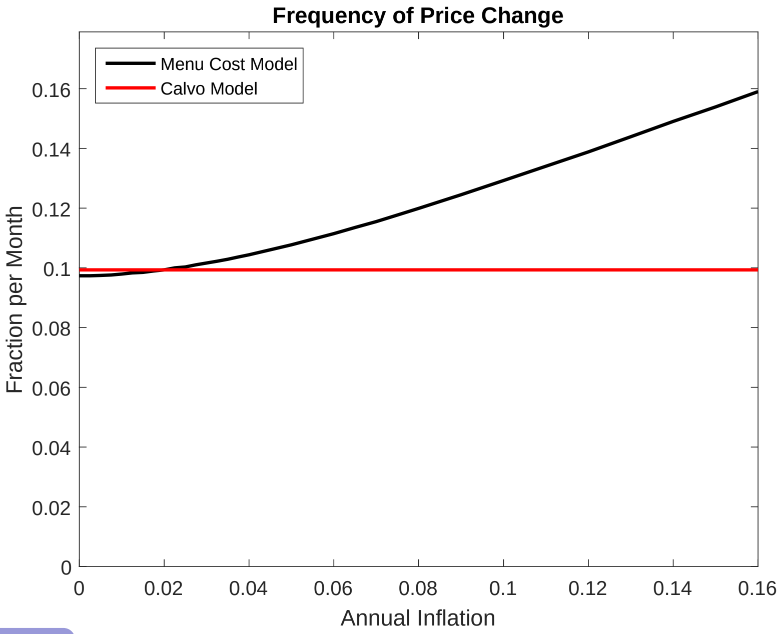
SUMMARY

- No evidence that mean or standard deviation of absolute size of price changes rose during Great Inflation
- Suggests inefficient price dispersion not any higher during Great Inflation
- Costs of inflation emphasized in New Keynesian models elusive

