Price setting away from zero inflation

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and usual suspects

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The wild speculations do not reflect the sane opinions of my coauthors

Many results/models hold around zero inflation and small shocks.

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Figure: But: “I have a feeling we’re not in Kansas anymore"

- Pass through of cost increases to price.
- How this effect depend on:
  - Level of Inflation
  - Size of the cost shock
- Theory and Empirical evidence
  - State (sS) vs Time Dependent (Calvo)
  - Review old evidence, present some new.
- Why is this relevant now?
  - Large cost increases due to supply bottle-necks & energy.
  - Medium term: high baseline inflation due fiscal policy & wage inertia.
- Question: Critical **level** of inflation and **size** of cost shocks.

- Review Theory, how to distinguish models (identification)
- Micro-Data on retail prices

1. Review of Argentina CPI1987-1997: two hyper-inflation and price stability
2. Review of Argentina 2012-2018: large cost increases
3. Review Mexico CPI around 1994: large cost increases and disinflation
4. Review US 1975-2005: conquest of American inflation
5. New: UK CPI 2018-2022: Covid and the return of inflation
6. New: US Scanner 2018-2022: Covid and the return of inflation

Different Models: TD vs SD

- Time dependent (e.g Calvo):
  - Price changes occurs at exogenously given times.
  - Firms only chose how much to change at those times
- State Dependent (e.g sS, menu cost):
  - Firms pay a cost and decide if they change prices
  - Size and frequency of price changes optimally chosen
- Firms maximize expected discounted profits, facing idiosyncratic shocks.
- Almost all models used by literature/policy are State Dependent.

SD & TD Models and Two Comparative Statics

- Compare results State Dependent (sS) and Time Dependent (Calvo)

  (general version of both type of models)

1. Frequency of price changes λ as Steady State Inflation π changes
   - (actually for future medium run inflation)
   - useful as diagnostic test
2. Pass-through of cost shocks δ to aggregate prices.
   - (cost shock = once and for all permanent increase in cost)
   - Impact effect on level and frequency
   - Important in itself for policy

First Comparative Static: steady state inflation

- Change on steady state inflation π, medium run.
- $\lambda(\pi)$ frequency of price changes as function of π.
- useful as diagnostic (test) device to distinguish SD vs TD

1. Time Dependent Models: Frequency $\lambda(\pi)$ constant.

   Insensitive to inflation $\frac{\partial}{\partial\pi}\lambda(\pi) = 0$ for all π

2. State Dependent Models: Frequency $\lambda(\pi)$
   - Insensitive for low inflation $\frac{\partial}{\partial\pi}\lambda(0) = 0$
   - Increasing in $|\pi|$, so approximately quadratic with: $\frac{\partial^2}{\partial\pi^2}\lambda(0) > 0$
   - As $\pi \to \infty$, then λ has constant elasticity 2/3.

First Comparative Static: steady state inflation (cont)

- $\lambda^{+}(\pi)$ frequency of price increases.
- $\lambda^{-}(\pi)$ frequency of price decreases.
- total frequency $\lambda(\pi) = \lambda^{+}(\pi) + \lambda^{-}(\pi)$ of price changes .

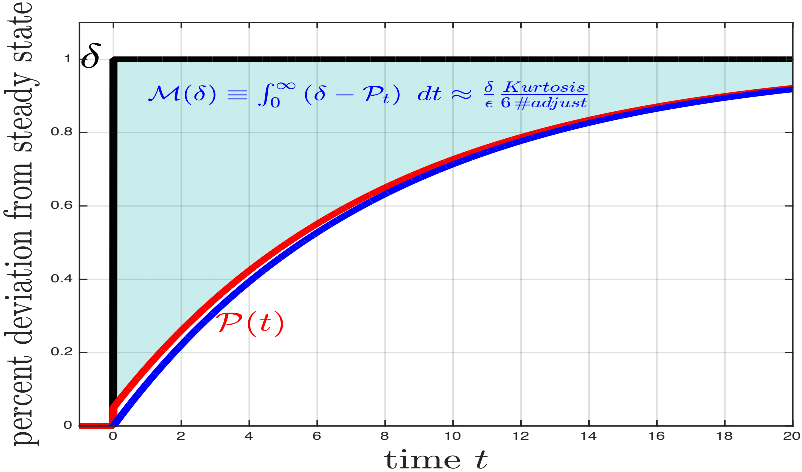
1. Time and State Dependent Models: $\lambda^{+}(\pi) - \lambda^{-}(\pi)$
   - $\frac{\partial}{\partial \pi}\lambda^{+}(\pi) - \frac{\partial}{\partial \pi}\lambda^{-}(\pi) > 0$ all π, including at $\pi = 0$
   - $\lambda(\pi)$ less sensitive than $\lambda(\pi) - \lambda(\pi)$ around $\pi = 0$.
2. TD: $\lambda(\pi) = \lambda^{+}(\pi) + \lambda^{-}(\pi)$ constant, independent of π
3. SD: $\lambda(\pi) = \lambda^{+}(\pi) + \lambda^{-}(\pi)$ insensitive to π only at $\pi = 0$

Second Comparative Static: cost shock δ

- Once and form all change in cost by δ.
- Effect on path of aggregate price, i.e pass-through.
- interesting in itself for policy

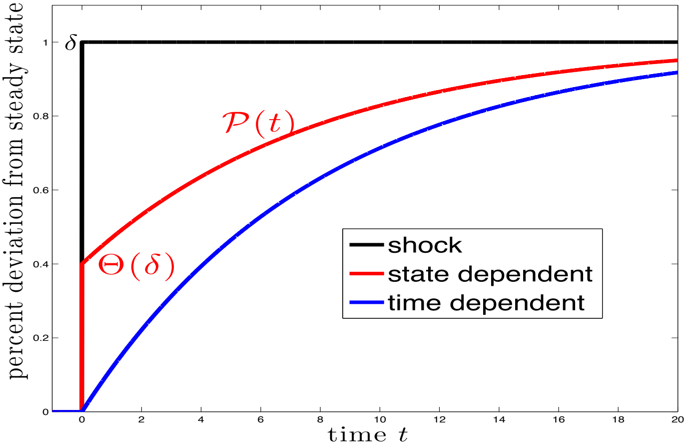
1. Time Dependent Models:
    - No impact effect of shock δ at $t = 0$,
    - Pass-through at horizon $t > 0$ is the **same** for all sizes of δ.
2. State Dependent Models:
    - Impact effect of shock at $t = 0$, increases with size of shock δ.
    - Pass-through at horizon $t > 0$ **increases** with size of δ.
    - Change in frequency λ on impact for large δ

Small shocks: similarities beyond impact



Same cumulated output response if **frequency** and **kurtosis** of Δp coincide

Differential Impact effect of large shocks



ST: $\Theta(\delta)$ impact effect, $\Theta'(0) = 0$, and $\Theta''(0) > 0$

State Dependent Models:

- Price Setting With Menu Cost for Multiproduct Firms, w/Lippi, Econometrica 2014
- The Real Effects of Monetary Shocks in Sticky Price Models: A Sufficient Statistic Approach, w/ Lippi and Lebihan, AER, 2016
- The Macroeconomics of Sticky Prices with Generalized Hazard Functions, w/Lippi and Oslkolkov, QJE, 2021
- The Analytic Theory of a Monetary Shock, w./Lippi, Econometrica, 2022
- From Hyperinflation to Stable Prices: Argentina's Evidence on Menu Cost Models, w/ Beraja, Gonzalez-Rozada, and Neumeyer, QJE 2019
- The Pass-Through of Large Cost Shocks in an Inflationary Economy, w/Neumeyer, Central Bank of Chile book chapter
- Price setting with strategic complementarities as a mean field game, w/ Lippi and Souganidis, Econometrica (R&R). ▸ MFG

