The Inflation Accelerator

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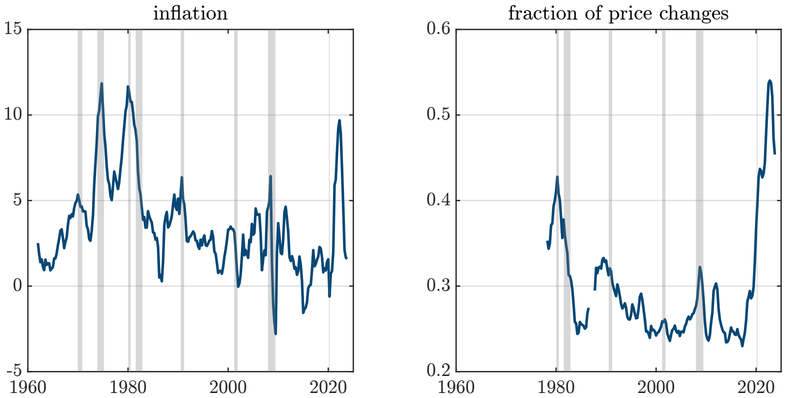
[1] The views expressed herein are those of the authors and not necessarily those of the Board of Governors of the Federal Reserve System, the Federal Reserve Bank of Atlanta or the Federal Reserve System.

Motivation

- Dynamics of inflation shaped critically by the slope of the Phillips curve
  - key determinant: fraction of price changes
- Empirical evidence: fraction of price changes increases with inflation
  - Gagnon (2009), Alvarez et al. (2018), Blanco et al. (2024)

Evidence from the U.S.



Source: Nakamura et al. (2018), Montag and Villar (2023). Fraction quarterly.

Motivation

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- Empirical evidence: fraction of price changes increases with inflation
  - Gagnon (2009), Alvarez et al. (2018), Blanco et al. (2024)
- How does the slope of the Phillips curve fluctuate in U.S. time series?
  - answer using model that reproduces this evidence

Existing Models

- Calvo model
  - widely used due to its tractability
  - constant fraction of price changes

- Menu cost model
  - less tractable: state of the economy includes distribution of prices
  - calibration consistent with micro price data: fraction nearly constant

- Our model
  - tractable model with time-varying endogenous fraction of price changes
  - multi-product firms choose *how many*, but not *which*, prices to change
  - exact aggregation: reduces to one-equation extension of Calvo

Our Findings

- Our model predicts a highly non-linear Phillips curve
  - slope fluctuates from 0.02 in 1990s to 0.12 in 1970s and 1980s
- Mostly due to the feedback loop between frequency and inflation
  - higher inflation increases the frequency of price changes
  - higher frequency further increases inflation
  - *inflation accelerator*
- Absent feedback loop slope would increase to only 0.04 in 1970s and 1980s

Model

Model Overview

- Multi-product firms: each sells a continuum of goods
  - decreasing returns labor-only technology
  - cost of changing prices
- Monetary policy targets nominal spending M_t
  - only source of aggregate uncertainty
- Quasi-linear preferences in labor
  - nominal wages proportional to M_t

Consumers

- Life-time utility

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\log c_t - h_t\right)$$

- Budget constraint

$$P_t c_t + \frac{1}{1+i_t} B_{t+1} = W_t h_t + D_t + B_t$$

- Monetary policy targets nominal spending $M_t = P_t c_t$

$$\log M_{t+1}/M_t = \mu + \sigma \varepsilon_{t+1}, \text{ with } \varepsilon_t \sim \mathbb{N}(0,1)$$

- Log-linear preferences imply $W_t = M_t$

Technology

- Final good used for consumption, produced using CES aggregator

$$c_t = y_t = \left(\int_0^1 \int_0^1 (y_{ikt})^{\frac{\theta-1}{\theta}} \, \mathrm{d}k \mathrm{d}i \right)^{\frac{\theta}{\theta-1}}$$

  – y_{ikt} output of good k produced by firm i, sold at price P_{ikt}

- Demand for individual product

$$y_{ikt} = \left(\frac{P_{ikt}}{P_t} \right)^{-\theta} y_t, \qquad \text{where} \qquad P_t = \left(\int_0^1 \int_0^1 (P_{ikt})^{1-\theta} \, \mathrm{d}k \mathrm{d}i \right)^{\frac{1}{1-\theta}}$$

- Individual goods produced with decreasing returns technology

$$y_{ikt} = (l_{ikt})^{\eta}$$

- Real flow profits of firm i

$$\int_0^1 \left(\left(\frac{P_{ikt}}{P_t} \right)^{1-\theta} y_t - \tau \frac{W_t}{P_t} \left(\frac{P_{ikt}}{P_t} \right)^{-\frac{\theta}{\eta}} y_t^{\frac{1}{\eta}} \right) \mathrm{d}k$$

Price Adjustment Costs

- Firm chooses fraction of prices to change n_{it}
  - but not which prices to change (similar to Greenwald 2018)

- Price adjustment cost, denominated in units of labor

$$\frac{\xi}{2}\left(n_{it}-\bar{n}\right)^2, \quad \text{if } n_{it} > \bar{n}$$

  - when $\xi \to \infty$, model collapses to Calvo with constant frequency $\bar{n}$