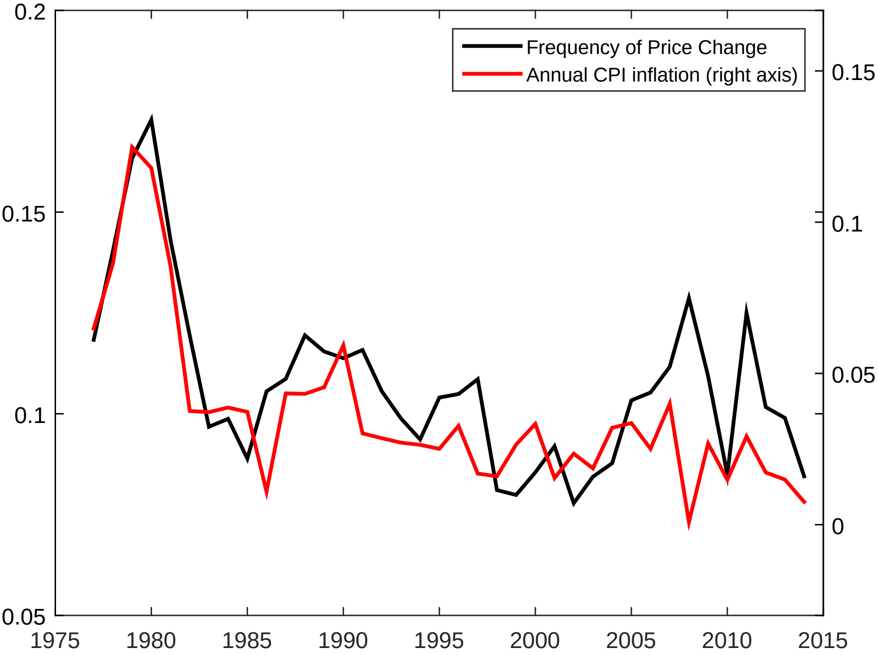
FREQUENCY OF PRICE CHANGE

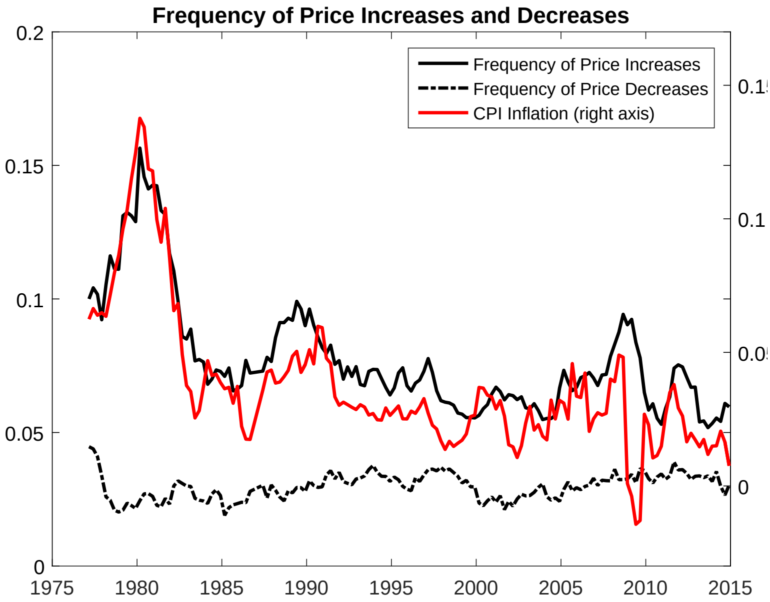
- Flip-side of "size" is frequency of price change
  - If size unaffected by inflation, frequency must vary
- Useful to distinguish between models of price setting:
  - Frequency constant in Calvo model ...

    ... but varies with inflation in menu cost model



Transitory Inflation


Frequency of Price Change
Annual CPI inflation (right axis)
0.2
0.15
0.1
0.05
0.15
0.1
0.05
0
1975
1980
1985
1990
1995
2000
2005
2010
2015


Frequency of Price Increases and Decreases
Frequency of Price Increases
Frequency of Price Decreases
CPI Inflation (right axis)
0.2
0.15
0.1
0.05
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
0.1
0

Sectors

Sample	1978-1987	1988-2014	1979-2014
Frequency of Price Changes	0.124	0.101	0.107
Frequency of Price Increases	0.095	0.069	0.076
Frequency of Price Decreases	0.025	0.031	0.030
Fraction of Price Increases	0.760	0.661	0.688
Absolute Size of Price Changes	0.073	0.075	0.075
Absolute Size of Price Increases	0.073	0.071	0.072
Absolute Size of Price Decreases	0.068	0.082	0.078
Std. Of Price Changes	0.050	0.055	0.054

TABLE: Summary Statistics by Sample

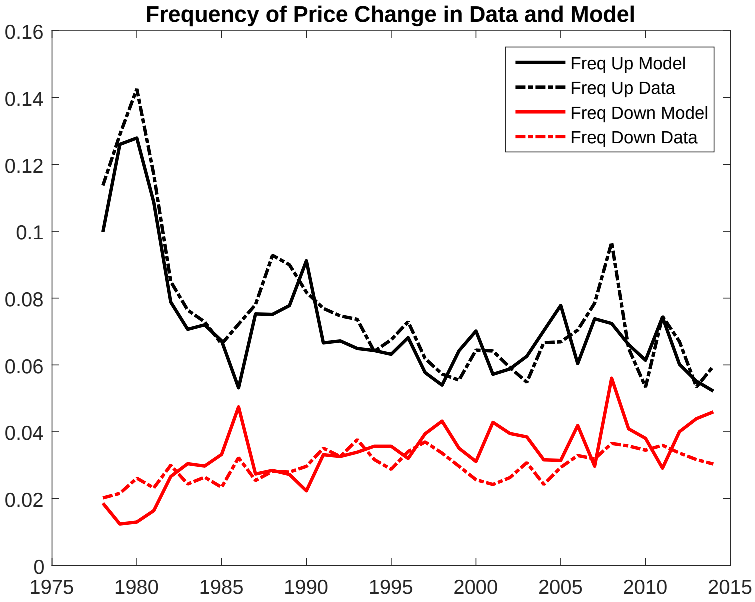
Have Prices Become More Flexible?

