Business Cycles when Consumers Learn by Shopping

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Consumers Expectations $\neq$ Professional Forecasts

Large dispersion in **expectations** about **future** inflation ...

- Orders of magnitude larger than that among professionals
  - *Mankiw et. al. (03) Gorodnichenko et. al. (19); D'Acunto et. al. (21); ...*

... but also large dispersion in **perceptions** about **current** inflation

- Het. in π perceptions $\Rightarrow$ Het. in π expectations
  - *Hobijn et. al. (09); D'Acunto et. al. (21); Gorodnichenko et. al. (21); ...*

Rely on **noisy memories shopping experiences** to form beliefs about inflation

- **But** het. in beliefs about π > het. in experienced π
  - *Cavallo et.al. (18); D'Acunto et.al. (20); Coibion et. al. (21); ...*

In other words, households ***learn by shopping***

This Paper: LBS in a NKM

Q. What are the implications of LBS for the transmission of **macro** shocks?

Theory: Standard **NK** model **+** HHs that **Learn by Shopping (LBS)**

- HHs with RE but Limited Info. about π
- Form beliefs about π bas on noisy info. from **shopping experiences**
- Make decisions **conditional on their beliefs**

Use model to study analytically and quantitatively the implications for

1. Transmission of **aggregate shocks (today)**
2. Design of **monetary policy (in the paper)**

Preview of Results

- **Amplification of AD-Driven Business Cycles**
  - Non-neutrality, even with flexible prices
  - Interaction with sticky prices greatly amplifies **impact** of AD shocks on output
  - Quantitatively important: up to **8 times larger** with LBS
- **Amplification of AS shocks on Inflation**

Outline

1. **The model**
2. **Analytical results**
3. **Quantitative relevance**

The model

Setup: Standard NKM + Info. Frictions among HHs

Continuum of households $i \in [0,1]$

- Consume a subset of available goods $\mathcal{B}_{i,t} \subset [0,1]$
- Supply labor $N_{i,t}$, save $B_{i,t}$, and consume $C_{i,j,t}$, with preferences

$$U\left(C_{i,t}, N_{i,t}\right) = \frac{C_{i,t}^{1-\sigma}}{1-\sigma} - \frac{N_{i,t}^{1+\varphi}}{1+\varphi}; \quad C_{i,t} \equiv \left[\int_{\mathcal{B}_{i,t}} C_{i,j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

- **Rational expectations** but **incomplete info.** about aggregates and $P_{i,t}$

Firms: Business as usual

- **Full information** and prob. of adjusting prices $1-\theta$
- Each firm visited by a subset of households $M \subset [0,1]$
- Produce using labor ($Y_{j,t} = N_{j,t}$) and redistribute dividends $D_{j,t}$

Central bank: Issue bonds and set nominal interest rate $i_t = \phi_\pi \pi_t$

Aggregate Shocks: AR(1) discount factor of all HHs z_t (AD)

Shopping and Paying (i)

Info. Friction: HH problem divided in two stages

- ***Stage 1: Shopping stage***
  - Draw a random consumption basket $\mathcal{B}_{i,t}$ from all available goods such that

$$\log P_{i,t} = \log P_t + \eta_{i,t}^P; \quad \eta_{i,t}^P \overset{iid}{\sim} \mathcal{N}\left(0, \sigma_P^2\right)$$

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  - Acquire a **noisy signal** about the prices of goods in consumption basket

$$\log S_{i,t} = \log P_{i,t} + \epsilon_{i,t}, \quad \epsilon_{i,t} \overset{iid}{\sim} \mathcal{N}\left(0, \sigma^2_\epsilon\right)$$

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    - Observe **own and shock faced** $W_{i,t}$, $R_{i,t}$, $Z_{i,t}$, $D_{i,t}$
    - Idiosyncratic across households, e.g.

$$\log W_{i,t} = \log W_t + \xi^w_{i,t}, \quad \xi^w_{i,t} \overset{iid}{\sim} \mathcal{N}\left(0, \zeta^2_x\right)$$

    - $\xi^w_{i,t}$: Auxiliary noise to prevents common knowledge

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  - $\xi^w_{i,t}$: Auxiliary noise to prevents common knowledge
  - Form beliefs about $P_{i,t}$ and P_t using Bayes rule
  - Choose $C_{i,j,t}$ and $N_{i,t}$ delivered in next stage