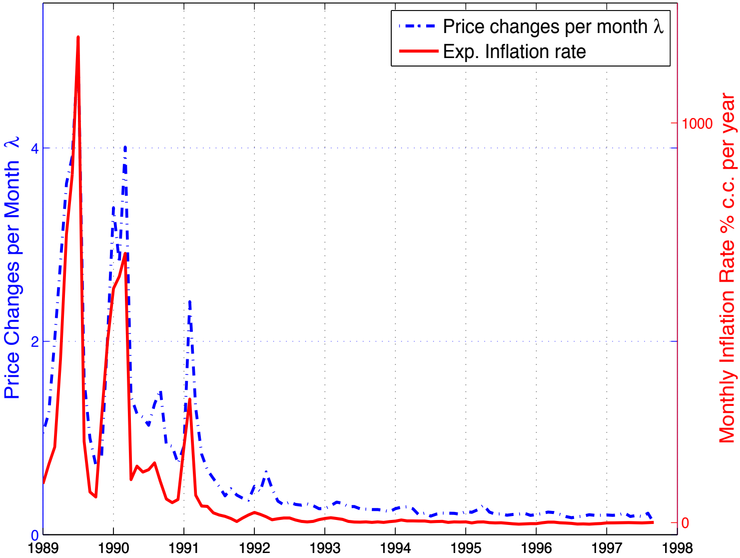
Time and State Dependent Models:

- Monetary Shocks in Models with Inattentive Producers, w/Lippi and Paciello, Rev Economic Studies 2015
- Optimal Price Setting With Observation and Menu Costs, w/Lippi and Paciello, QJE, 2011
- Are State and Time-Dependent Models Really Different?, w/Lippi and Passadore, Macro Annual 2016

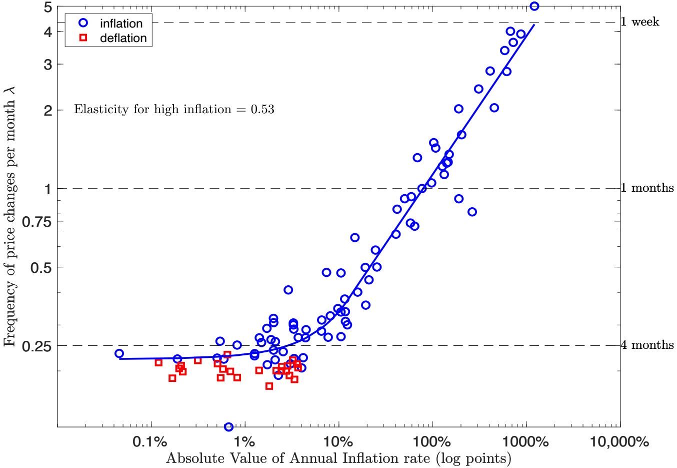
Review Argentina: 1988-1997

- Argentina: 1988-1997: From hyperinflation to stable prices
- Based upon QJE 2019, Alvarez, Beraja, Neumeyer, and Rosada.
- One calendar year with inflation higher than 5,500%
- Before 1991, several (unssucesfull stabilization plans)
- Mid 1991, successful stabilization plan
- After 1992, price stability
- Using CPI data –except regulated prices, and housing.
- Some goods prices gathered monthly, some twice a month

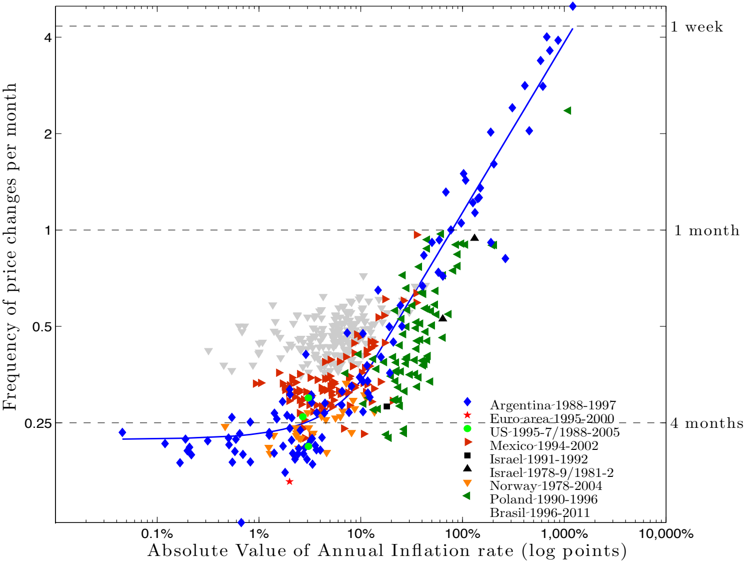
Frequency price changes, inflation



Frequency price changes vs expected inflation

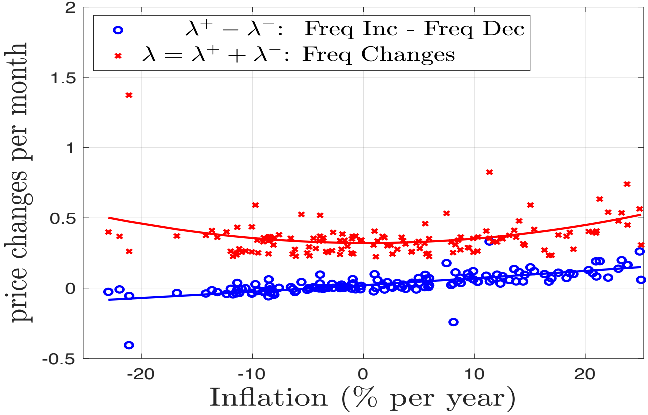


Frequency price changes vs inflation, other countries



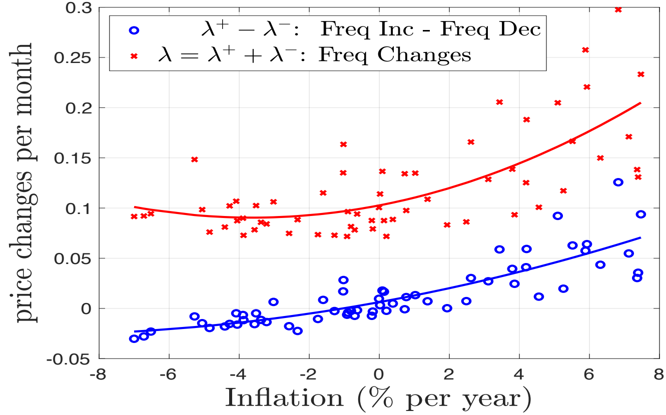
Frequency price changes vs expected inflation, levels

Heterogenous goods/services (monthly)

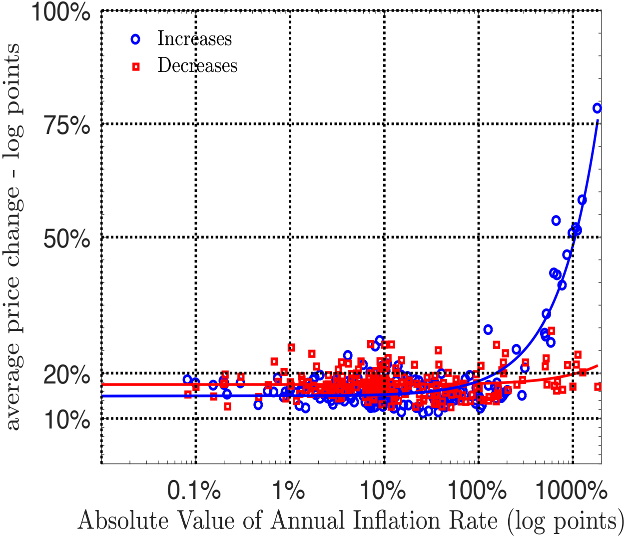


Frequency price changes vs expected inflation, levels

Homogeneous goods (twice a month)