- Large changes in technology over past 40 years
- Perhaps costs of changing prices have fallen?
- This would make price changes more frequent

Have Prices Become More Flexible?

- Large changes in technology over past 40 years
- Perhaps costs of changing prices have fallen?
- This would make price changes more frequent

- Can evolution of frequency of price (excluding sales) change be explained by menu cost model with a constant menu cost over entire sample period?

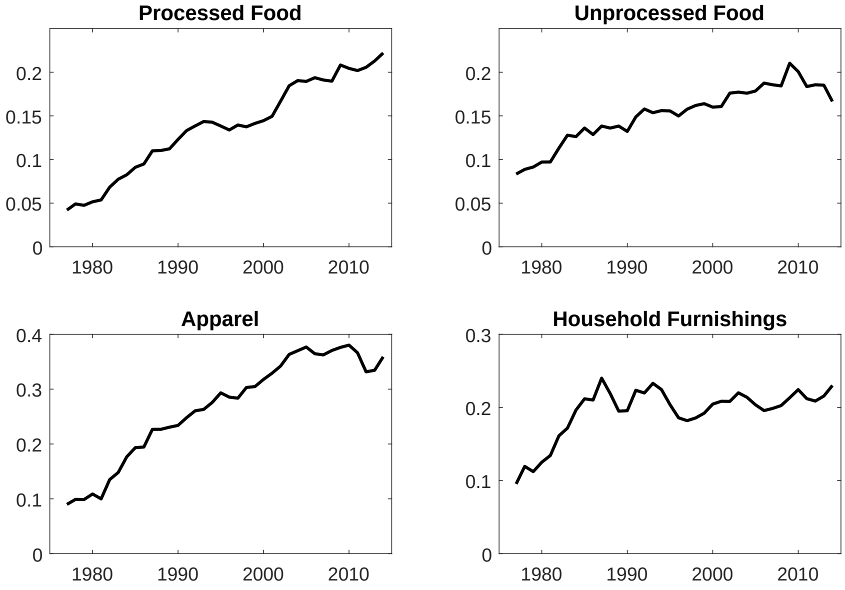


Frequency of Price Change in Data and Model
Freq Up Model
Freq Up Data
Freq Down Model
Freq Down Data
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

Have Prices Become More Flexible?

- Regular prices (excluding sales) have not become more flexible

- What about temporary sales? Have they become more prevalent?


Processed Food
Unprocessed Food
Apparel
Household Furnishings
0
0.05
0.1
0.15
0.2
0.3
0.4
1980
1990
2000
2010

Sales and Price Flexibility

- Frequency of temporary sales has increased dramatically
- What does this imply about aggregate price flexibility?
  - i.e., how rapidly aggregate price level responds to shocks

Sales and Price Flexibility

- Frequency of temporary sales has increased dramatically
- What does this imply about aggregate price flexibility?
  - i.e., how rapidly aggregate price level responds to shocks
- Sizable recent literature has largely concluded that effects of sales on aggregate price flexiblity are small:
  - Sales are very transient
  - Sales are strategic substitutes
  - Sales are “on autopilot”

