Inflation Persistence and a new Phillips Curve

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Introduction

- NK-model is dominant paradigm for studying business cycles and stabilization
- Standard model features simple time-dependent price-adjustment frictions
- Built around the New Keynesian Phillips Curve (NKPC)
- Perfect relationship between (future-discounted) marginal costs and inflation
- However empirical literature estimating NKPC finds inflation persistence

This Paper

What we do:

- **State-dependent** "menu-cost" model
- Study shocks to the **growth rate** of nominal demand

Findings:

- Growth shocks can break the co-movement between inflation and MC
- Replicate inflation persistence in the NKPC

Next steps (not today):

- Add realistic consumption block (HA)
- Study inflation consequences of policy stimulus

Key idea

- In **Calvo model**:
  - Only intensive margin movements in prices
  - Purely forward looking
- In **state-dependent** model:
  - Now adds extensive margin choice of when to adjust prices
  - Distribution of prices matters for which firms adjust
  - History dependence:
    past variables $\Rightarrow$ distribution $\Rightarrow$ ext. margin $\Rightarrow$ inflation
  - Amplified by autocorrelated growth rate shocks

Simple Household Demand

- Composite consumption:

$$C_t = \left[\int_0^1 c_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}.$$

- Households $\max C_t$ s.t.

$$D_t = \int_0^1 p_t(i) c_t(i) di$$

- Demand for each good i:

$$c_t(i) = \left(\frac{p_t(i)}{P_t} \right)^{-\epsilon} \frac{D_t}{P_t},$$

- Price index:

$$P_t = \left[\int_0^1 p_t(i)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$$

- Intratemporal consumption-leisure optimality:

$$MC_t = \frac{W_t}{P_t} = \frac{u_h(C_t, H_t)}{u_c(C_t, H_t)} = \left(\frac{D_t}{P_t} \right)^{\varphi+\sigma}$$

Quantitative Price Setting Model

High level modeling choices

- Follow Midrigan (ECMA 2011)
- Idiosyncratic firm productivity follows a geometric random walk
- Stochastic (exponential) adjustment costs
- No mass points – continuous price distribution

Price Setting Model

With idiosyncratic productivity

- Real profits at time t with productivity z_t:

$$\left(\frac{p_t}{P_t} - MC\left(\frac{D_t}{P_t}\right)\frac{1}{z_t}\right)\left(\frac{p_t}{P_t}\right)^{-\epsilon}\frac{D_t}{P_t}.$$

- Rewriting using firm-specific markup μ_t:

$$\underbrace{(\mu_t - 1)\,\mu_t^{-\epsilon} z_t^{\epsilon-1}}_{\text{idiosyncratic}} \times \underbrace{\left(MC\left(\frac{D_t}{P_t}\right)\right)^{1-\epsilon}\frac{D_t}{P_t}}_{\text{aggregate}}.$$

- Fixed price adjustment costs $z_t^{\epsilon-1}\xi_t$

Price Setting Model
Infinite Horizon

$$V_t^{noadj}(\mu, z) = (\mu - 1)\mu^{-\epsilon} z^{\epsilon-1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} + \beta \mathbb{E} V_{t+1}(\mu', z')$$

$$\text{s.t.} \quad z' = \eta' z$$

$$\mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu$$

$$V_t^{adj}(\mu, z|\xi) = \max_{\mu^*} (\mu^* - 1)(\mu^*)^{-\epsilon} z^{\epsilon-1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} - z^{\epsilon-1}\xi + \beta \mathbb{E} V_{t+1}(\mu', z')$$