Shopping and Paying (ii)

- ***Stage 2: Paying stage***
  - Observe total expenditures $M_{i,t} \equiv \int_{\mathcal{B}_{i,t}} P_{j,t} C_{i,j,t} dj$
  - Infer $P_{i,t}$ and adjust savings $B_{i,t}$ to make sure budget constraint binds

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Households Info. Set:

$$\mathcal{I}_{i,t} = \{W_{i,t},\ R_{i,t},\ Z_{i,t},\ D_{i,t}\} \cup \left\{P^R_{j,t}\right\}_{j \in \mathcal{B}_{i,t}} \cup \{S_{i,t}\} \cup \{P_{i,t-1}\}$$

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- **SPANK**

The main equations in a nutshell

Focus on log-linear approx. of noisy RE eq. around non-stoch. SS

Standard relationship between inflation and marginal costs...

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \lambda_{PS}{}^{-1} \underbrace{(w_t - p_t)}_{\text{Marg. Cost.}}; \quad \lambda_{PS} \equiv \frac{\theta}{(1-\theta)(1-\beta\theta)}$$

Standard **labor supply** and **Euler equation** at individual level...

$$\boxed{\varphi n_{i,t} + \sigma c_{i,t} = w_{i,t} - \mathrm{E}_{i,t} p_t}$$

$$\boxed{c_{i,t} = \mathrm{E}_{i,t} c_{i,t+1} - \frac{1}{\sigma}\left(i_{i,t} - \mathrm{E}_{i,t}\pi_{t+1} + \mathrm{E}_{i,t} z_{i,t+1} - z_{i,t}\right)}$$

...but HH's condition their decisions to their own **information set** $\mathcal{I}_{i,t}$

Characterizing the Equilibrium

- Complicated by the fact that HH's learn about an **endogenous** variable
- Fixed point can be solved **numerically** (algorithm in the paper)
- Two assumptions allow to characterize the equilibrium in **closed form:**

A1. Learn **only** by shopping: HH's only use $S_{i,t}$ to learn about $P_{i,t}$ and P_t

- Equivalent to assuming $\sigma_{\epsilon}^2/\zeta_x^2 \rightarrow 0$
- Simplifies belief formation process

A2. No het. in consumption baskets: $\sigma_P^2 \rightarrow 0$

- $\mathcal{B}_{i,t} = [0,1] \Rightarrow p_{t-1} \in \mathcal{I}_{i,t} \Rightarrow$ **Common knowledge about the past**

Analytical Results

Beliefs about inflation at the micro level

- **Shopping experiences** ⇒ **Noisy signal about inflation**

$$\pi^*_{i,t} = \pi_t + \epsilon_{i,t}, \quad \epsilon_{i,t} \overset{iid}{\sim} \mathcal{N}\left(0, \sigma^2_\epsilon\right)$$

- **Bayesian updating** ⇒ **Dispersion in perceptions**

$$\mathrm{E}_{i,t}\pi_t = \psi_\pi \underbrace{\mathrm{E}_{i,t-1}}_{=\mathbb{E}_{t-1}\pi_t} \pi_t + \left(1 - \psi_\pi\right) \pi^*_{i,t}$$

... and **endogenous degree-of-anchoring**:

$$\boxed{\psi_\pi = 1 - \frac{\mathrm{Var}\left[\pi_t | \mathcal{I}_{i,t}\right]}{\mathrm{Var}\left[\pi_t | \mathcal{I}_{i,t}\right] + \sigma^2_\epsilon}}$$

- Which drives dispersion in **expectations**

$$\mathrm{E}_{i,t}\pi_{t+1} = \rho^\pi_1 \mathrm{E}_{i,t}\pi_t + \rho^\pi_2 \pi_{t-1} + \rho^\pi_3 \pi_{t-3} + \dots$$

Beliefs about inflation at the macro level

- **Anchoring $\Rightarrow$ Under-reaction of average perceptions across HHs**

$$\overline{\mathrm{E}}_t \pi_t \equiv \int \mathrm{E}_{i,t} \pi_t di = \psi_\pi \mathbb{E}_{t-1} \pi_t + (1 - \psi_\pi)\, \pi_t$$

- ...and their expectations

$$\overline{\mathrm{E}}_t \pi_{t+1} \equiv \int \mathrm{E}_{i,t} \pi_{t+1} di = \rho_1^\pi \overline{\mathrm{E}}_t \pi_t + \rho_2^\pi \pi_{t-1} + \rho_3^\pi \pi_{t-3} + \dots$$

Anchored HH's expectations and the slope of the NKPC

Recall the standard relationship between inflation and marginal costs...