Size of Price Changes vs expected inflation, levels



Taking Stock: evidence in favor of SD

- Total Freq. $\lambda = \lambda^+ + \lambda^-$ insensitive at $\pi = 0$, but increasing in $|\pi|$
- Total Freq. $\lambda = \lambda^+ + \lambda^-$ tends to constant elasticity for large $|\pi|$
- Freq Inc - Dec : $\lambda^+ - \lambda^-$ increases with π everywhere
- Symmetry for frequencies and size around $\pi = 0$
- Small effects of changes on size around $\pi = 0$

Review Mexico: 1994-2002

- Based upon Gagnon, QJE 2009.
- Start just before the 1994 crises
- Conventional stabilization (“corto" & fiscal policy).
- Road to full fledge inflation targeting
- Uses CPI data, excluding regulated goods

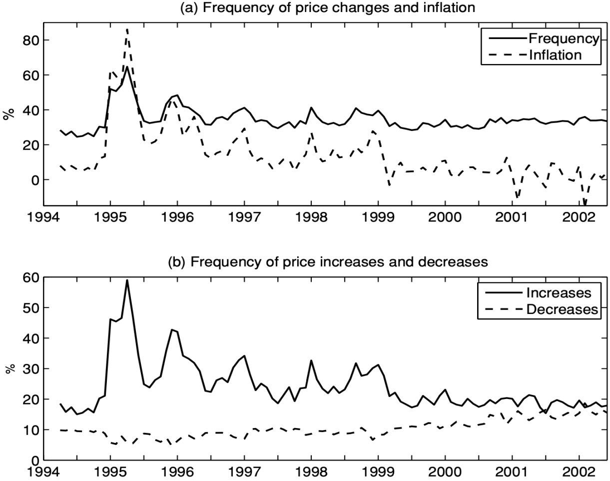
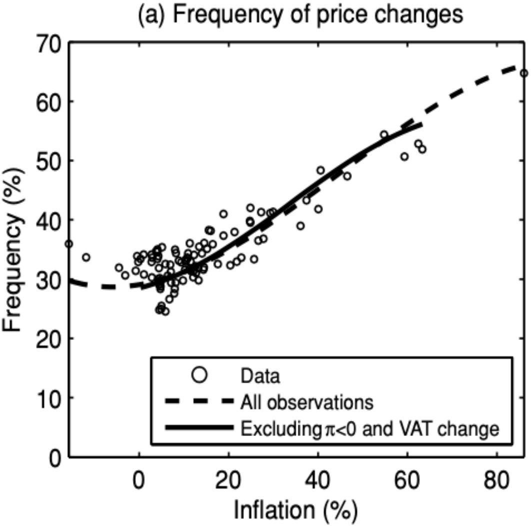


FIGURE III
Monthly Frequency of Price Changes (Nonregulated Goods)
All statistics in the figure, including inflation, are computed using the sample of nonregulated goods.


(a) Frequency of price changes
Frequency (%)
Inflation (%)
70
60
50
40
30
20
10
0
0
20
40
60
80
Data
All observations
Excluding π<0 and VAT change

Mexico: 1994-2002

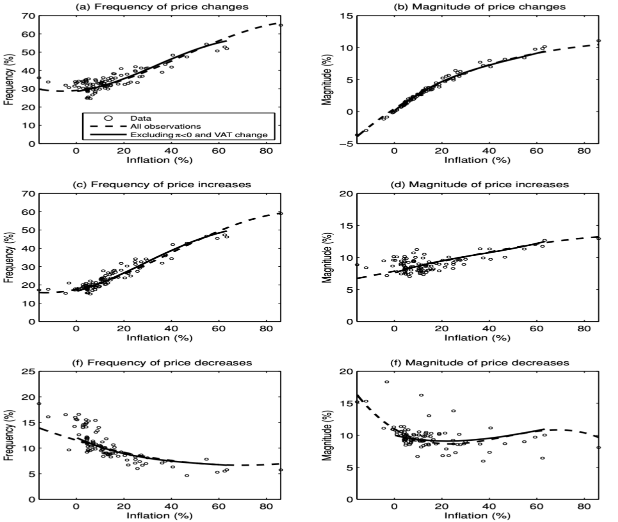


FIGURE IV
Scatterplot of the Monthly Frequency and Average Magnitude of Price Changes and Inflation (Nonregulated Goods)
Each panel contains a scatter plot of the annualized monthly inflation rate

Review US: 1975-2015

- Based upon Nakamura, Steinsson, Sun and Villar , QJE 2018.
- 1970's inflation, Volcker disinflation, low stable inflation
- Uses CPI data, redigitized by authors.

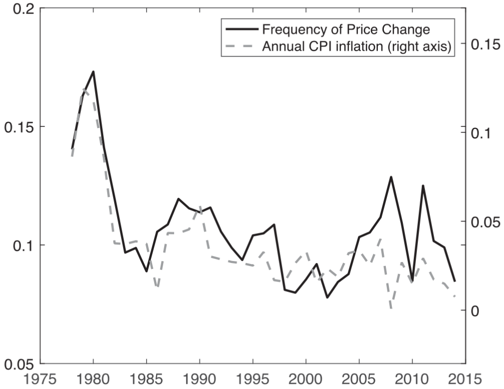


FIGURE XIV

Frequency of Price Change in U.S. Data

To construct the frequency series plotted in this figure, we calculate the mean frequency of price change in each ELI for each year. We then take the weighted median across ELIs.

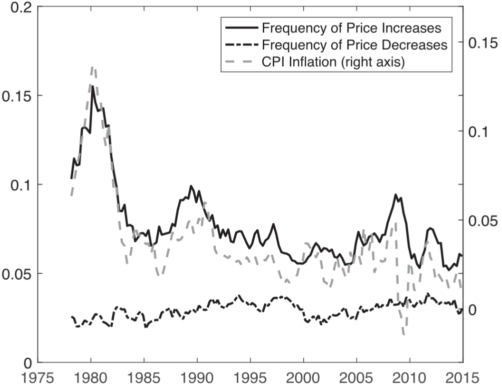
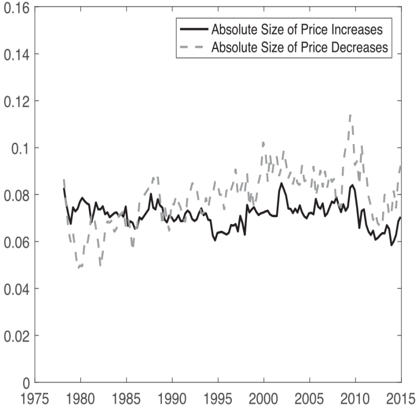


FIGURE XV

Frequency of Price Increases and Decreases

To construct the frequency series plotted in this figure, we calculate the mean frequency of price increases and decreases in each ELI for each month. We then take the weighted median across ELIs. Finally, for each quarter we take the average over the past 12 months.



APPENDIX FIGURE A.3

Absolute Size of Price Increases and Decreases

To construct the series plotted in this figure, we calculate the mean absolute size of price increases and decreases in each ELI for each month. We then take the weighted median across ELIs. Finally, for each quarter we take the average of the resulting series over the past 12 months.

Taking Stock: evidence in favor of SD

- Total Freq. $\lambda = \lambda^+ + \lambda^-$ insensitive at $\pi = 0$, but increasing in $|\pi|$
- Freq Inc - Dec : $\lambda^+ - \lambda^-$ increases with π everywhere
- Symmetry for frequencies and size around $\pi = 0$
- Small effects of changes on size around $\pi = 0$
- Smaller range of variation on inflation than Argentina.