- If adjust $P_{ikt} = P^*_{it}$, otherwise $P_{ikt} = P_{ikt-1}$

Firm-Level Aggregation

- Firm-level output y_{it} and labor l_{it}

$$y_{it} = \left(\int_0^1 (y_{ikt})^{\frac{\theta-1}{\theta}} \, \mathrm{d}k \right)^{\frac{\theta}{\theta-1}} \qquad \text{and} \qquad l_{it} = \int_0^1 l_{ikt} \mathrm{d}k$$

- Firm-level production function

$$y_{it} = \left(\frac{X_{it}}{P_{it}} \right)^{\theta} l_{it}^{\eta}$$

  - depends on firm price index P_{it} and losses from misallocation X_{it}

$$P_{it} = \left(\int_0^1 (P_{ikt})^{1-\theta} \, \mathrm{d}k \right)^{\frac{1}{1-\theta}} \qquad \text{and} \qquad X_{it} = \left(\int_0^1 (P_{ikt})^{-\frac{\theta}{\eta}} \, \mathrm{d}k \right)^{-\frac{\eta}{\theta}}$$

  - absent price dispersion $X_{it}/P_{it} = 1$, otherwise $X_{it}/P_{it} < 1$

Firm Problem

- Choose reset price P^*_{it} and fraction of price changes n_{it} to maximize

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\underbrace{\left(\frac{P_{it+s}}{P_{t+s}}\right)^{1-\theta}}_{\text{sales}} - \underbrace{\tau \left(\frac{X_{it+s}}{P_{t+s}}\right)^{-\frac{\theta}{\eta}} y_{t+s}^{\frac{1}{\eta}}}_{\text{labor costs}} - \underbrace{\frac{\xi}{2}\left(n_{it+s} - \bar{n}\right)^2}_{\text{repricing costs}} \right]$$

- P^*_{it} and n_{it} affect firm price index and misallocation at all future dates

$$\begin{aligned}(P_{it+s})^{1-\theta} &= n_{it+s}\left(P^*_{it+s}\right)^{1-\theta} + \left(1 - n_{it+s}\right) n_{it+s-1}\left(P^*_{it+s-1}\right)^{1-\theta} + \cdots \\ &+ \prod_{j=1}^{s}\left(1 - n_{it+j}\right) n_{it}\left(P^*_{it}\right)^{1-\theta} + \prod_{j=1}^{s}\left(1 - n_{it+j}\right)\left(1 - n_{it}\right)\left(P_{it-1}\right)^{1-\theta}\end{aligned}$$

▸ misallocation

- History encoded in two state variables: P_{it-1} and X_{it-1}
  - exact aggregation because adjustment hazard does not depend on P_{ikt-1}

Optimal Reset Price

- Optimal reset price

$$\left(\frac{P_{it}^*}{P_t}\right)^{1+\theta\left(\frac{1}{\eta}-1\right)} = \frac{b_{2it}}{b_{1it}}$$

- Present value of marginal revenue and costs in future dates
  - weighted by the probability that a price is still in effect at a future date

$$b_{1it} = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \prod_{j=1}^{s} (1 - n_{it+j}) \left(\frac{P_{t+s}}{P_t}\right)^{\theta-1}$$

$$b_{2it} = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \prod_{j=1}^{s} (1 - n_{it+j}) \left(\frac{P_{t+s}}{P_t}\right)^{\frac{\theta}{\eta}} \underbrace{y_t^{1/\eta} \eta^{-1}}_{=\eta^{-1} w_t y_t^{1/\eta - 1}}$$

- Similar to Calvo, except n_{it} time-varying

Optimal Fraction of Price Changes

- Equate marginal cost to marginal benefit

$$\xi\left(n_{it}-\bar{n}\right)=b_{1it}\left(\left(\frac{P_{it}^{*}}{P_{t}}\right)^{1-\theta}-\left(\frac{P_{it-1}}{P_{t}}\right)^{1-\theta}\right)-\tau b_{2it}\left(\left(\frac{P_{it}^{*}}{P_{t}}\right)^{-\frac{\theta}{\eta}}-\left(\frac{X_{it-1}}{P_{t}}\right)^{-\frac{\theta}{\eta}}\right)$$

- Marginal benefit: higher n_{it}
  - changes firm price index
  - and reduces misallocation
  - weighted by the same terms b_{1it} and b_{2it} that determine P_{it}^{*}

Symmetric Equilibrium

- Since firms are identical, in equilibrium $P^*_{it} = P^*_t$, $n_{it} = n_t$, ...