CONCLUSIONS

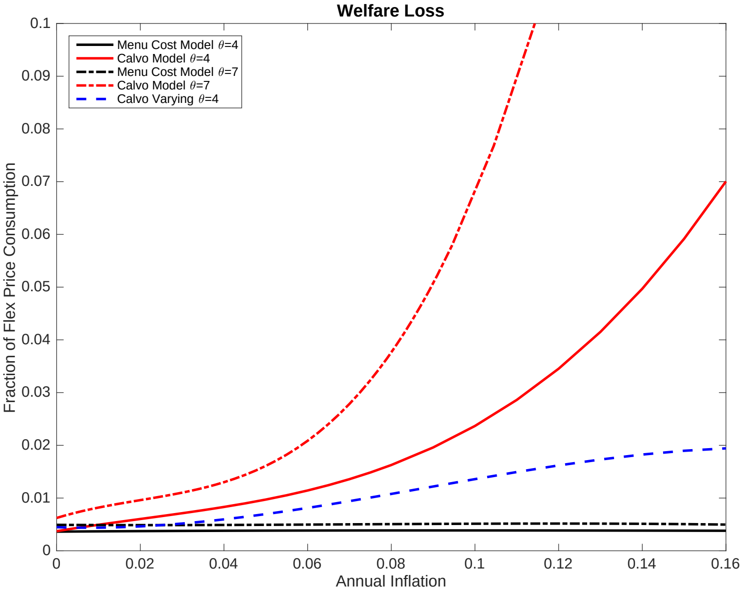
- New micro dataset on consumer prices from Great Inflation period
- No evidence that price dispersion was higher during Great Inflation
- Main costs of inflation in New Keynesian models elusive in data

CONCLUSIONS

- New micro dataset on consumer prices from Great Inflation period
- No evidence that price dispersion was higher during Great Inflation
- Main costs of inflation in New Keynesian models elusive in data

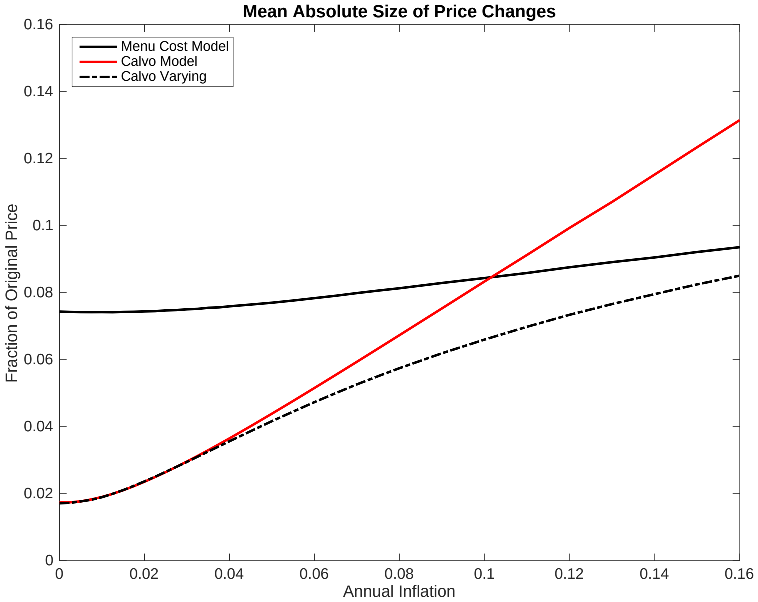
- No change in price flexibility of regular prices over 40 years
- Dramatic increase in frequency of temporary sales