Review: Argentina large utility price changes in 2010's

- Argentina: time period 2012-2018
- By 2014: 5 years of utility prices frozen, while inflation was high
- Exchange rate controls, multiple exchange rate, heavily rationed.
- Adjustments liberalizations in 2014, 2016, and 2018.
- Extremely large adjustment on utility prices.
- Focus on Core inflation (non-utilities) and from city of Buenos Aires

Figure: Changes in Energy Prices, Depreciation and Inflation

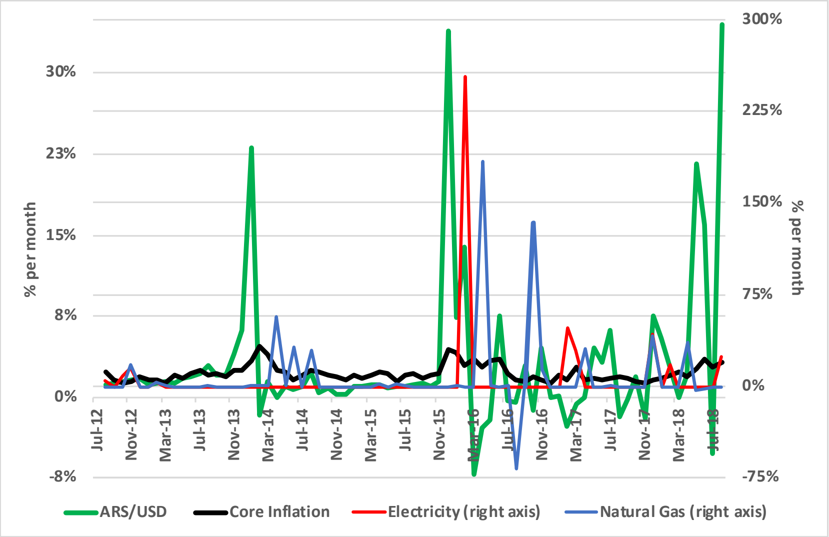


Figure: Frequency of Price Changes and Inflation

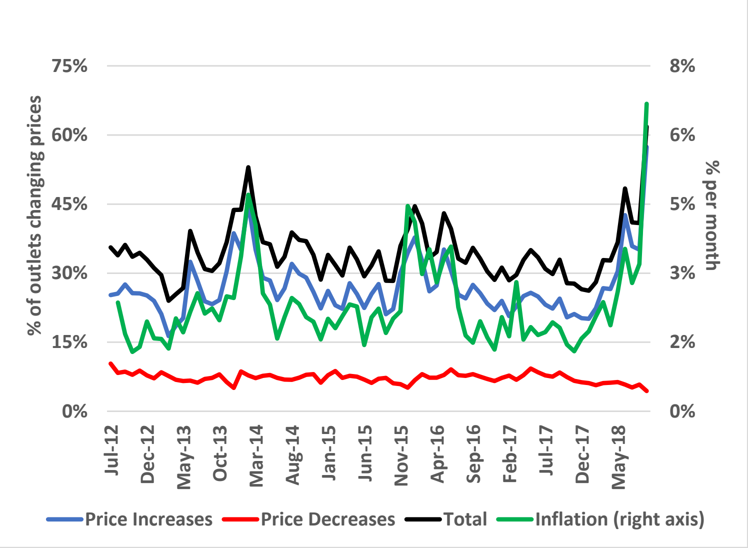
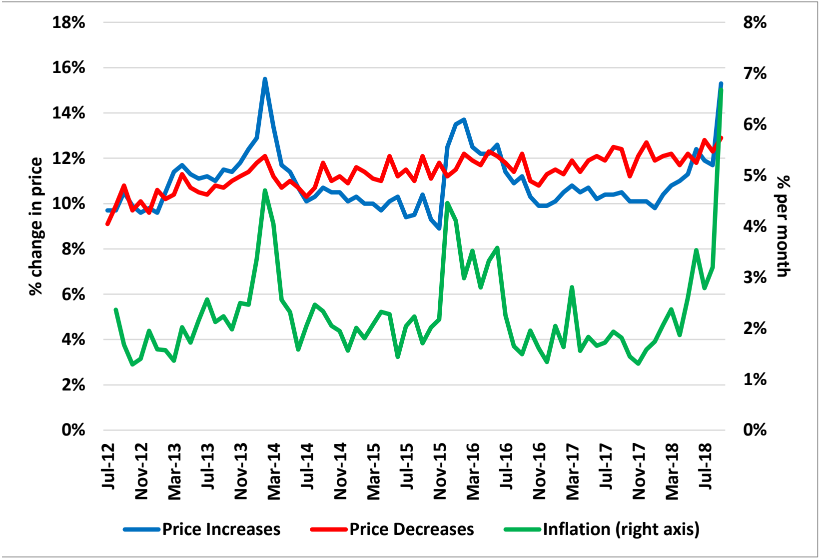


Figure: Size of Price Changes and Inflation



Core consumer prices for the City of Buenos Aires. Left axis is the average size of price in(de)creases conditional on outlets changing prices. Inflation is % per month

Taking Stock: evidence in favor of SD

- Total Freq. $\lambda = \lambda^{+} + \lambda^{-}$ jumps at the time of shock δ
- Jump is specially on λ^{+}
- Average size increase jumps at the time of shock δ.
- Fast pass-through of large shock
- Also: Karadi and Reiff, AEJ-Macro 2018 on large shocks

Taking Stock: evidence in favor of SD

- Total Freq. $\lambda = \lambda^{+} + \lambda^{-}$ jumps at the time of shock δ
- Jump is specially on λ^{+}
- Average size increase jumps at the time of shock δ.
- Fast pass-through of large shock
- Also: Karadi and Reiff, AEJ-Macro 2018 on large shocks
- Other literature finds the same in different contexts:
  - Switzerland end of peg
    (Bonadio, Fischer, & Saure 16, Auer, Burstein, & Lein 18)
  - Panel of changes on exchange rates for flexible rates,
    Alvarez, Passadore and Lippi 16
  - Non-linear Jorda projectins US, Ascari and Haber 18,