$$\text{s.t.} \quad z' = \eta' z$$

$$\mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu^*$$

$$V_t(\mu, z) = \max\{V_t^{noadj}(\mu, z), V_t^{adj}(\mu, z|\xi)\}$$

Price Setting Model
Homogeneity in z

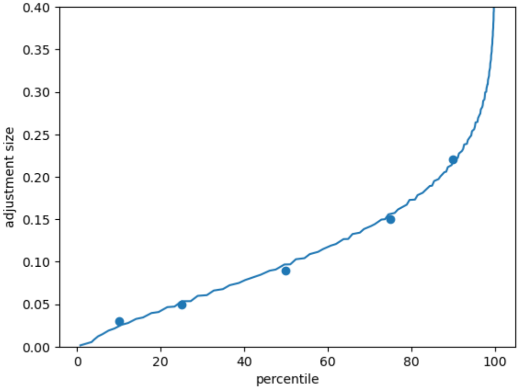
We guess and verify that all value functions satisfy $V(\mu, z) = v(\mu)z^{\epsilon-1}$:

$$
\begin{aligned}
v_t^{noadj}(\mu) &= (\mu - 1)\mu^{-\epsilon} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t}^{\epsilon-1} + \\
&\quad \beta\mathbb{E}\left[(\eta')^{\epsilon-1} v_{t+1}\left(\eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu\right)\right] \\
v_t^{adj}(\mu|\xi) &= \max_{\mu^*} (\mu^* - 1)(\mu^*)^{-\epsilon} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} - \xi \\
&\quad + \beta\mathbb{E}\left[(\eta')^{\epsilon-1} v_{t+1}\left(\eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu^*\right)\right] \\
v_t(\mu|\xi) &= \max\{v_t^{noadj}(\mu), v_t^{adj}(\mu|\xi)\} \\
v_t(\mu) &= \mathbb{E}_\xi \left[v_t(\mu|\xi)\right]
\end{aligned}
$$

Shock Calibration

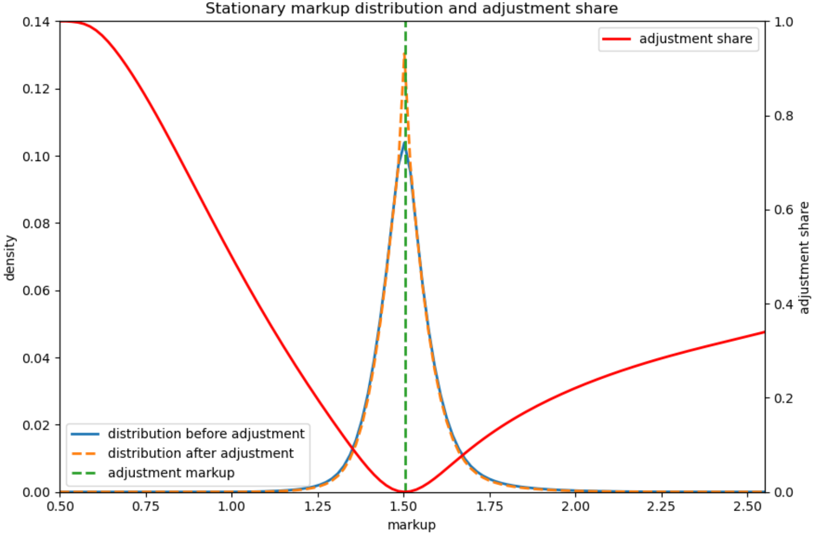
Calibrate shock parameters to match key steady state targets:

- Frequency of (regular) weekly price changes: 2.9%.
- Size distribution of (regular) price changes



Steady State Distribution

- Steady state with 2% annual inflation



Validation Experiments:

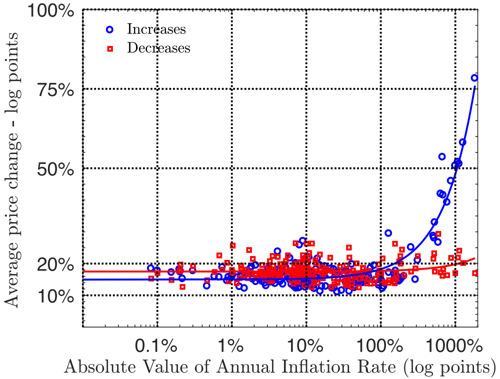
- Compare steady-state properties of intensive and extensive margin to empirical results in
  Alvarez, Beraja, Gonzalez-Rozada and Neumeyer (QJE 19):
  "From hyperinflation to stable prices: Argentina's evidence on menu cost models"
- Experiment: increase steady-state growth rate of nominal demand $\Rightarrow$ increased steady-state inflation rate (all other parameters unchanged)