Appendix

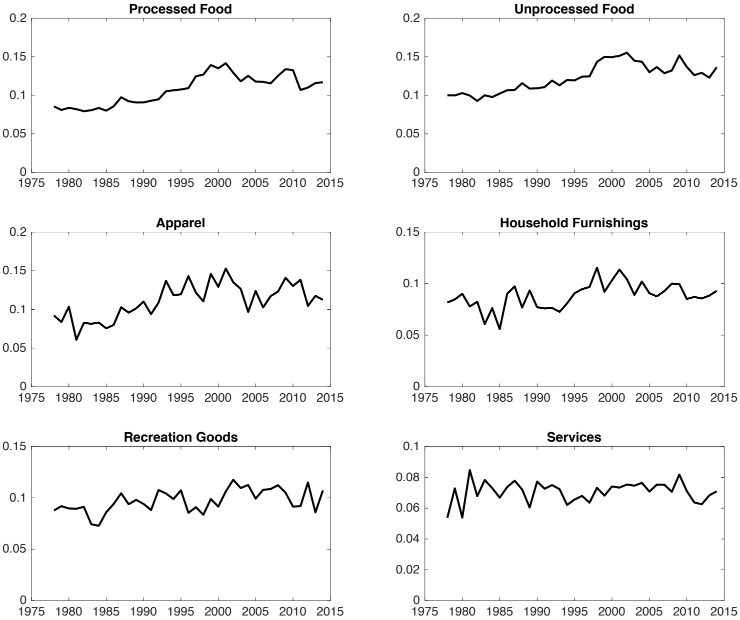


Welfare Loss
Menu Cost Model θ=4
Calvo Model θ=4
Menu Cost Model θ=7
Calvo Model θ=7
Calvo Varying θ=4
Fraction of Flex Price Consumption
Annual Inflation
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

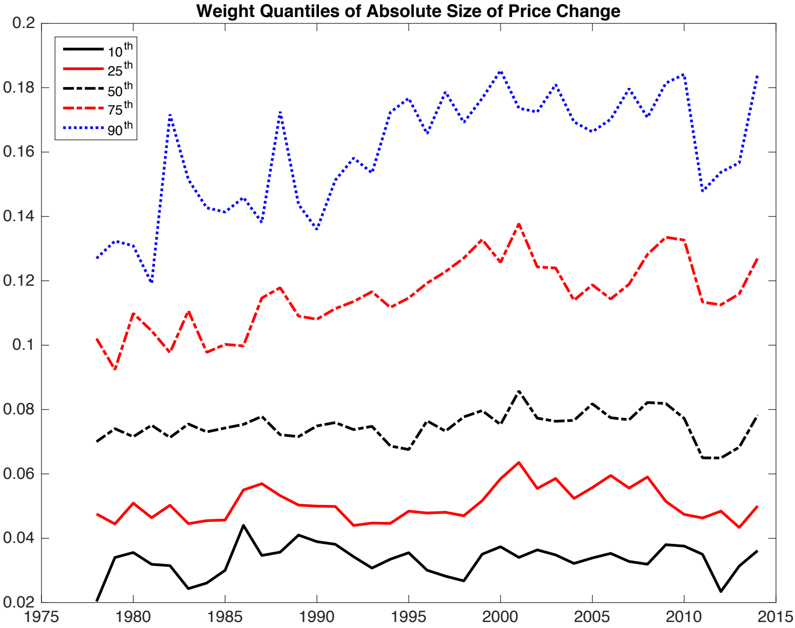
Back


Mean Absolute Size of Price Changes
Menu Cost Model
Calvo Model
Calvo Varying
Fraction of Original Price
Annual Inflation
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

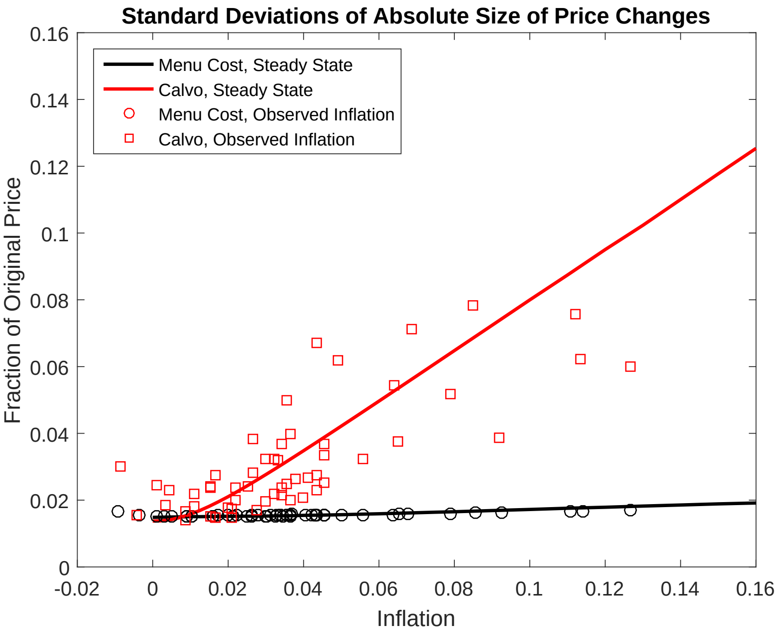
Back


Processed Food
Unprocessed Food
Apparel
Household Furnishings
Recreation Goods
Services
0
0.02
0.04
0.05
0.06
0.08
0.1
0.15
0.2
1975 1980 1985 1990 1995 2000 2005 2010 2015