- Going forward: $p_t = P_t/M_t$, $p^*_t = P^*_t/M_t$, $x_t = X_t/P_t$ and $\pi_t = P_t/P_{t-1}$

- Equilibrium conditions

  – reset price: $\frac{p^*_t}{p_t} = \left(\frac{b_{2t}}{b_{1t}}\right)^{\frac{1}{1+\theta\left(\frac{1}{\eta}-1\right)}}$

  – price index: $1 = n_t \left(\frac{p^*_t}{p_t}\right)^{1-\theta} + (1-n_t)\,\pi_t^{\theta-1}$

  – losses from misallocation: $x_t^{-\frac{\theta}{\eta}} = n_t \left(\frac{p^*_t}{p_t}\right)^{-\frac{\theta}{\eta}} + (1-n_t)\,x_{t-1}^{-\frac{\theta}{\eta}}\pi_t^{\frac{\theta}{\eta}}$

  – fraction of price changes:
  $\xi\left(n_t - \bar{n}\right) = b_{1t}\left(\left(\frac{p^*_t}{p_t}\right)^{1-\theta} - \left(\frac{1}{\pi_t}\right)^{1-\theta}\right) - \tau\eta b_{2t}\left(\left(\frac{p^*_t}{p_t}\right)^{-\frac{\theta}{\eta}} - \left(\frac{x_{t-1}}{\pi_t}\right)^{-\frac{\theta}{\eta}}\right)$

Computation

- Model collapses to one-equation extension of Calvo
  - the additional equation determines the fraction of price changes
  - as $\xi \to \infty$, $n_t = \bar{n}$ so our model nests Calvo
- Two state variables: previous period price and misallocation
  - do not need to keep track of joint distribution of these variables
  - because firms are ex-post identical
- Solve the model globally, but third-order perturbation reasonably accurate

Parameterization

Calibration Strategy

- Assigned parameters
  - period 1 quarter so $\beta = 0.99$
  - demand elasticity $\theta = 6$ and span of control $\eta = 2/3$
- Calibrated parameters
  - mean and standard deviation of nominal spending growth μ and σ
  - fraction of free price changes $\bar{n}$ and price adjustment cost ξ
- Calibration targets
  - mean and standard deviation of inflation
  - mean fraction of price changes
  - slope of fraction of price changes on absolute value of inflation

Calibrated Parameters

Targeted Moments

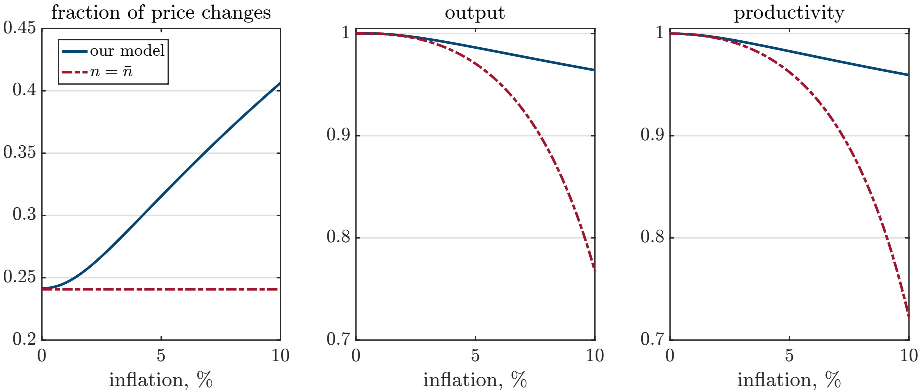
	Data	Our model	Calvo
mean inflation	3.517	3.517	3.517
s.d. inflation	2.739	2.739	2.739
mean fraction	0.297	0.297	0.297
slope of n_t on $\|\pi_t\|$	0.016	0.016	–

Calibrated Parameters

		Our model	Calvo
μ	mean spending growth rate	0.035	0.035
σ	s.d. monetary shocks	0.022	0.024
$\bar{n}$	fraction free price changes	0.241	0.297
ξ	adjustment cost	1.767	–

- Price adjustment costs account for 0.65% of all labor costs

Steady-State Output and Productivity



- Inflation less distortionary in our model

  ▸ equations

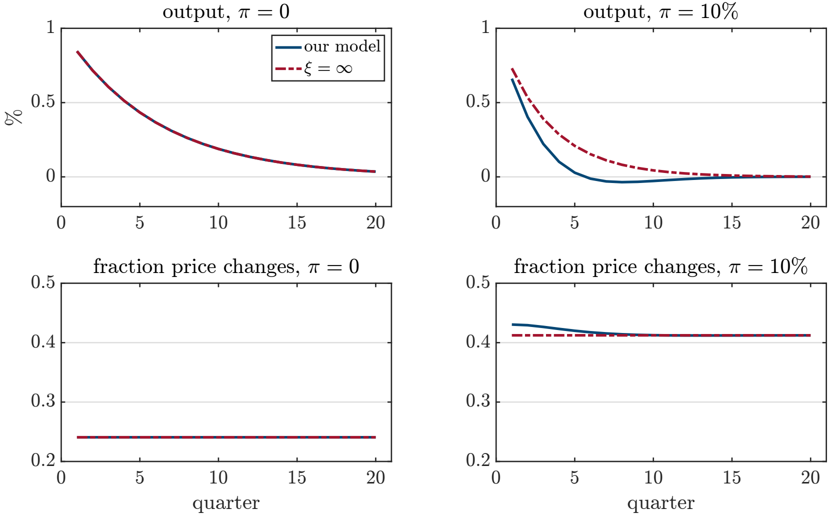
  – because more frequent price changes, as in menu cost models

Real Effects of Monetary Shocks

- Response to 1% monetary shock
  - in economies with 0 and 10% trend inflation
  - compare to economy with steady-state frequency as our model, but $\xi = \infty$