Intensive and Extensive Margin

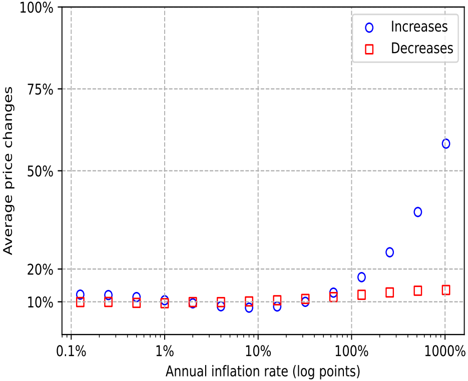
Model and Data

Intensive Margin Price Adjustments:

DATA



MODEL

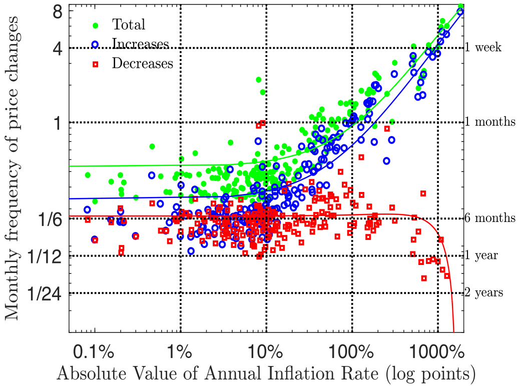


Intensive and Extensive Margin

Model and Data

Extensive Margin Price Adjustments:

DATA



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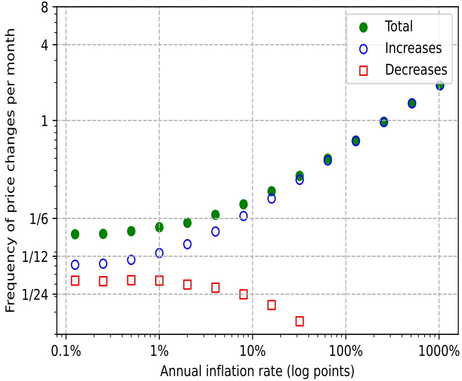
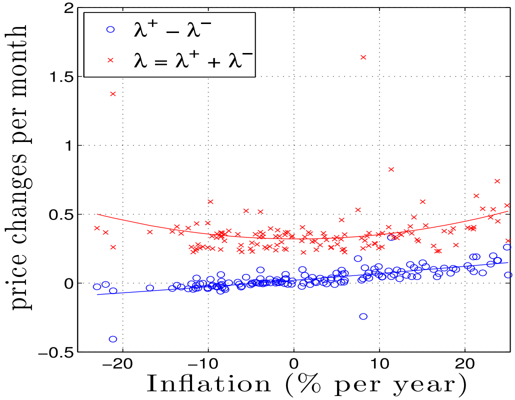


Intensive and Extensive Margin

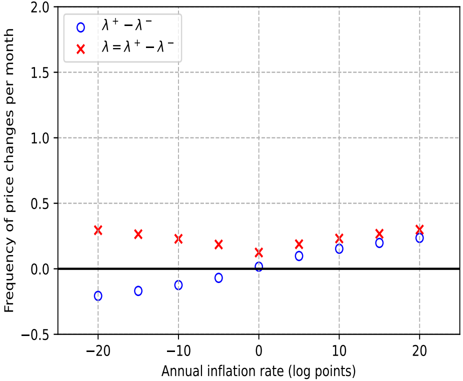
Model and Data

Price increases vs decreases:

DATA



MODEL



Experiments

- Study response of model to shocks to nominal demand growth ΔD_t
- Consider quarterly autocorrelation $\rho_D = 0.5$ (as in the data)
- Linearize model with small MIT-shocks in sequence space (Boppart, Krusell & Mitman 2018, Auclert et al 2021)
- Implement quarterly Phillips curve regressions:

$$\pi_t = \alpha \sum \mathbb{E}[\beta^k mc_{t+k}] + \gamma \pi_{t-1} + \delta \Delta D_{t-1} + \epsilon_t$$

Results: Demand shock $\rho_D = 0.5$

New Keynesian Calvo Specifications:

	$\sum$ mc	π_{t-1}
Calvo PC	1.0963	
	(0.014)	
+ Lagged Inflation	0.8623	0.4588
	(0.011)	(0.0078)

Standard errors in parentheses.