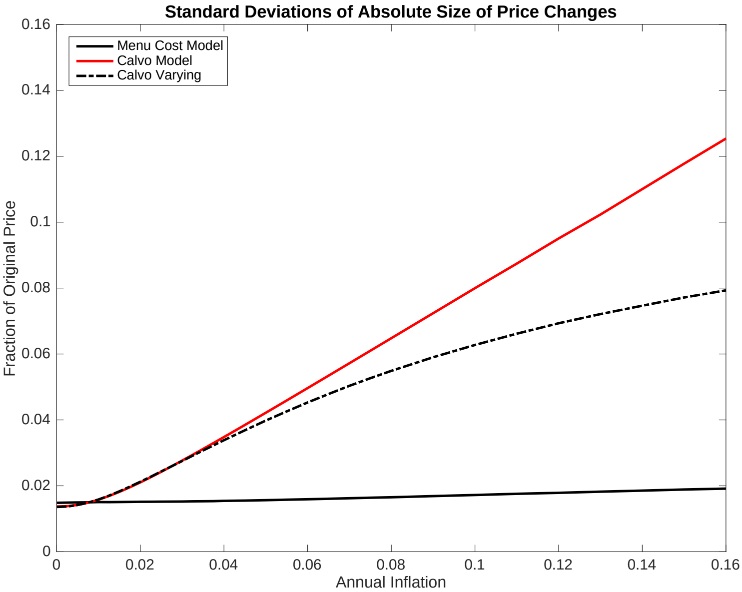
Back


Weight Quantiles of Absolute Size of Price Change
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
1975
1980
1985
1990
1995
2000
2005
2010
2015
10th
25th
50th
75th
90th

Back

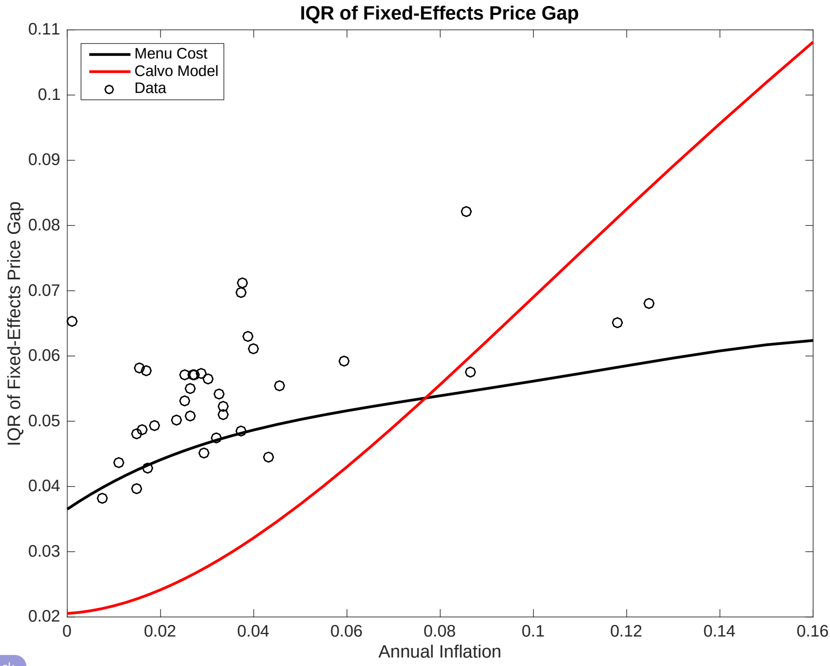

Standard Deviations of Absolute Size of Price Changes
Menu Cost, Steady State
Calvo, Steady State
Menu Cost, Observed Inflation
Calvo, Observed Inflation
Fraction of Original Price
Inflation
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