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + {\lambda_{PS}}^{-1} \underbrace{(w_t - p_t)}_{\text{Marg. Cost.}}$$

...but now labor supply is non-standard

$$y_t = \left(\frac{1}{\varphi + \sigma}\right) \left(w_t - p_t + \underbrace{p_t - \overline{\mathbb{E}}_t p_t}_{\text{Disagreement}} \right)$$

⇒ NKPC when consumers *learn by shopping*

$$\boxed{\pi_t = (1 - \Psi_\pi)\, \beta \mathbb{E}_t \pi_{t+1} + \Psi_\pi \mathbb{E}_{t-1} \pi_t + \alpha_{PC} y_t}$$

$$\boxed{\alpha_{PC} \equiv \frac{\sigma + \varphi}{\lambda_{PS} + \psi_\pi}} \qquad \boxed{\Psi_\pi \equiv \frac{\psi_\pi}{\lambda_{PS} + \psi_\pi}} \qquad \boxed{\psi_\pi = 1 - \frac{\text{Var}\left[\pi_t | \mathcal{I}_{i,t}\right]}{\text{Var}\left[\pi_t | \mathcal{I}_{i,t}\right] + \sigma_\epsilon^2}}$$

Info. friction affects simultaneously the aggregate demand

- **Aggregate Euler Equation**

$$\boxed{y_t = -\frac{1}{\sigma}\left(i_t - \mathbb{E}_t \pi_{t+1} + \mathbb{E}_t z_{t+1} - z_t\right) + \mathbb{E}_t y_{t+1} + \mathcal{H}_t + \mathcal{R}_t}$$

- $\mathcal{H}_t$: Avg. misperception of **permanent income**

$$\mathcal{H}_t \equiv \chi\left(p_t - \overline{\mathrm{E}}_t p_t\right) + \sum_{k=1}^{\infty} \beta^k \int_0^1 \left\{\mathrm{E}_{i,t} y_{t+k} - \mathbb{E}_t y_{t+k}\right\} di$$

- $\mathcal{R}_t$: Avg. misperception of **real interest rate**

$$\mathcal{R}_t \equiv \sum_{k=0}^{\infty} \beta^k \int_0^1 \left\{\mathrm{E}_{i,t}\left\{i_{i,t+k} - \pi_{t+k+1}\right\} - \mathbb{E}_t\left\{i_{t+k} - \pi_{t+k+1}\right\}\right\} di$$

Result 1: Equilibrium Existence

Proposition (Augmented Taylor Principle): The eq. exists and is unique if

$$\boxed{\phi_\pi > \beta^{-1} + \left(\frac{\lambda_{PS} \left(1-\beta\right) \left(\beta^{-1} - \rho_z\right)}{1 + \varphi/\sigma} \right)}$$

Result 2: Non-Neutrality

Proposition (Non-Neutrality): Assume $\lambda_{PS} = 0$. If the ATP holds, then:

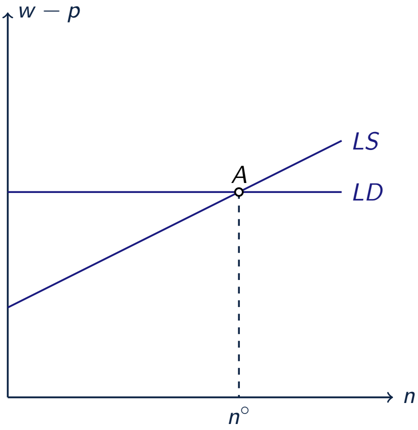
$$\boxed{\frac{\partial \pi_t}{\partial \eta_t^{AD}} = \Delta_\pi > 0, \qquad \frac{\partial y_t}{\partial \eta_t^{AD}} = \frac{\psi_\pi}{\sigma + \varphi}\Delta_\pi > 0}$$

with

$$\Delta_\pi \equiv \left(\frac{\phi_\pi + \left(\frac{\beta\rho_z}{1-\beta\rho_z}\right)\left(\phi_\pi - \beta^{-1}\right)\psi_\pi}{\phi_\pi + \left(1 + \varphi/\sigma\right)^{-1}\left(1 - \chi\left(\sigma + \varphi\right)\right)\psi_\pi} \right) \underbrace{\left(\frac{1 - \rho_z}{\phi_\pi - \rho_z} \right)}_{\left[\partial \pi_t / \partial \eta_t^{AD}\right]^{FI}}$$

