Inflation Persistence and a new Phillips Curve

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Motivation

- 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):

$$\pi_t = \alpha \sum_{j=0}^{\infty} \beta^j \mathbb{E}\left[mc_{t+j}\right]$$

Motivation

- NK-model is dominant paradigm for studying business cycles and stabilization
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- Built around the New Keynesian Phillips Curve (NKPC):

$$\pi_t = \alpha \sum_{j=0}^{\infty} \beta^j \mathbb{E}\left[mc_{t+j}\right]$$

- However empirical literature estimating NKPC finds inflation persistence (Gali and Gertler, 1999; Fuhrer, 2010)

$$\pi_t = \hat{\alpha} \sum_{j=0}^{\infty} \beta^j \mathbb{E}\left[mc_{t+j}\right] + \hat{\gamma}\pi_{t-1}, \quad \hat{\gamma} > 0 \text{ significant and relevant}$$

What we do

- **State-dependent** "menu-cost" model (Golosov and Lucas, 2007; Midrigan, 2011)
- Study shocks to the **growth rate** of nominal demand
- Quarterly **autocorrelation** $\rho_D = 0.5$
- Solve non-linearly for an **MIT-shock** on the growth rate of nominal demand
- IRF as **numerical derivative** to simulate (Boppart, Krusell, and Mitman, 2018)
- Run **Phillps-Curve regressions**

Main Findings

Menu Cost + Growth Rate Shocks:

- **Inflation inertia**: hump-shaped response in a purely forward looking model
- Break the **perfect comovement** between inflation and MC
- Replicate **inflation persistence** in the NKPC

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

Quantitative Price Setting Model

High level modeling choices

- Follow Midrigan (ECMA 2011)
- Weekly frequency
- Firm productivity with idiosyncratic shocks
- Stochastic (exponential) adjustment costs
- No mass points – continuous price distribution

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:

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

Price Setting Model
With idiosyncratic productivity

- Firms have linear technology in labor $y_t = z_t l_t$
- Real profits at time t with productivity z_t and price p_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:

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

Price Setting Model

Infinite Horizon

$$
\begin{aligned}
V_t^{noadj}(\mu, z) = (\mu - 1)\mu^{-\epsilon} z^{\epsilon - 1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} \\
+ \beta \mathbb{E} V_{t+1}(\mu', z') \\
\text{s.t. } z' = \eta' z \\
\mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu
\end{aligned}
$$

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$$

$$
\begin{aligned}
V_t^{adj}(\mu, z|\xi) = \max_{\mu^*} (\mu^* - 1)(\mu^*)^{-\epsilon} z^{\epsilon-1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} - z^{\epsilon-1}\xi \\
+ \beta \mathbb{E} V_{t+1}(\mu', z') \\
\text{s.t. } z' = \eta' z \\
\mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \mu^*
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\end{aligned}
$$

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

Shocks and Menu Costs

- Productivity follows a geometric random walk:

$$
\begin{aligned}
z_{t+1} &= \eta z_t \\
\log(\eta_{t+1}) &= p u_t + (1-p)\frac{u_t}{10}, \quad u_t \sim \mathcal{N}(-(\epsilon-1){\sigma_\eta}^2/2, {\sigma_\eta}^2)
\end{aligned}
$$

- Menu costs: $\xi_t \sim Exp(\kappa)$:

$$
\mathbb{P}(\xi_t \leq x) = 1 - e^{-\kappa x}
$$

- Calibrate p, σ_η, κ to match key steady state targets from Midrigan (2011)

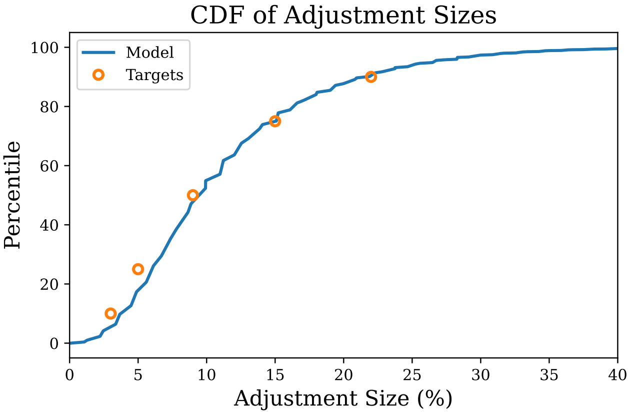
Calibration

Parameter	**Value**	**Description**	**Source**
β	$0.96^{1/52}$	Discount factor	Midrigan (2011)
σ	1	CRRA	Midrigan (2011)
ψ	1	Frisch elasticity	Midrigan (2011)
ϵ	3	Elasticity of subst.	Midrigan (2011)
p_t	0.022	Mixture weight	Internal
σ_η	0.127	Volatility	Internal
κ	1.35	Menu cost	Internal