Back



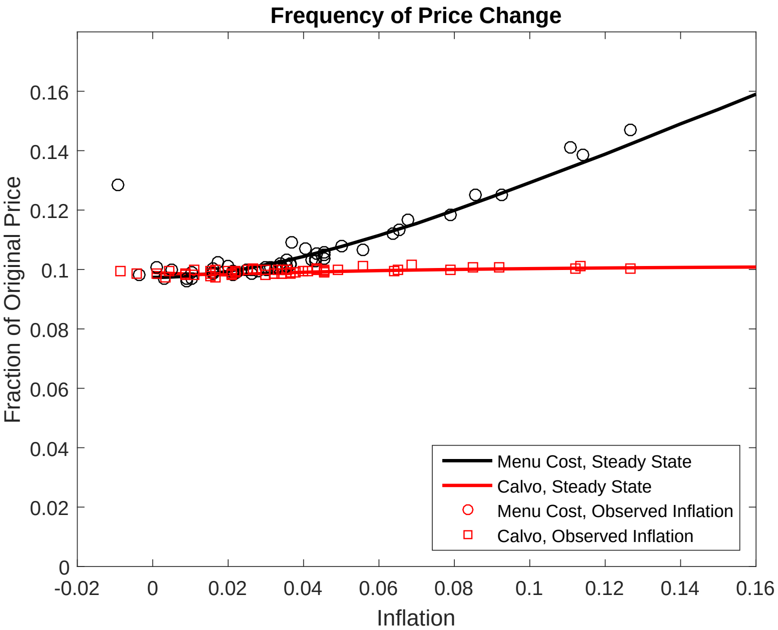
Standard Deviations of Absolute Size of Price Changes
Menu Cost Model
Calvo Model
Calvo Varying
Fraction of Original Price
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Annual Inflation

Back

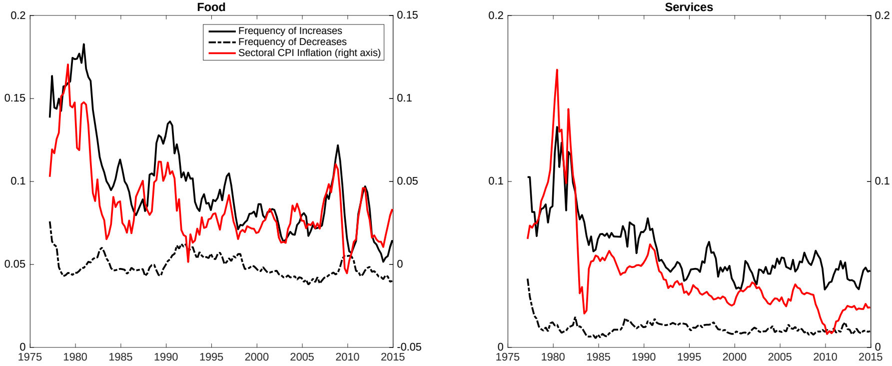


IQR of Fixed-Effects Price Gap
Menu Cost
Calvo Model
Data
IQR of Fixed-Effects Price Gap
Annual Inflation
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

Back


Frequency of Price Change
Fraction of Original Price
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Inflation
Menu Cost, Steady State
Calvo, Steady State
Menu Cost, Observed Inflation
Calvo, Observed Inflation

Back


Food
Frequency of Increases
Frequency of Decreases
Sectoral CPI Inflation (right axis)
0.2
0.15
0.1
0.05
0
0.15
0.1
0.05
0
-0.05
1975
1980
1985
1990
1995
2000
2005
2010
2015
Services
0.2
0.1
0
0.2
0.1
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

Back