Approx. symmetric distribution at zero inflation

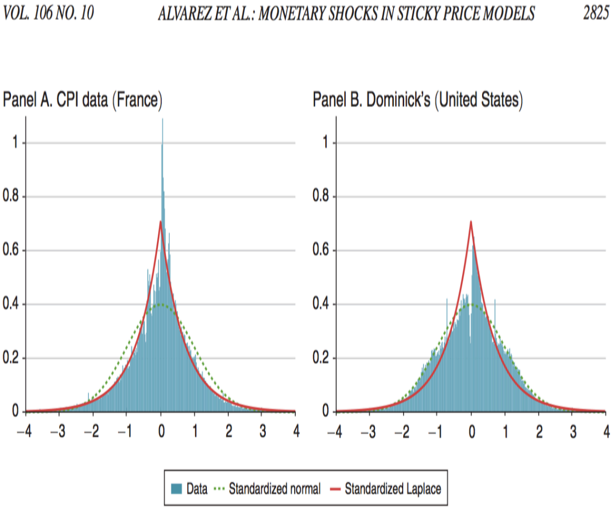


FIGURE 1. HISTOGRAM OF STANDARDIZED PRICE CHANGES: FRANCE AND UNITED STATES

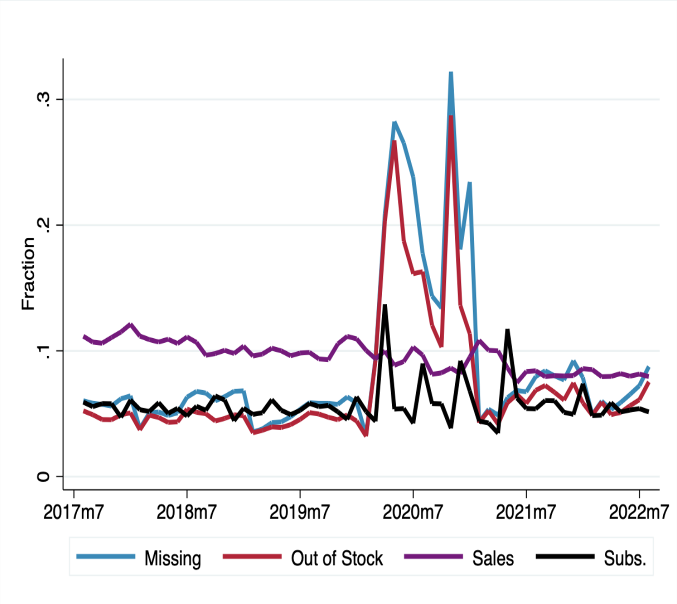
New: UK 2017-2022

- CPI: Aprox 90 Coicop 6 categories
- Before Covid, Covid and return of Inflation
- Lots of missing and out of stock during Covid.
- Ignore Sales (iron them), about 9 millions quaotes

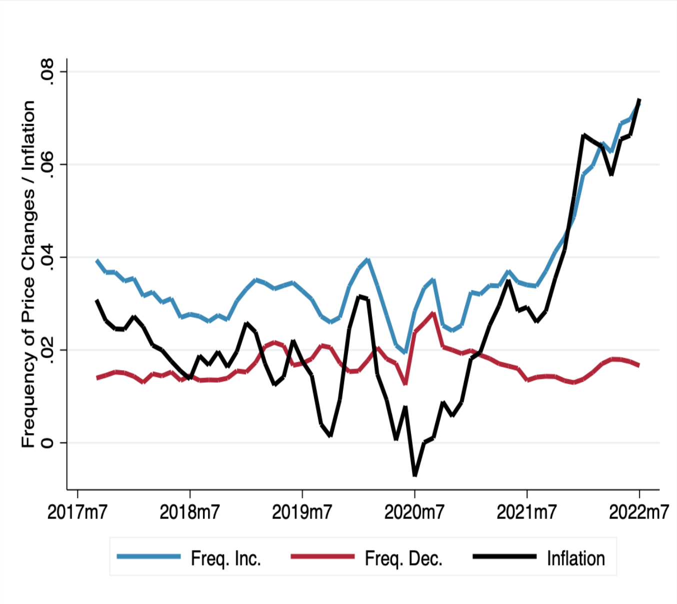
- Eliminate two sectors: frequency almost one per month

  housing-water-electricity other fuels, &
  restaurants and accommodations services

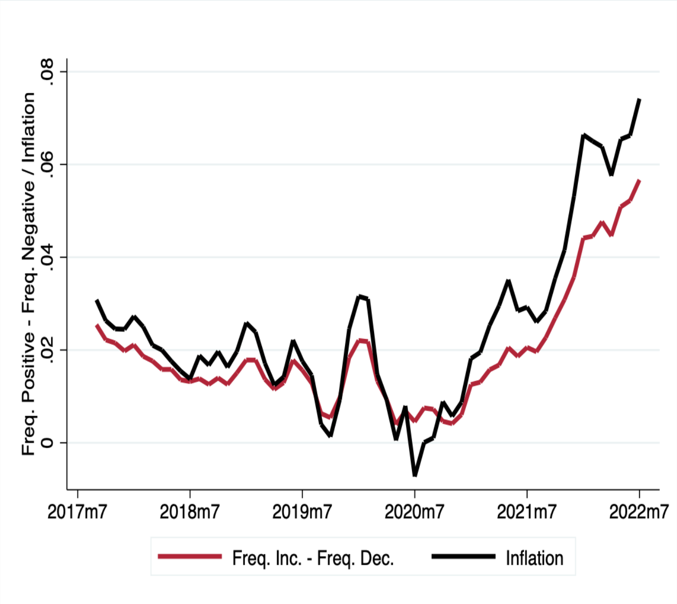
Covid has large effect on 2020



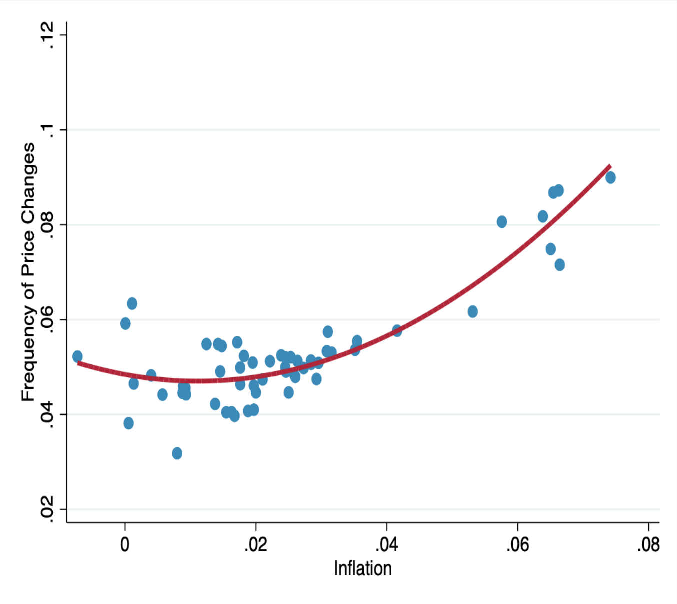
Inflation and Frequency of Price Changes



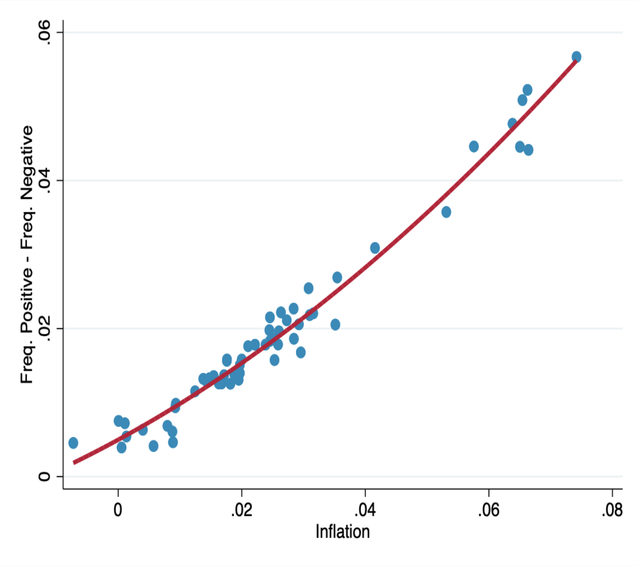
Inflation and Frequency of Price Inc - Dec.



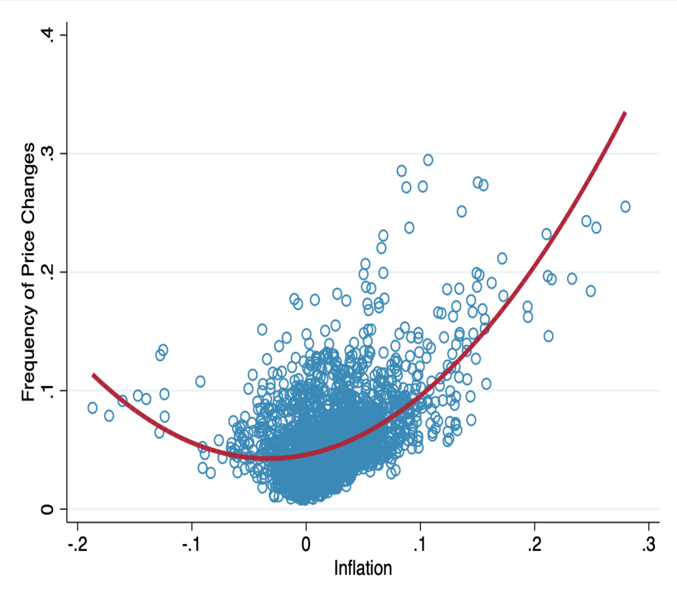
Inflation π & Freq. P. Changes: λ month agg.