Calibration Targets

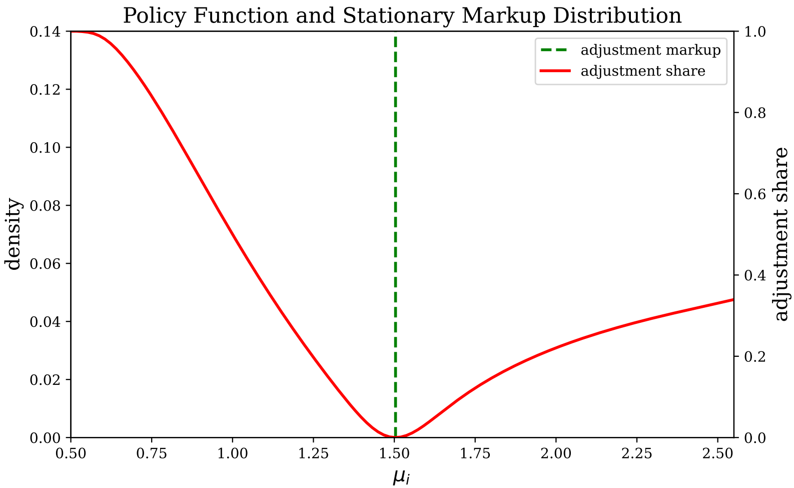
Targets from **Midrigan, 2011**:

- Frequency of (regular) weekly price changes: 2.9%
- Average size of price changes: 11.1%
- Size distribution of (regular) price changes:



Steady State

- Steady state with 2% annual inflation



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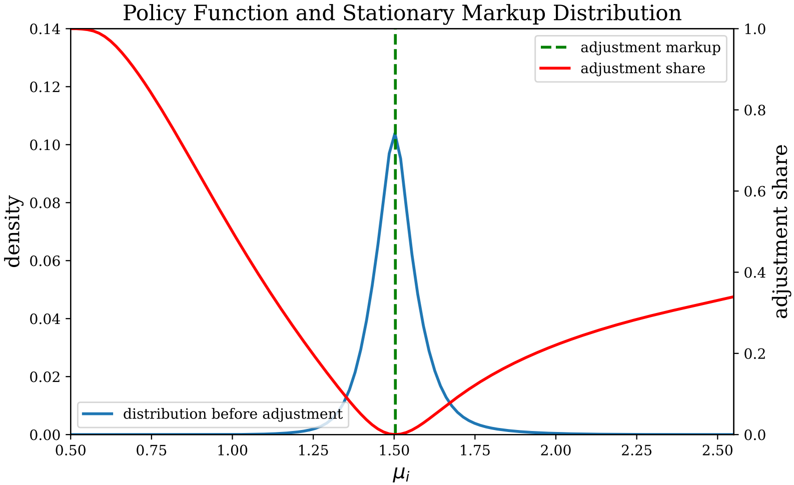

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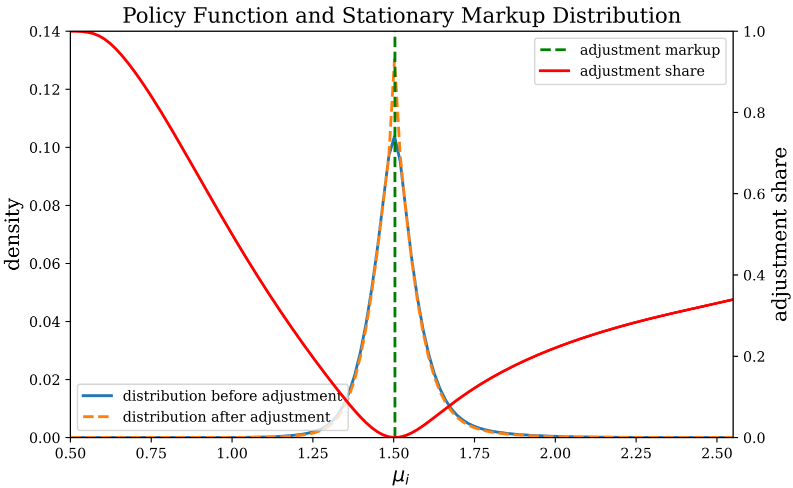