Results: Demand shock $\rho_D = 0.5$

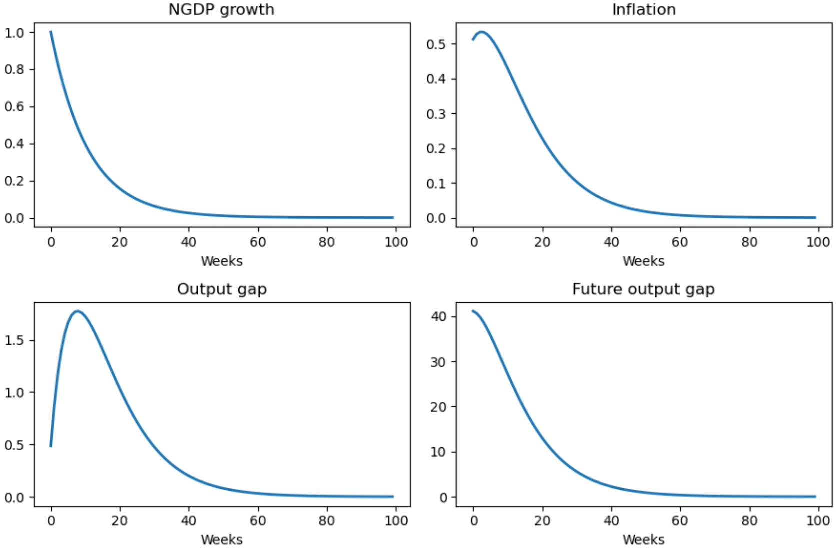
Full specification:

	$\sum$ mc	π_{t-1}	ΔD_{t-1}
Calvo + Lagged Inflation	0.8623 (0.0011)	0.4588 (0.0078)	
Full Specification	0.5325 (0.0069)	0.0071 (0.0063)	7.4127 (0.0764)

Standard errors in parentheses.