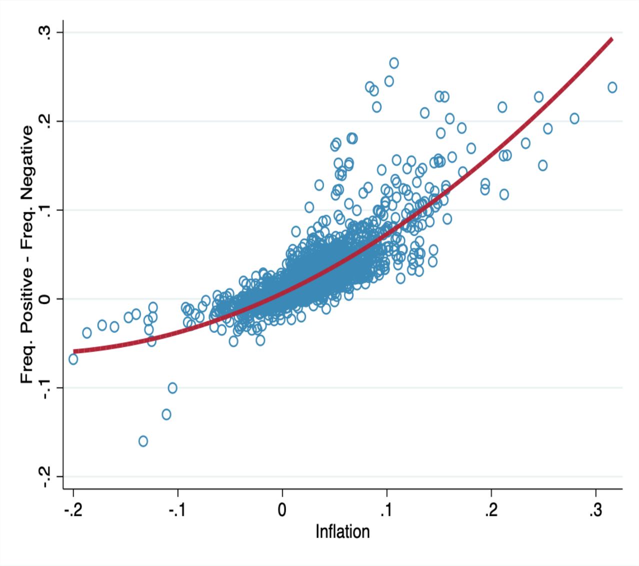
Inflation π & Freq. of Inc-Dec: $\lambda^+ - \lambda^-$ month agg.



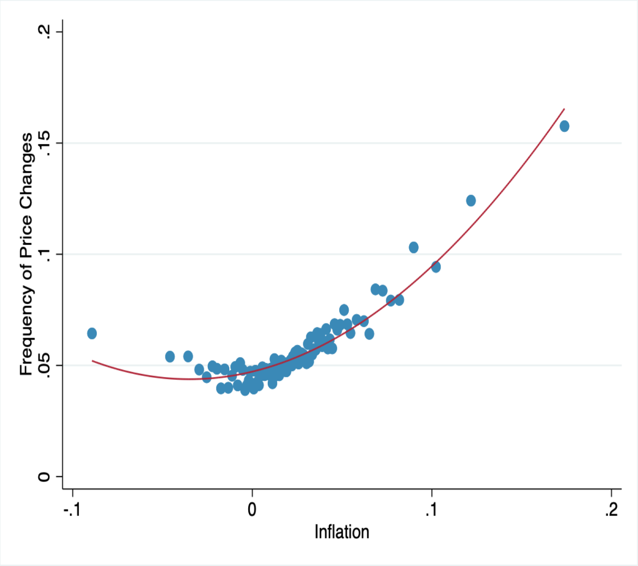
Inflation π & Freq. of P. Changes λ: monthly, by cat.



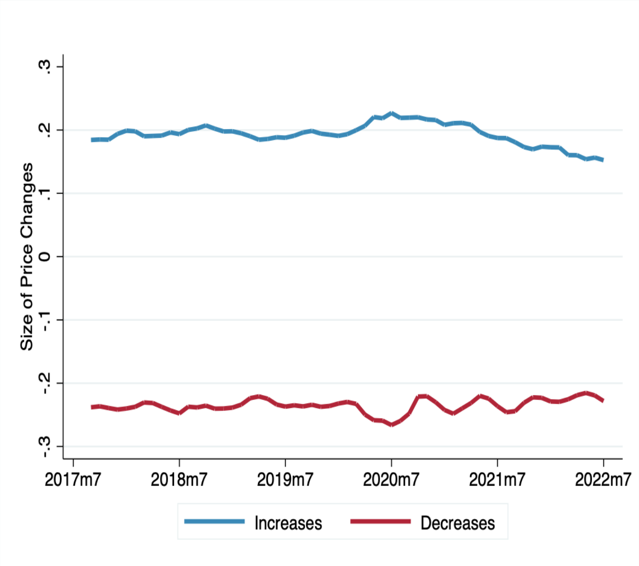
Inflation: π & Freq Inc-Dec: $\lambda^{+} - \lambda^{-}$: monthly, by cat.



Inflation π& Freq. of P. Changes π: monthly by category, bin scatter and fixed effects



Inflation & Size of P. Changes: monthly aggregates



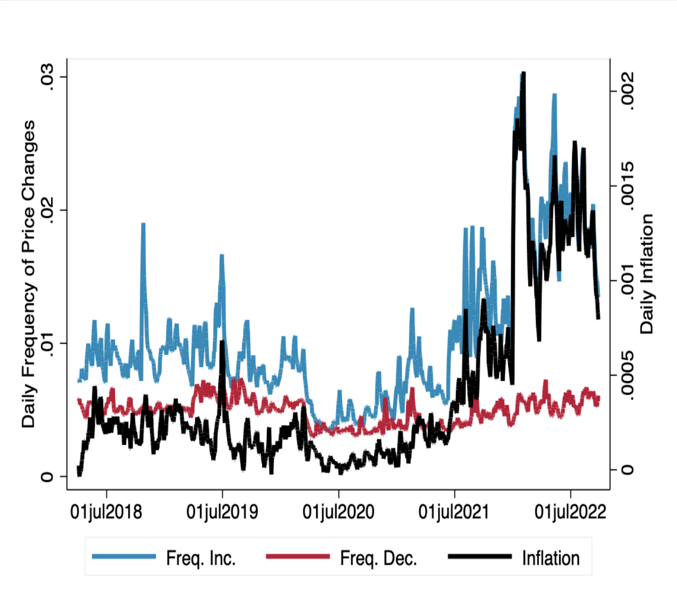
Taking Stock: UK recent years

- Similar patterns than Argentina and Mexico at similar inflation
- Similar patterns US during 70's
- Hence, supportive evidence for State Dependent models.

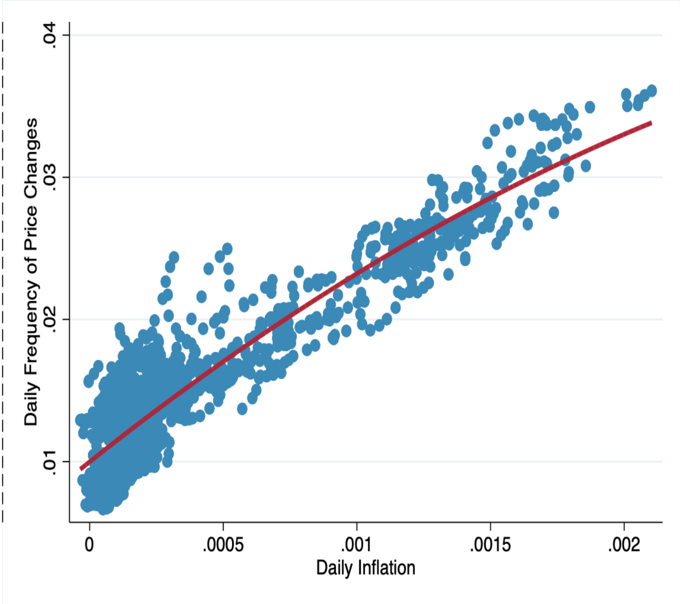
US: scanner data 2018 to September 2022

- New Decadata: daily (actually transaction), 500 stores nationwide
- 500 stores, 392 categories, 13 UPC per category with positive sales
- 2018 to September 2022 $\approx$ 1600 days, $\implies$ 4 Billions of observations.
- Similar type of goods as Nielsen. Has also quantities, and cost data.
- Report daily frequency and inflation
- Equally weighted goods with positive sales in a day
- Results are very preliminary, as it is a new data set.
- Joint work Argente, Lee and Moreira.