Flex. prices ($\theta = 0$) and Full Info. ($\sigma_\epsilon^2 = 0$)

$\downarrow \eta_t^{AD} \Rightarrow \downarrow w_t \Rightarrow \downarrow p_t \Rightarrow w_t = p_t \Rightarrow n_t = 0$



Labor demand

$$\boxed{w_t - p_t = 0}$$

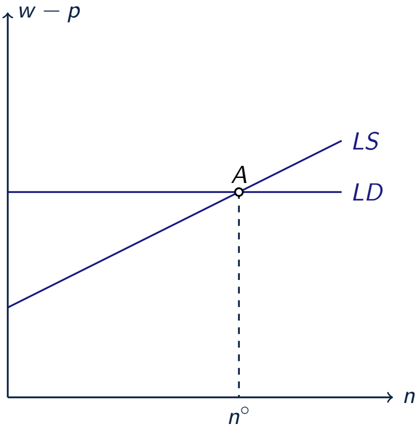
Labor supply

$$\boxed{n_t = \left(\frac{1}{\varphi + \sigma}\right)(w_t - p_t)}$$

- With flexible prices and full-info, real wages remain constant and the AD shock has no real effects

Flex. prices ($\theta = 0$) and LBS ($\sigma_\epsilon^2 > 0$)

$\downarrow \eta_t^{AD} \Rightarrow \downarrow w_t \Rightarrow \downarrow p_t$



Labor demand

$$\boxed{w_t - p_t = 0}$$

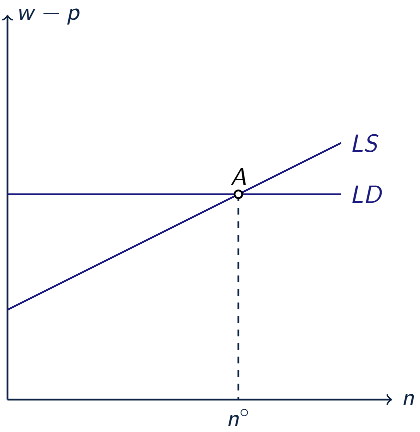
Labor supply

$$\boxed{n_t = \left(\frac{1}{\varphi + \sigma}\right)\left(w_t - \overline{\mathrm{E}}_t p_t\right)}$$

- With LBS, **perceived** real wages fall

Flex. prices ($\theta = 0$) and LBS ($\sigma_\epsilon^2 > 0$)

$\downarrow \eta_t^{AD} \Rightarrow \downarrow w_t \Rightarrow \downarrow p_t < \downarrow \overline{\mathrm{E}}_t p_t$



Labor demand

$$w_t - p_t = 0$$

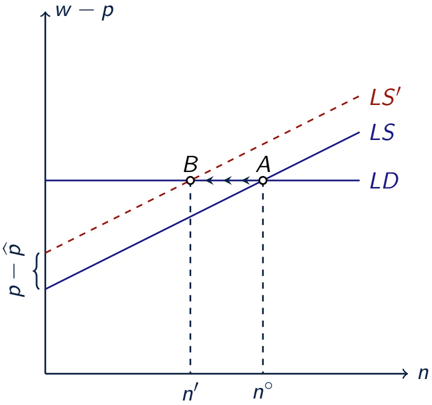
Labor supply

$$n_t = \left(\frac{1}{\varphi + \sigma}\right)\left(w_t - p_t + \underbrace{p_t - \overline{\mathrm{E}}_t p_t}_{\nu_t^p}\right)$$

- With LBS, **perceived** real wages fall, and HH's reduce labor supply

Flex. prices ($\theta = 0$) and LBS ($\sigma_\epsilon^2 > 0$)