- Focus on output response
  - $M_t = P_t y_t$, so output response depends on how sticky prices are

Response to 1% Monetary Shock



Understanding the Result

- Small jump in frequency has large effect on price level

- To see why, log-linearize expression for aggregate price index

$$\hat{\pi}_t = \underbrace{\frac{1}{(1-n)\,\pi^{\theta-1}}\frac{\pi^{\theta-1}-1}{\theta-1}}_{\mathcal{M}}\,\hat{n}_t + \underbrace{\frac{1-(1-n)\,\pi^{\theta-1}}{(1-n)\,\pi^{\theta-1}}}_{\mathcal{N}}\,(\hat{p}^*_t - \hat{p}_t)$$

- Elasticity $\mathcal{N}$ to reset price changes: identical to Calvo

- Elasticity $\mathcal{M}$ to frequency: increases with inflation, zero if $\pi = 1$
  - so price level more responsive to changes in n at high inflation
  - intuition: inflation $\approx$ average price change $\times$ fraction of price changes

large shock

Inflation Accelerator

- Expression for price index: higher frequency increases inflation

$$\hat{\pi}_t = \mathcal{M}\hat{n}_t + \mathcal{N}\left(\hat{p}_t^* - \hat{p}_t\right)$$

  - elasticity $\mathcal{M}$ increases with inflation, zero if $\pi = 1$

- Optimal frequency increases with inflation

$$\hat{n}_t = \mathcal{A}\hat{\pi}_t + \mathcal{B}\left(\hat{p}_t^* - \hat{p}_t\right) - \mathcal{C}\hat{x}_{t-1} + \frac{n - \bar{n}}{n}\hat{b}_{1t}$$

  - elasticities $\mathcal{A}$ and $\mathcal{B}$ increase with inflation, zero if $\pi = 1$

equations

- Feedback loop amplifies inflation response to changes in reset price

$$\hat{\pi}_t = \frac{\mathcal{M}\mathcal{B} + \mathcal{N}}{1 - \mathcal{M}\mathcal{A}}\left(\hat{p}_t^* - \hat{p}_t\right) - \frac{\mathcal{M}\mathcal{C}}{1 - \mathcal{M}\mathcal{A}}\hat{x}_{t-1} + \frac{\mathcal{M}}{1 - \mathcal{M}\mathcal{A}}\frac{n - \bar{n}}{n}\hat{b}_{1t}$$

Phillips Curve

- Can derive Phillips curve: $\hat{\pi}_t = \mathcal{K}\widehat{mc}_t + \dots$

▸ Phillips Curve

- Slope of the Phillips curve

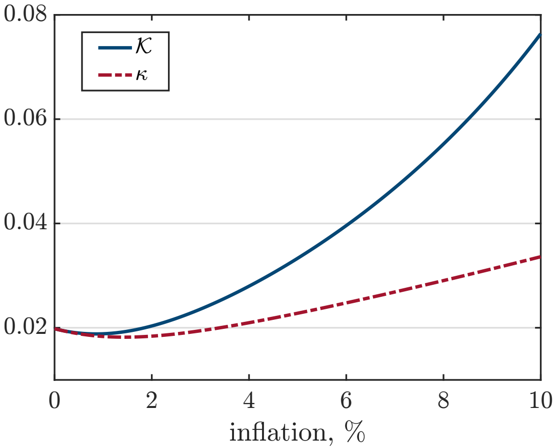
$$\mathcal{K} = \underbrace{\frac{1}{1+\theta\left(\frac{1}{\eta}-1\right)}}_{\text{complementarities}} \times \underbrace{\left(1-\beta\left(1-n\right)\pi^{\frac{\theta}{\eta}}\right)}_{\text{horizon effect}} \times \underbrace{\frac{\mathcal{MB}+\mathcal{N}}{1-\mathcal{MA}}}_{\text{reset price}}$$

- If $\xi = \infty$, reduces to slope in Calvo

$$\kappa = \frac{1}{1+\theta\left(\frac{1}{\eta}-1\right)} \times \left(1-\beta\left(1-n\right)\pi^{\frac{\theta}{\eta}}\right) \times \underbrace{\frac{1-\left(1-n\right)\pi^{\theta-1}}{\left(1-n\right)\pi^{\theta-1}}}_{=\mathcal{N}}$$

- Difference between $\mathcal{K}$ and κ captures inflation accelerator

Slope of the Phillips Curve



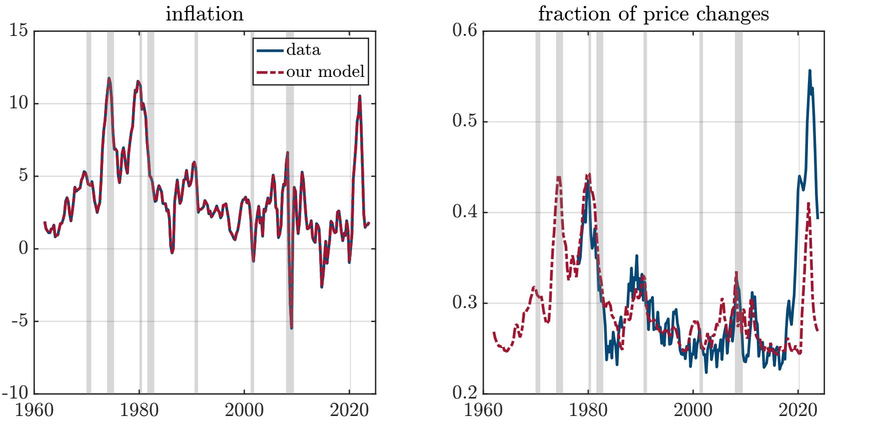
Much steeper at high inflation, mostly due to inflation accelerator