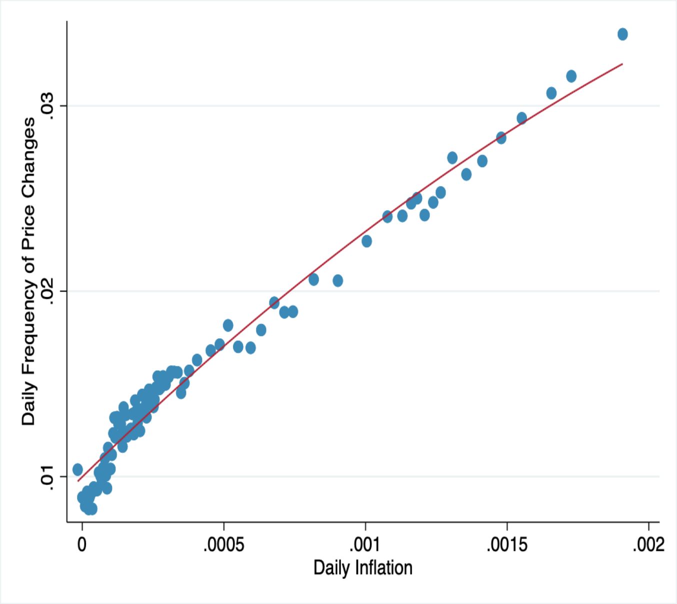
Inflation & Freq. of P. Changes: daily



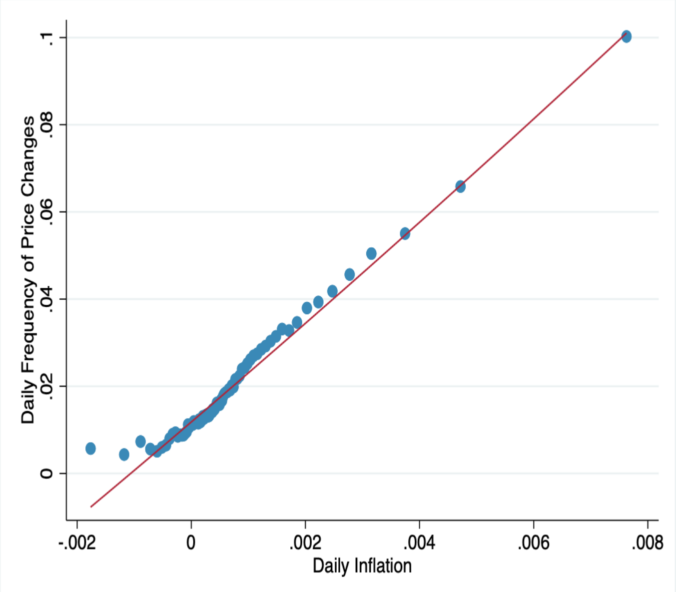
Inflation & Freq. of P. Changes: daily aggregate



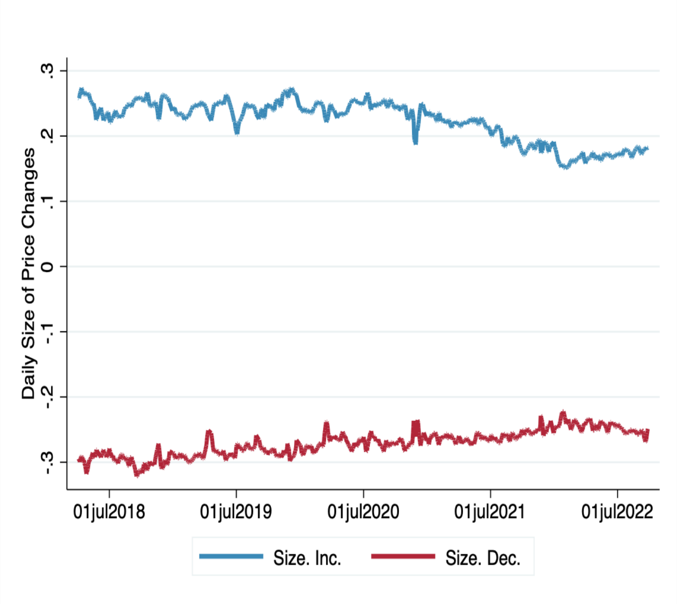
Inflation & Freq. of P. Changes: daily aggregate



Inflation & Freq. of P. Changes: daily × category, bin-scatter w/ cat. fixed effects



Inflation & Size of Price Changes: daily aggregates



Conclusions

- Empirical evidence:
  - For non-negligible inflation: correlated with total frequency of changes
  - Large cost shocks correlated with total frequency of price changes
- Interpretation: inflation and cost shocks $\implies$ frequency
- Vast majority of models used in Central Banks: Calvo (TD).

\- Inconsistent with this interpretation of the evidence

- Underestimates pass through for large cost shocks.
- Cavallo's Jackson hole Amazon effect: secular exogenous trend

\- Instead, effect emphasized here is endogenous to size of shocks.

o Asymmetric response to positive and negative shocks.

General Equilibrium Set Up (Klenow-Willis)

$$\text{HH Utility}: \int_0^\infty e^{-\rho t} \left(U(C(t)) - \mathrm{a}\, L(t) + \log \frac{M(t)}{P(t)} \right) dt$$

$$\text{Kimball Aggregator } C(t) : \quad 1 = \left(\int_0^1 \Upsilon \left(\frac{c_k(t)}{C(t)} A_k(t) \right) dk \right)$$

- $q_k(t) + c_k(t) = (L_k(t)/Z_k(t))^{\alpha}\, l_k(t)^{1-\alpha}$ all $k \in [0,1], t \geq 0$.
- $\ell(t) + \int_0^1 L_k(t)\, dk = L(t)$ where $\ell(t)$ labor used in menu cost
- Random cost shock $d \log Z_k(t) = \sigma d\mathcal{W}(t)$, i.i.d.
- Intermediates: $\int_0^1 l_k(t)\, dk = Q(t)$ and $1 = \int_0^1 \Upsilon \left(\frac{q_k(t)}{Q(t)} A_k(t) \right) dk$
- Random menu cost, ψ (% profits) w/pr $1 - \zeta dt$ or zero w/pr ζdt.

Prelim: Second order approx of firm max. profit

- Profit function $\Pi(p,P) \equiv D\left(\frac{p}{P}\right)(p-\chi)$, cost $\chi \equiv (W/Z)^{\alpha} P^{1-\alpha}$
- Optimal markup: $\frac{p^*-\chi}{p^*} = 1/\eta\left(\frac{p^*}{P}\right) \equiv 1/\text{elasticity}$.
- Consider $\bar{P}$ such that $(p^*(\bar{P}), \bar{P}) = (\bar{P}, \bar{P})$

$$\frac{\Pi(p,P)}{\Pi(\bar{P},\bar{P})} = 1 - \underbrace{\frac{1}{2} B \left(\underbrace{\frac{p-\bar{P}}{\bar{P}}}_{x} + \theta \underbrace{\frac{P-\bar{P}}{\bar{P}}}_{X} \right)^2}_{F(x,X)} + \text{higher order}$$

$$B \equiv -\frac{\Pi_{11}(\bar{P},\bar{P})}{\Pi(\bar{P},\bar{P})} \bar{P}^2$$

$$\theta \equiv -\frac{\bar{P}}{p^*(\bar{P})} \frac{\partial p^*(\bar{P})}{\partial P} = -\frac{\underbrace{\frac{\eta'(1)}{\eta(1)(\eta(1)-1)}}_{\text{micro elasticity}} + \underbrace{1-\alpha}_{\text{macro elasticity}}}{1 + \frac{\eta'(1)}{\eta(1)(\eta(1)-1)}}$$

GE approx. and MFG

Ignores GE effects of 3^{rd} order in firm's problem at equilibrium.