$\downarrow \eta_t^{AD} \Rightarrow \downarrow w_t \Rightarrow \downarrow p_t < \downarrow \overline{\mathrm{E}}_t p_t \Rightarrow \downarrow \left(w_t - \overline{\mathrm{E}}_t p_t\right) \Rightarrow \downarrow n_t$



Labor demand

$$w_t - p_t = 0$$

Labor supply

$$n_t = \left(\frac{1}{\varphi + \sigma}\right)\left(w_t - p_t + \underbrace{p_t - \overline{\mathrm{E}}_t p_t}_{\nu_t^p}\right)$$

- **Disagreement** between HH's and firms causes shock to have real effects

Result 3: Amplification from Interaction with Sticky Prices

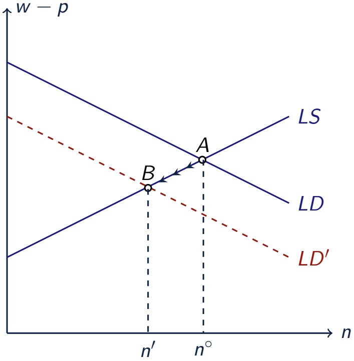
Proposition (Interaction with price-stickiness): If the ATP holds, then:

$$\boxed{\left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{LBS+SP} = \left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{SP} \times \Psi_{LBS}}$$

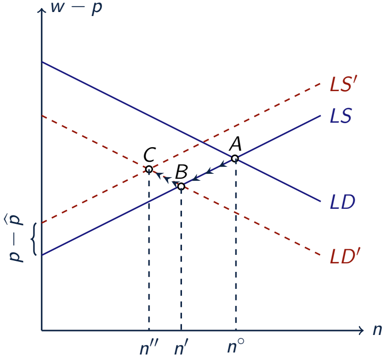
with

$$\Psi_{LBS} \equiv \left(\frac{\psi_\pi + \lambda}{\lambda\left(1-\beta\rho_z\right)}\right)\left(\frac{\Lambda + \Theta\rho_z\psi_\pi}{\Lambda + \left(1-\left(\sigma+\varphi\right)\chi\right)\psi_\pi}\right) - \left(\frac{\beta\rho_z}{1-\beta\rho_z}\right) > 1$$

Full Info. + Sticky Prices



LBS + Sticky Prices



- LBS shifts labor supply, amplifying impact of reduction in labor demand due to sticky prices

Result 4: LBS x Sticky Prices > LBS + Sticky Prices

Proposition (Non-linear amplification): If the ATP holds, then:

$$\boxed{\left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{LBS+SP} = \left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{SP} + \left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{LBS} + \underbrace{\Omega_{LBS}^{AD}}_{>1}\left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{SP} \times \left[\frac{\partial y_t}{\partial \eta_t^{AD}}\right]^{LBS}}$$

Intuition:

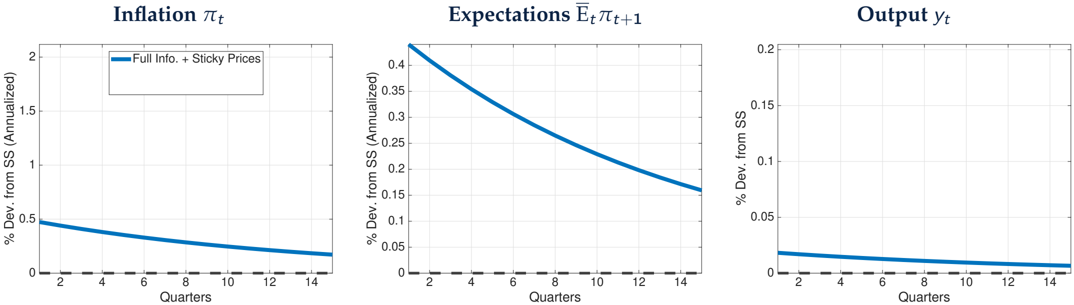
$$\frac{\partial \text{Var}\left[\pi_t | \mathcal{I}_{i,t}\right]}{\partial \lambda_{PS}} < 0 \Rightarrow \frac{\partial \psi_\pi}{\partial \lambda_{PS}} > 0$$