Phillips Curve in the Time-Series

Approach

- Use non-linear solution to back out shocks that match U.S. inflation series
  - initialize 1962 in stochastic steady state
- Derive Phillips curve by perturbing equilibrium conditions at each date

Fraction of Price Changes



Reproduces fraction well, except post-Covid because lower inflation

output gap

Slope of the Phillips Curve

- Slope of the Phillips curve

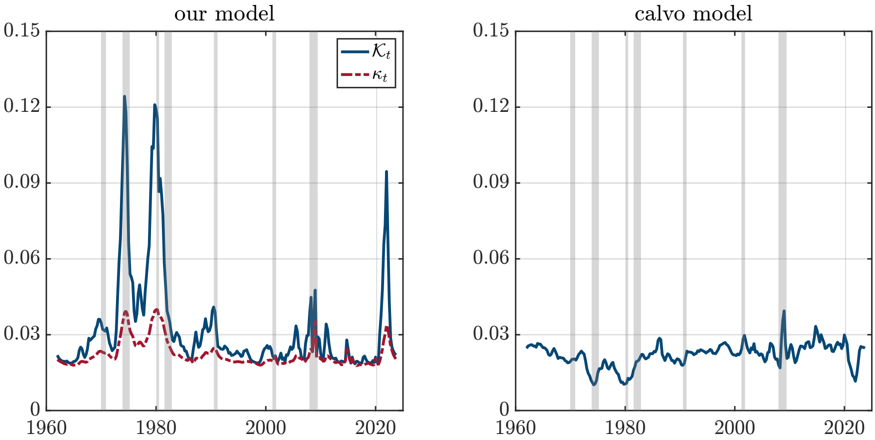
$$\mathcal{K}_t = \frac{1}{1+\theta\left(\frac{1}{\eta}-1\right)} \quad \times \quad \frac{y_t^{\frac{1}{\eta}}}{b_{2t}} \quad \times \quad \frac{\mathcal{M}_t\mathcal{B}_t+\mathcal{N}_t}{1-\mathcal{M}_t\mathcal{A}_t}$$

- Absent endogenous frequency response

$$\kappa_t = \frac{1}{1+\theta\left(\frac{1}{\eta}-1\right)} \quad \times \quad \frac{y_t^{\frac{1}{\eta}}}{b_{2t}} \quad \times \quad \underbrace{\frac{1-(1-n_t)\,\pi_t^{\theta-1}}{(1-n_t)\,\pi_t^{\theta-1}}}_{=\mathcal{N}_t}$$

- The difference $\mathcal{K}_t - \kappa_t$ captures the inflation accelerator

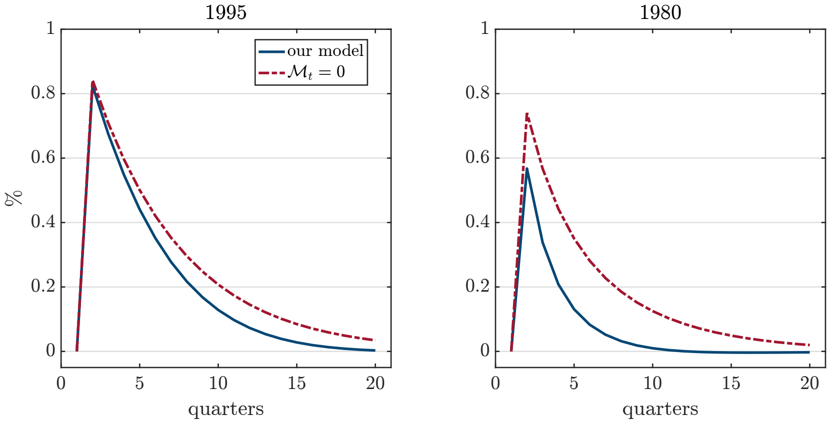
Time-Varying Slope of the Phillips Curve



Ranges from 0.02 to 0.12, mostly due to inflation accelerator

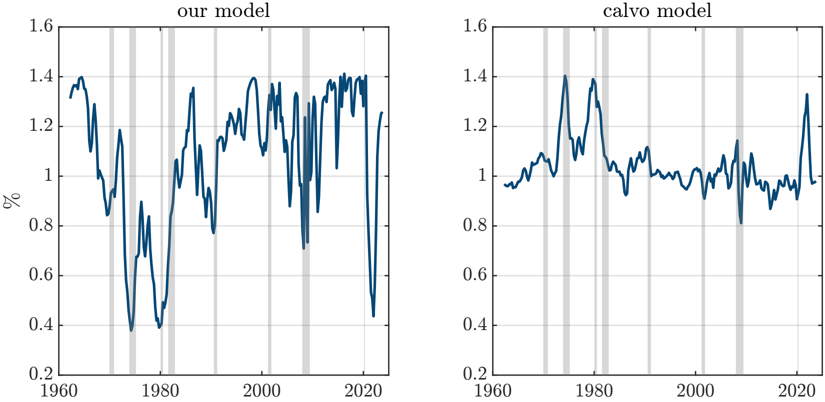
Implication 1: Time-Varying Responses to Shocks