- Approximation is accurate if we assume :
  1. Shock δ is small
  2. Small idiosyncratic shocks
  3. Log Money in Utility
  4. Linear Leisure (infinite Frisch)
- If Labor Frisch is finite or Decreasing returns to scale:
  θ has different interpretation, but same approximation

The firm's dynamic problem with complementarities

- value function $u(x,t)$ for the firm 's problem:

$$u(x,t) =$$
$$\min_{\{\tau_j, \Delta x_j\}} \mathbb{E}\Big[\int_t^{\infty} e^{-\rho(s-t)} F(x(s), X(s)) ds + \sum_{j=1, \tau_j \neq \bar{\tau}_j}^{\infty} e^{-\rho(\tau_j - t)} \psi \Big| x(t) = x \Big]$$

- Firm takes path $\{X(t)\}_{t=0}^{\infty}$ as given = **average of x's of all firms**
- Firm decides stopping times τ_j and changes Δx_j
- Does not pay the fixed cost are random times -Calvo fairy
- Optimal policy given by thresholds PATH: $\underline{x}(t) < x^*(t) < \bar{x}(t)$
  – Inaction in interval $[\underline{x}(t), \bar{x}(t)]$ for all $t \geq 0$ and

  – Impulse control to $x^*(t)$ outside the inaction range.
- $F(x, X) \equiv B(x + \theta X)^2$; Strategic complementarity if $\theta < 0$

MFG: HJB and KFE

A MFG is given by functions $u, m, \underline{x}, \bar{x}, x^*, X$ satisfying for all $t \in [0, T]$

$$0 = \partial_t u(x,t) - (\rho + \zeta)u(x,t) + \frac{\sigma^2}{2}\partial_{xx}u(x,t) + F(x, X(t)) - \zeta u(x^*(t), t)$$
$$\text{all } x \in [\underline{x}(t)\,,\ \bar{x}(t)]$$

$$0 = -\partial_t m(x,t) + \frac{\sigma^2}{2}\partial_{xx}m(x,t) - \zeta m(x,t) \ \text{ all } x \in [\underline{x}(t)\,,\ \bar{x}(t)], x \neq x^*(t)$$

$$X(t) = \int_{\underline{x}(t)}^{\bar{x}(t)} x\, m(x,t)dx$$

– Classical boundary conditions for u for all $t > 0$:

smooth pasting + optimal x^*: $\partial_x u(\bar{x}(t), t) = \partial_x u(\underline{x}(t), t) = \partial_x u(x^*(t), t) = 0$

value matching: $u(\bar{x}(t), t) = u(\underline{x}(t), t) = u(x^*(t), t) + \psi$

– Terminal condition: Back to steady state at $t = T$, and $T \to \infty$.

MFG: HJB and KFE

A MFG is given by functions $u, m, \underline{x}, \bar{x}, x^*, X$ satisfying for all $t \in [0, T]$

$$0 = \partial_t u(x,t) - (\rho+\zeta)u(x,t) + \frac{\sigma^2}{2}\partial_{xx}u(x,t) + F(x, X(t)) - \zeta u(x^*(t), t)$$
all $x \in [\underline{x}(t), \bar{x}(t)]$

$$0 = -\partial_t m(x,t) + \frac{\sigma^2}{2}\partial_{xx}m(x,t) - \zeta m(x,t) \text{ all } x \in [\underline{x}(t), \bar{x}(t)], x \neq x^*(t)$$

$$X(t) = \int_{\underline{x}(t)}^{\bar{x}(t)} x\, m(x,t) dx$$

–Classical boundary conditions for m for all $t \in (0, T]$:

no mass outside inaction: $0 = m(x,t) = 0$ all $x \notin [\underline{x}(t), \bar{x}(t)]$

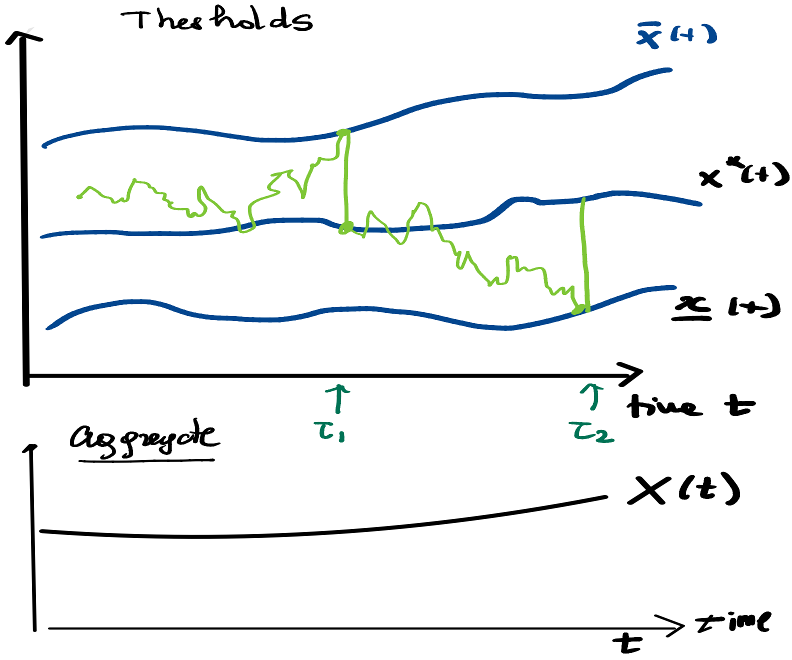
continuity: $0 = m(\bar{x}(t), t) = m(\underline{x}(t), t)$

mass preservation: $1 = \int_{\underline{x}(t)}^{\bar{x}(t)} m(x,t) dx$

– Initial condition: for all x:

$m(x,0) = \tilde{m}(x) + \delta\nu(x)$ e.g. $= \tilde{m}(x+\delta) = \tilde{m}(x) + \tilde{m}'(x)\delta + o(\delta)$

Perturbation: size δ direction ν on s.s. density $\tilde{m}$.


Thresholds
$\bar{x}(t)$
$x^*(t)$
$\underline{x}(t)$
time t
τ_1
τ_2
aggregate
$X(t)$
time
t

Insensitivity of frequency of price changes

- $\lambda(t;\delta)$: frequency of price changes t periods after shock δ.

- $\lambda(t;\delta) = \underbrace{\frac{\sigma^2}{2} m_x(\underline{x}(t), t;\delta)}_{\text{hit bottom barrier}} \underbrace{- \frac{\sigma^2}{2} m_x(\bar{x}(t), t;\delta)}_{\text{hit top barrier}} + \underbrace{\zeta}_{\text{Calvo}}$

- $\lambda(t;\delta) = \lambda_{ss} + \frac{\sigma^2}{2} \left[n_x(-\bar{x}_{ss}, t;\delta)(-1,t) - n_x(\bar{x}_{ss}, t;\delta) \right] \delta + o(\delta)$

  where $n(x,t) \equiv \frac{\partial}{\partial \delta} m(x,t;\delta)|_{\delta=0}$

- We show that $n(\cdot, t)$ is antisymmetric, i.e.: $n(x,t) = -n(-x,t)$, so $n_x(\cdot, t)$ is symmetric.

- Then: $\lambda(t,\delta) = \lambda_{ss} + o(\delta)$, i.e. no change on the frequency.

- Notice that:
  - the three boundaries of the sS policy move
  - there is a density that initially is outside the inaction region Theory