Quantitative Relevance

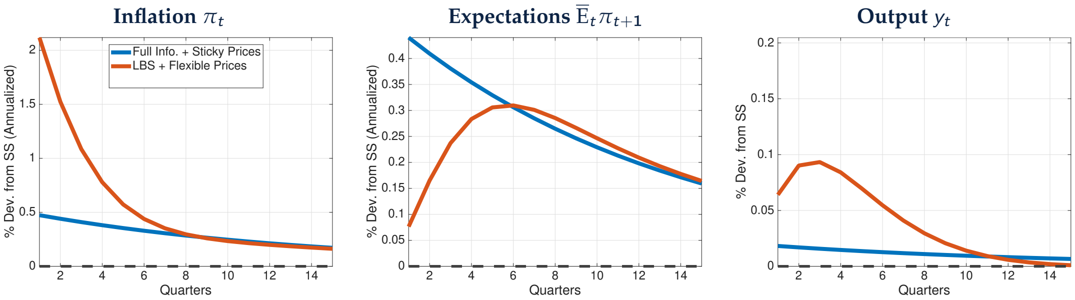
Calibration Targets

- Fix most parameters to standard calibrations of NK model
- **Aggregate Shocks**
  - Target volatility and persistence of π_t and y_t
- **Inflation heterogeneity across households** σ_P^2
  - Dispersion of π at HH level found by Kaplan and Schulhofer-Wohl (2017)
- **Noise in signals** σ_ϵ^2
  - Simulate panel of household in the model
  - Run regression between $\mathrm{E}_{i,t}\pi_{t+12}^{12m}$ and $\pi_{i,t}^{12m}$
  - Match R^2 from similar exercise by D'Acunto, Malmendier, Ospina, and Weber (2021)

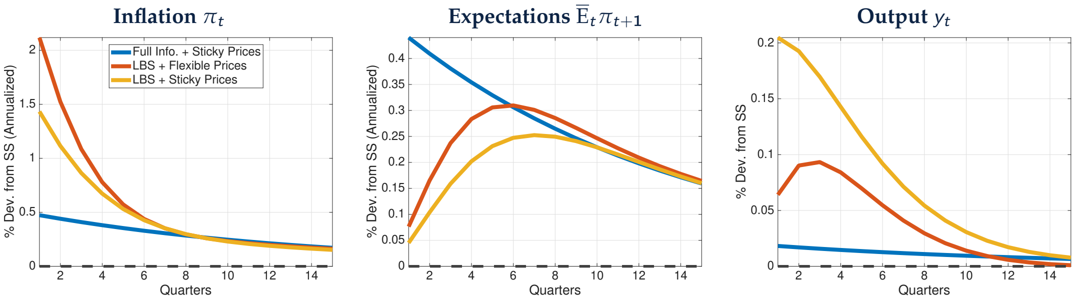
AD shock increases output and inflation under sticky prices...



...with LBS, response is stronger hump-shaped...



...interaction increases 8 times response of y on impact



More in the paper!

- **LBS makes aggregate supply shocks more inflationary**
  - HH's underestimate movements in real wages
  - Attenuates impact of changes in permanent income on c_t and n_t
  - Adjustment to shocks takes place through **prices**
- **A more hawkish monetary policy stance ($\uparrow \phi_\pi$) flattens the NKPC**
  - Reduces volatility of π and increases degree of anchoring ψ_π
  - Quant. accounts for fall in π persistence and volatility in post-Volcker era
  - Predicts that impact of AD shocks **increased** after this change in policy
- **Rational inattention to π amplifies the impact of policy changes**
  - $\uparrow \phi_\pi \Rightarrow$ Lower inflation volatility $\Rightarrow$ Less incentives to pay attention to π
  - Optimally choose lower σ_ϵ, increasing ψ_π and **amplifying** the effects of LBS

Concluding Remarks

- **HH's data on inflation expectations**...
  - Reveal information about their **expectations** of future...
  - But also reveal information about their **perceptions** of current inflation and cost of living
- This paper suggests a crucial role for HH's **inflation perceptions**
  - Driver of **heterogeneity** in expectations about future inflation
  - Affects **transmission** of aggregate shocks and monetary policy
- **Policy implications**
  - Stronger response of CB to inflation...

    → **Anchors** households beliefs about inflation

    → Helps to **attenuate** impact of **supply bottlenecks** (but makes them more inflationary)

    → Gives more room to **stimulate** the economy during **recessions**...

    → ...but can also **amplify** negative effect of other AD shocks (e.g. **financial crisis**)

Thank you for your attention!