- Consider response to 1% shock in 1995 (low π_t) and 1980 (high π_t)
- Build intuition by computing log-linear approximation
  - repeat setting $\mathcal{M}_t = 0$ to isolate inflation accelerator



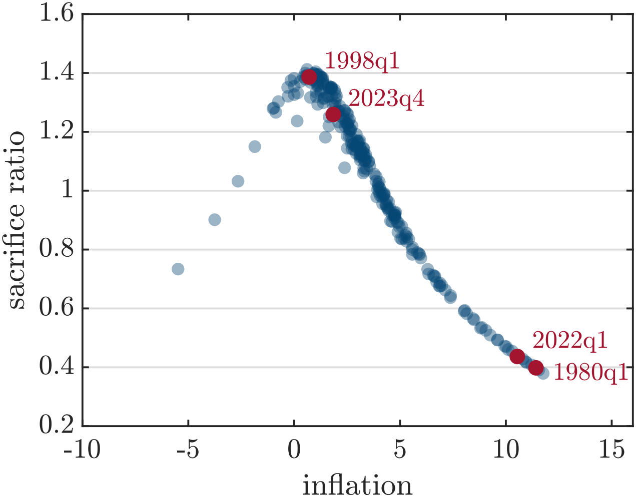
Implication 2: Sacrifice Ratio

- Time-varying slope: reducing inflation less costly when inflation is high
- Calculate average drop in output needed to reduce π by 1pp over a year



Ranges from 0.4% (high inflation) to 1.4% (low inflation), opposite of Calvo

Inflation and the Sacrifice Ratio



Conclusions

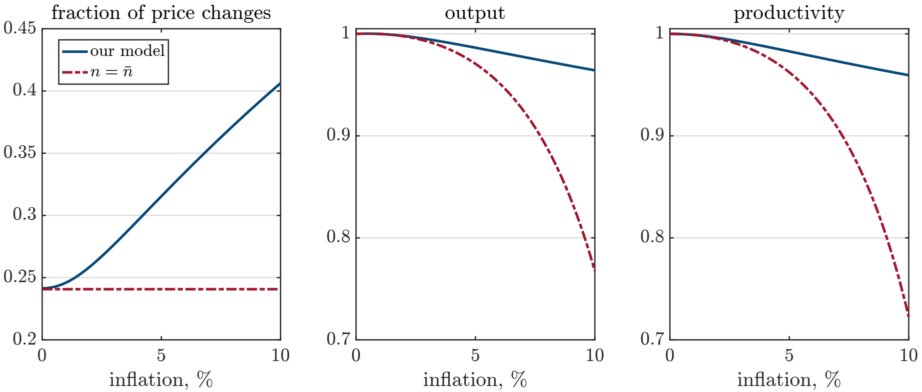
- Data: fraction of price changes rises with inflation
- Developed tractable model consistent with this evidence
  - firms choose how many, but not which prices to change
  - collapses to one-equation extension of Calvo
- Implies slope of Phillips curve increases considerably with inflation
  - partly because more frequent price changes
  - primarily due to endogenous frequency response – *inflation accelerator*

Losses from Misallocation

$$\left(X_{it+s}\right)^{-\frac{\theta}{\eta}} = n_{it+s}\left(P^*_{it+s}\right)^{-\frac{\theta}{\eta}} + \left(1 - n_{it+s}\right) n_{it+s-1}\left(P^*_{it+s-1}\right)^{-\frac{\theta}{\eta}} + \cdots$$
$$+ \prod_{j=1}^{s}\left(1 - n_{it+j}\right) n_{it}\left(P^*_{it}\right)^{-\frac{\theta}{\eta}} + \prod_{j=1}^{s}\left(1 - n_{it+j}\right)\left(1 - n_{it}\right)\left(X_{it-1}\right)^{-\frac{\theta}{\eta}}$$