Validation Experiments:

- Compare steady-state properties of intensive and extensive margin to empirical results in
  Alvarez, Beraja, Gonzalez-Rozada and Neumeyer (2019):
  "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)

Inflation Accounting Identity

- Inflation accounting into intensive and extensive margins:

$$\pi = \lambda^{+}\Delta^{+} - \lambda^{-}\Delta^{-}$$

- Where:
  - λ^{+}: Frequency of price increases
  - λ^{-}: Frequency of price decreases
  - Δ^{+}: Average size of price increases
  - Δ^{-}: Average size of price decreases

Inflation Accounting Identity

- Inflation accounting into intensive and extensive margins:

$$\pi = \lambda^{+}\Delta^{+} - \lambda^{-}\Delta^{-}$$

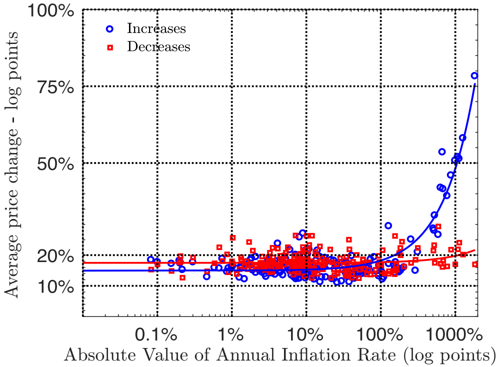
- Where:
  - λ^{+}: Frequency of price increases
  - λ^{-}: Frequency of price decreases
  - Δ^{+}: Average size of price increases
  - Δ^{-}: Average size of price decreases
- Changes in inflation decomposed into extensive and intensive margin:

$$\frac{\partial \pi_t}{\partial \pi_t} = \underbrace{\frac{\partial \lambda^{+}}{\partial \pi_t}\Delta^{+} - \frac{\partial \lambda^{-}}{\partial \pi_t}\Delta^{-}}_{\text{Extensive Margin}} + \underbrace{\lambda^{+}\frac{\partial \Delta^{+}}{\partial \pi_t} - \lambda^{-}\frac{\partial \Delta^{-}}{\partial \pi_t}}_{\text{Intensive Margin}}$$

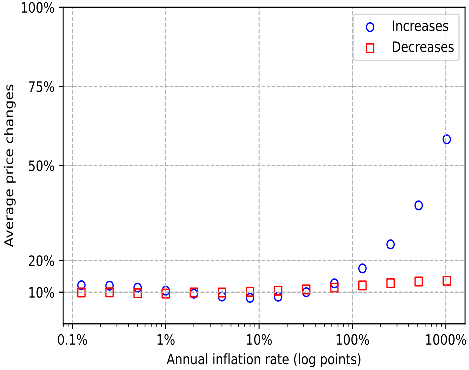
Intensive Margin

$$\frac{\partial \Delta^+}{\partial \pi}, \quad \frac{\partial \Delta^-}{\partial \pi}$$

DATA



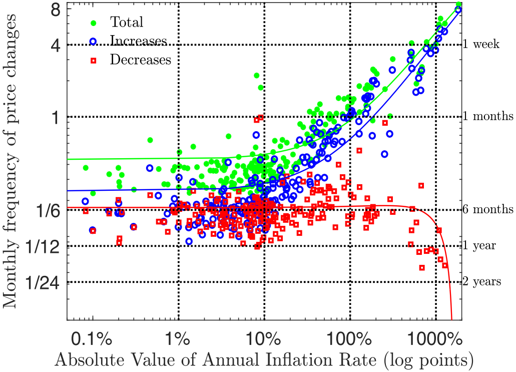
MODEL



Extensive Margin

$$\frac{\partial \lambda^+}{\partial \pi}, \quad \frac{\partial \lambda^-}{\partial \pi}, \quad \frac{\partial \lambda^+}{\partial \pi} + \frac{\partial \lambda^-}{\partial \pi}$$