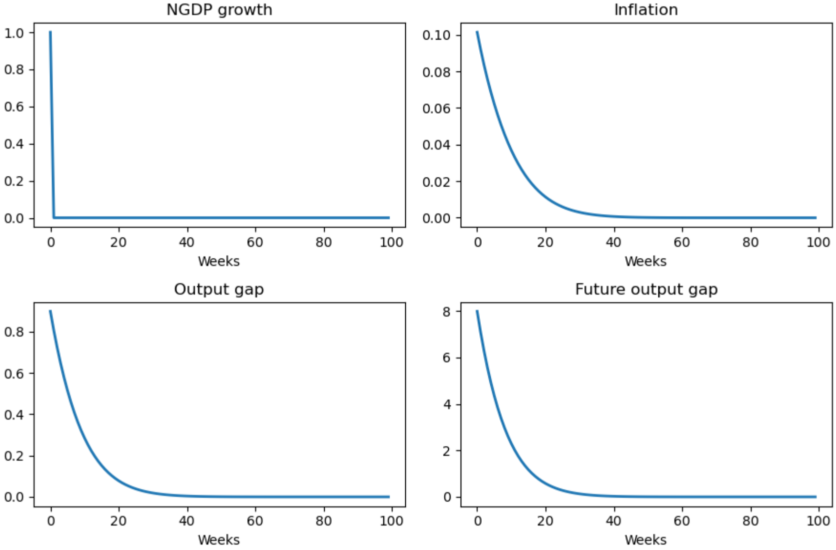
Understanding the Results

$$\rho_D = 0.5$$

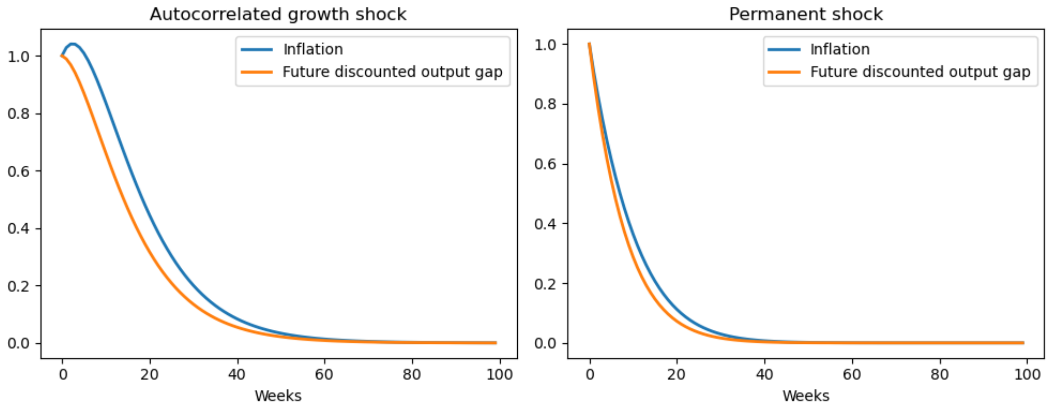


Understanding the Results

$$\rho_D = 0$$



Normalized IRFs



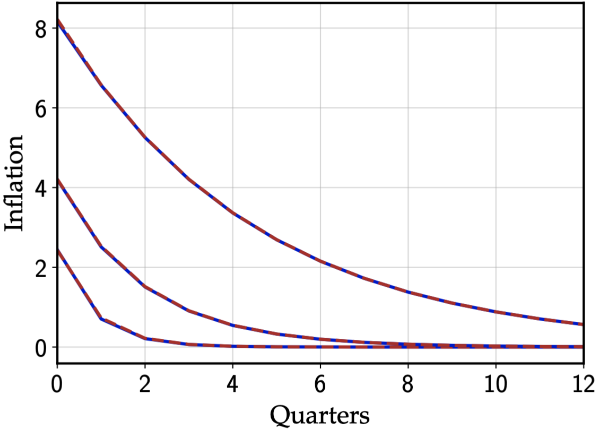
Comparision to Auclert et al 2024 Shock size matters

Conclusion

- In the data: estimated NKPC exhibits inflation persistence
- In **Calvo model**: one-to-one relationship between inflation and marginal costs
- We showed that **menu-cost model**:
  - can replicate empirical findings on NKPC
  - breaks one-to-one relationship between inflation and marginal costs
  - nominal demand (and other past variables) matter for inflation dynamics
- Next steps: add realistic household block, study non-linearities ...

Comparison to Auclert et al 2024

With AR(1) shocks ($\rho = \{0.3, 0.6, 0.8\}$) to real marginal costs, inflation and (expected discounted) output gaps coincide



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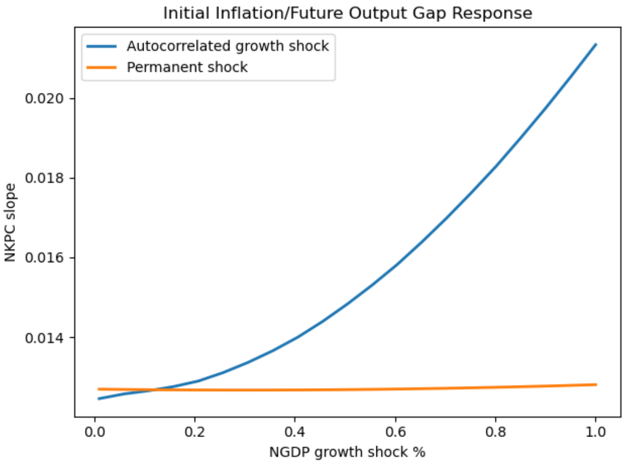
Increasing the Shock Size

Initial response of $\pi_t / \sum_{s=0}^{\infty} \beta^s mc_{t+s}$



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