back

Steady-State Output and Productivity



- Inflation less distortionary in our model

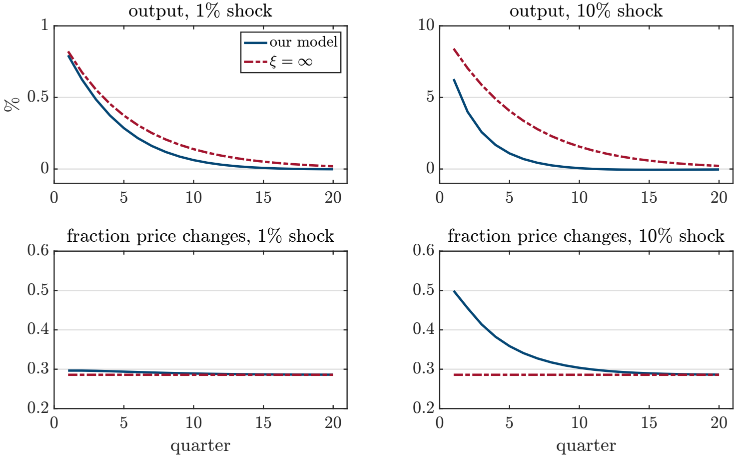
  ▸ equations

  – because more frequent price changes, as in menu cost models

  ▸ back

Response to Large Shock

- 10% shock starting from non-stochastic steady state of baseline model



Strong non-linearities, as in menu cost model

back

Elasticities $\mathcal{A}$ and $\mathcal{B}$

- Log-linearize optimal fraction of price changes

$$\hat{n}_t = \mathcal{A}\hat{\pi}_t + \mathcal{B}\left(\hat{p}_t^* - \hat{p}_t\right) - \mathcal{C}\hat{x}_{t-1} + \frac{n-\bar{n}}{n}\hat{b}_{1t}$$

- Elasticities $\mathcal{A}$ and $\mathcal{B}$ increase with trend inflation

$$\mathcal{A} = \frac{\theta-1}{\xi n}\frac{1}{1-\beta\left(1-n\right)\pi^{\theta-1}}\frac{\pi^{\frac{\theta}{\eta}}-\pi^{\theta-1}}{1-\left(1-n\right)\pi^{\frac{\theta}{\eta}}}$$

$$\mathcal{B} = \left(1-\tau\eta\right)\frac{\theta-1}{\xi n}\frac{1-\left(1-n\right)\pi^{\theta-1}}{1-\beta\left(1-n\right)\pi^{\theta-1}}\frac{1}{n}\frac{\pi^{\frac{\theta}{\eta}}-1}{1-\left(1-n\right)\pi^{\frac{\theta}{\eta}}}$$

  - zero when $\pi = 1$, so our model identical to Calvo up to a first-order

back

Phillips Curve

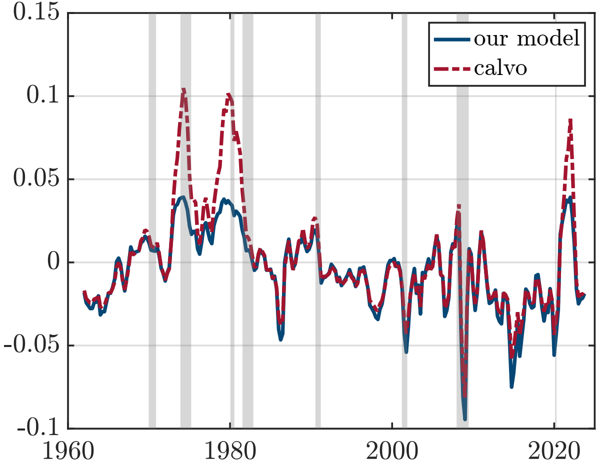
- Let $\widehat{mc}_t = \frac{1}{\eta}\hat{y}_t^{1/\eta}$ aggregate real marginal cost

- Phillips curve

$$
\begin{aligned}
\hat{\pi}_t \quad &= \quad \mathcal{K}\widehat{mc}_t + \beta(1-n)\left(\frac{\frac{\theta}{\eta}\pi^{\frac{\theta}{\eta}} - (\theta-1)\,\pi^{\theta-1}}{1+\theta\left(\frac{1}{\eta}-1\right)}\frac{\mathcal{MB}+\mathcal{N}}{1-\mathcal{MA}} + \pi^{\frac{\theta}{\eta}}\right)\mathbb{E}_t\hat{\pi}_{t+1} \\
&+ \quad \beta(1-n)\left(\frac{\pi^{\frac{\theta}{\eta}} - \pi^{\theta-1}}{1+\theta\left(\frac{1}{\eta}-1\right)}\frac{\mathcal{MB}+\mathcal{N}}{1-\mathcal{MA}} - \pi^{\frac{\theta}{\eta}}\frac{\mathcal{M}}{1-\mathcal{MA}}\frac{n-\bar{n}}{n}\right)\mathbb{E}_t\hat{b}_{1t+1} \\
&- \quad \beta n\frac{\pi^{\frac{\theta}{\eta}} - \pi^{\theta-1}}{1+\theta\left(\frac{1}{\eta}-1\right)}\frac{\mathcal{MB}+\mathcal{N}}{1-\mathcal{MA}}\mathbb{E}_t\hat{n}_{t+1} \\
&+ \quad \beta(1-n)\,\pi^{\frac{\theta}{\eta}}\frac{\mathcal{MC}}{1-\mathcal{MA}}\hat{x}_t - \frac{\mathcal{MC}}{1-\mathcal{MA}}\hat{x}_{t-1} + \frac{\mathcal{M}}{1-\mathcal{MA}}\frac{n-\bar{n}}{n}\hat{b}_{1t}
\end{aligned}
$$