DATA



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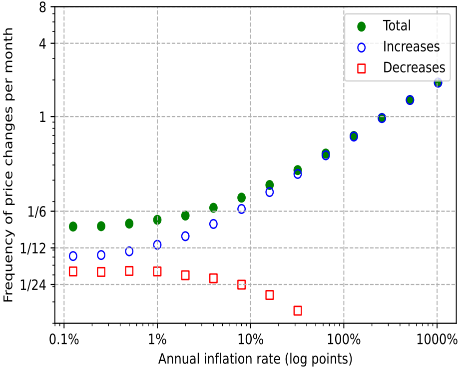
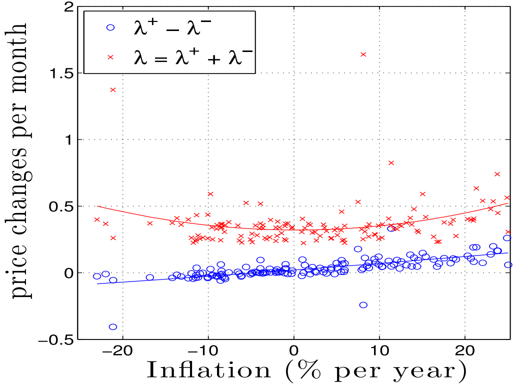


Selection Effect

$$\frac{\partial(\lambda^+ - \lambda^-)}{\partial\pi}, \quad \frac{\partial(\lambda^+ + \lambda^-)}{\partial\pi}$$

DATA



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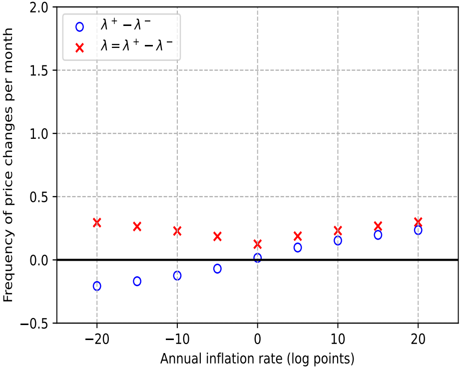


Experiments

- 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

Results: Demand shock $\rho_D = 0.5$

New Keynesian Calvo Specifications:

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

	$\sum \beta^k mc_{t+k}$	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 $\rho_D = 0.5$

New Keynesian Calvo Specifications:

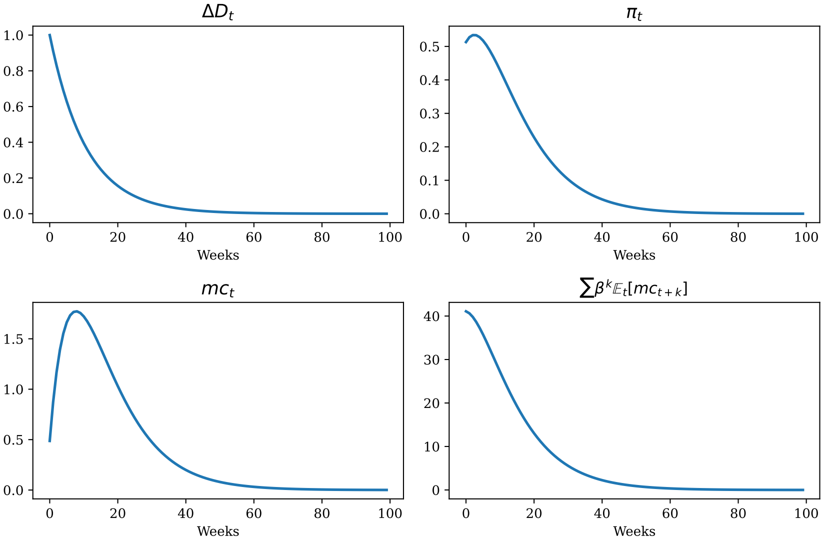
$$\pi_t = \alpha \sum \mathbb{E}[\beta^k mc_{t+k}] + \gamma \pi_{t-1} + \delta \Delta D_{t-1} + \epsilon_t$$

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

Standard errors in parentheses.

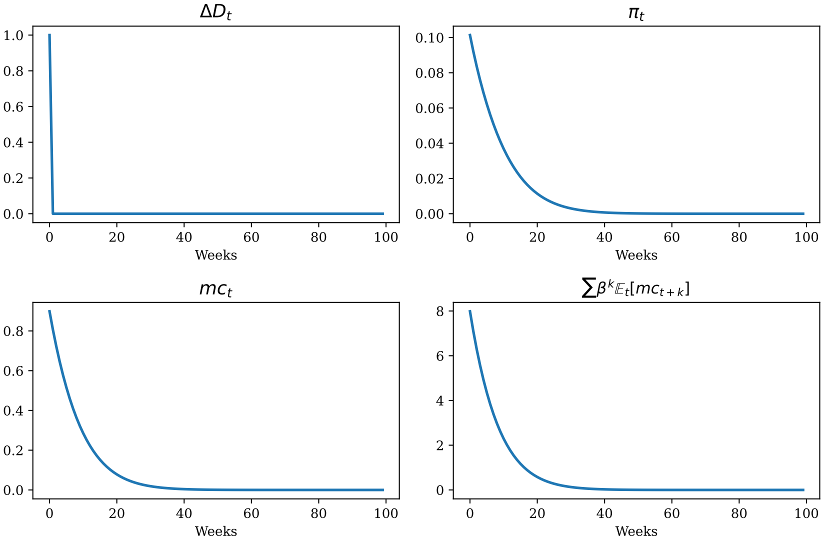
Understanding the Results

$\rho_D = 0.5$; No full frontloading

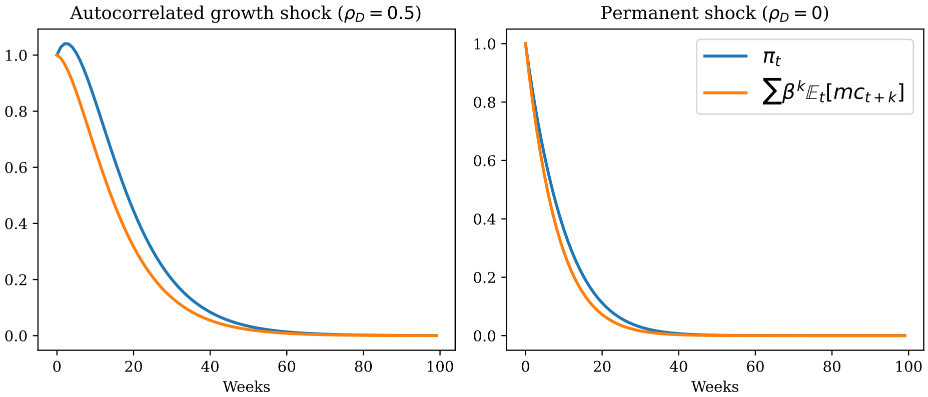


Understanding the Results

$\rho_D = 0$; Full frontloading



Normalized IRFs



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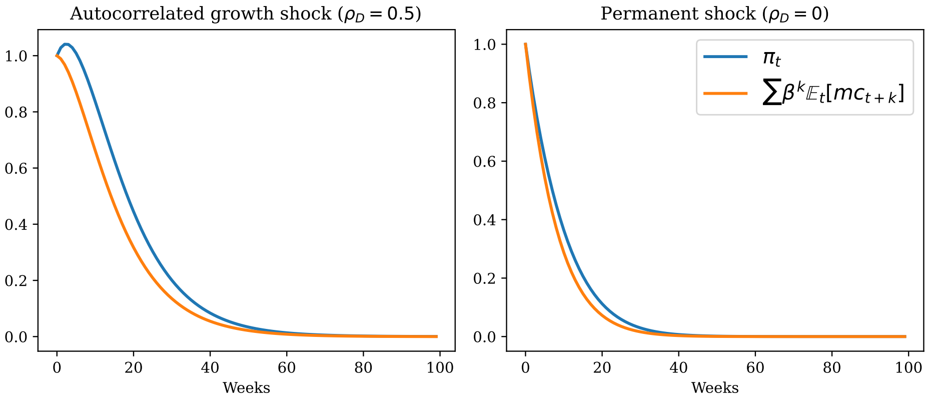


$$\pi_t = 0.011 \sum_{k=0}^{\infty} \beta^k mc_{t+k} + 0.25\pi_{t-1}, \quad \pi_t = 0.012 \sum_{k=0}^{\infty} \beta^k mc_{t+k} + 0.13\pi_{t-1}$$

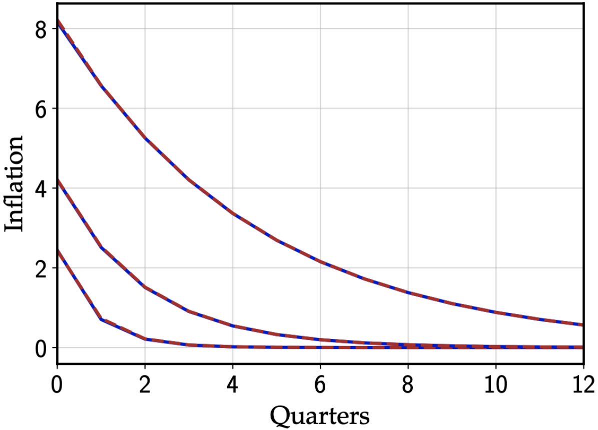
Comparision to Auclert et al 2024

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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