back

Output Gap



Our model: smaller output gap in periods of high inflation

back

Eliminate Strategic Complementarities

- Set $\eta = 1$, recalibrate model

back

Targeted Moments

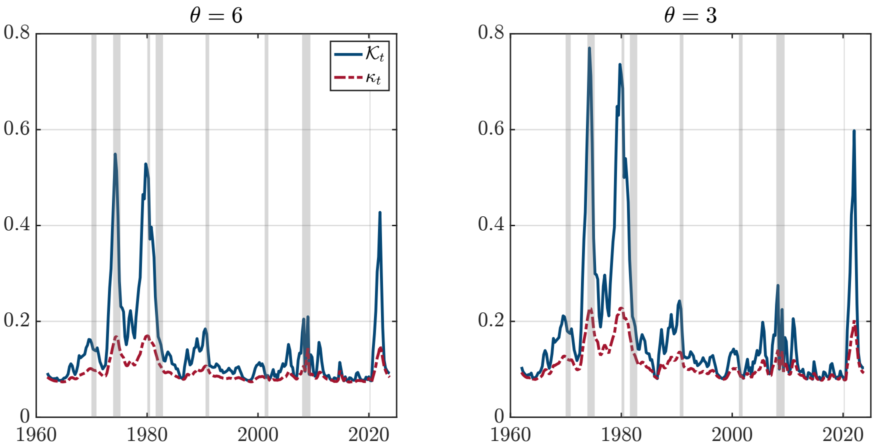
	Data	$\theta = 6$	$\theta = 3$
mean inflation	3.517	3.517	3.517
s.d. inflation	2.739	2.739	2.739
mean frequency	0.297	0.297	0.297
slope of n_t on $\lvert\pi_t\rvert$	0.016	0.016	0.016

Calibrated Parameters

		$\theta = 6$	$\theta = 3$
μ	mean spending growth rate	0.035	0.035
σ	s.d. monetary shocks	0.019	0.018
$\bar{n}$	fraction free price changes	0.232	0.227
ξ	adjustment cost	0.365	0.109

- Smaller price adjustment costs because less curvature in profit function

Slope of the Phillips Curve



Larger absent complementarities, but fluctuates as much

back

Taylor Rule

- Replace nominal spending target with Taylor rule

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\phi_i} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\phi_y}\right)^{1-\phi_i} \exp\left(u_t\right)$$

- Two versions
  - u_t shocks iid
  - serially correlated with persistence ρ to match autocorrelation inflation
- Use Justiniano and Primiceri (2008) estimates
  - $\phi_i = 0.65$, $\phi_\pi = 2.35$, $\phi_y = 0.51$

back

Calibration of Economy with a Taylor Rule

Targeted Moments

	Data	$\rho = 0$	$\rho > 0$
mean inflation	3.517	3.517	3.517
s.d. inflation	2.739	2.739	2.739
mean frequency	0.297	0.297	0.297
slope of n_t on $\lvert\pi_t\rvert$	0.016	0.016	0.016
autocorr. inflation	0.942	*0.913*	0.942

Calibrated Parameters

		$\rho = 0$	$\rho > 0$
$\log \pi$	inflation target	0.040	0.037
σ	s.d. monetary shocks $\times 100$	2.626	0.551
ρ	persistence monetary shocks	–	0.685
$\bar{n}$	fraction free price changes	0.241	0.241
ξ	adjustment cost	1.671	1.688

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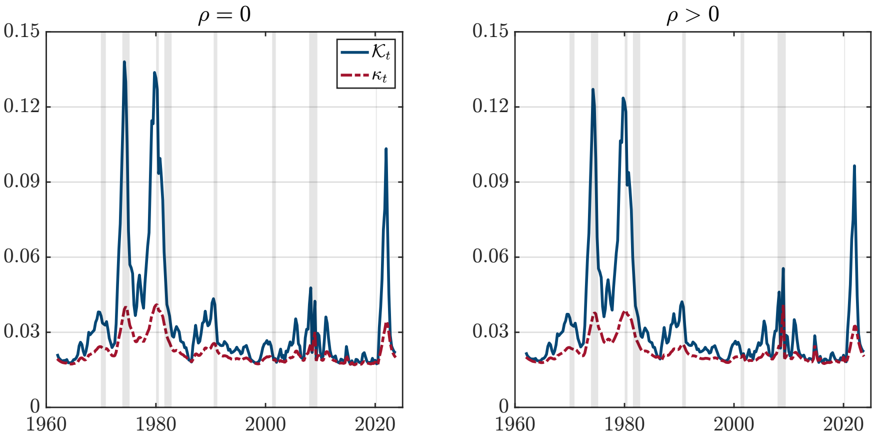
Slope of the Phillips Curve



Our results are robust to assuming a Taylor rule

back

Steady-State Output and Productivity

- Output

$$y^{\frac{1}{\eta}} = \eta \frac{1 - \beta (1 - n) \pi^{\frac{\theta}{\eta}}}{1 - \beta (1 - n) \pi^{\theta - 1}} \left(\frac{n}{1 - (1 - n) \pi^{\theta - 1}} \right)^{\frac{1 + \theta \left(\frac{1}{\eta} - 1 \right)}{\theta - 1}}$$

  - absent trend inflation $y = \eta^{\eta}$

- Productivity

$$x^{\theta} = \left(\frac{1 - (1 - n) \pi^{\frac{\theta}{\eta}}}{n} \right)^{\eta} \left(\frac{1 - (1 - n) \pi^{\theta - 1}}{n} \right)^{-\frac{\theta}{\theta - 1}}$$

  - absent trend inflation $x^{\theta} = 1$

back