Heterogeneous Price Rigidities and Monetary Policy

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Introduction

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  - Normative perspective
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  - Incidence of unemployment
  - Income composition
  - Cash holdings heterogeneity

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  - Normative perspective
  - But also positive implications for MP transmission mechanism
- Previous work:
  - Savers and debtors
  - Incidence of unemployment
  - Income composition
  - Cash holdings heterogeneity
- Does heterogeneity in price rigidities across sectors matter?
  - Price stickiness is source of monetary non-neutrality in NK models
  - Price stickiness is known to be heterogeneous across sectors
  - What are the implications for distributional and/or aggregate effects of MP?

This paper

1. New stylized facts (BLS/CEX/ACS data): prices are more rigid in industries...
   - ... selling to richer/more educated households (“expenditure channel”)
   - ... employing richer/more education households (“earnings channel”)
   - Example: services and manufacturing

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2. Heterogeneous Agent New Keynesian model with many sectors and household types
   - Quantify the aggregate and distributional implications
   - Consumption of college-educated households is 30% more sensitive
   - Aggregate real effect of a 100bps MP tightening is dampened by 7%

Literature

Distributional implications of MP: Doepke and Schneider (2006), Carpenter and Rogers (2004), Albanesi (2007), Williamson (2009), Ledoit (2009), Coibion et al. (2016), Auclert (2017)

Empirical work on price stickiness: Blinder et al. (2008), Bils and Klenow (2002, 2004), Bils et al. (2003), Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008)

Models with heterogeneous price stickiness: Aoki (2001), Bils and Klenow (2002), Carlstrom et al. (2006), Carvalho (2006), Barsky et al. (2006), Nakamura and Steinsson (2007)

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Our contribution: We study an enriched HANK model with firm and household heterogeneity.

Outline

1. Conceptual framework

2. Data and stylized facts

3. Quantitative analysis

The simple model

- Two periods: $t = 1, 2$
- Two sectors: $s \in \{A, B\}$
- Finite household types i with different sectoral exposures

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Household i solves:

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Household i solves:

$$\max \sum_{t=1}^{2} \beta^{t-1} U[(c_{i,t}^{A})^{1-\alpha^i} (c_{i,t}^{B})^{\alpha^i}]$$

subject to

$$\underbrace{c_{i,1}^{A} + \frac{c_{i,2}^{A}}{R}}_{\text{Spending on A}} + \underbrace{p_1 c_{i,1}^{B} + p_2 \frac{c_{i,2}^{B}}{R}}_{\text{Spending on B}} = \underbrace{\frac{b_{i,1}}{\pi_1^A}}_{\text{Initial wealth}} + \underbrace{\gamma^i (Y_1^A) + \frac{\gamma^i (Y_2^A)}{R}}_{\text{Earnings from A}} + \underbrace{p_1 \gamma^i (Y_1^B) + p_2 \frac{\gamma^i (Y_2^B)}{R}}_{\text{Earnings from B}}$$

where $p_t = \frac{P_t^B}{P_t^A}$ is relative price, α^i expenditure exposure and γ^i earnings exposure.

Simple perturbation: partial equilibrium

- Consider the general perturbation $\{dR, dY_1^A, dY_1^B, dp, d\pi^A\}$

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$$MPC_{i,1} \equiv \frac{\partial}{\partial y_i} p^{\alpha^i} c_{i,1}.$$

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Proposition: Household i's behavioral consumption response can be decomposed into

$$dc_{i,1} = \overbrace{-\frac{1}{\gamma} MPS_{i,1} c_{i,1} \frac{dR}{R}}^{\text{Substitution effect}} + MPC_{i,1} \Bigg\{ \overbrace{b_{i,2} \frac{dR}{R}}^{\text{Interest rate exposure}} - \overbrace{\frac{b_{i,1}}{\pi^A} \frac{dP^A}{P^A}}^{\text{Bond revaluation}}$$

$$\underbrace{+\gamma_i^A dY_1^A + p\gamma_i^B dY_1^B}_{\text{Heterogeneous earnings channel}} + \underbrace{\gamma_i^B p \left(Y_1^B + \frac{1}{R} Y_2^B \right) \frac{dp}{p}}_{\text{Relative price effect on real earnings}} - \underbrace{\alpha^i p^{\alpha^i} \left(c_{i,1} + \frac{1}{R} c_{i,2} \right) \frac{dp}{p}}_{\text{Relative price effect on real expenditures}} \Bigg\}.$$

Simple perturbation: general equilibrium

Proposition: In response to our proposed aggregate perturbation, the change in aggregate demand can be decomposed as

$$dY_1 = \left[\text{Cov}_I\left(\mu\text{MPC}_{i,1}, b_{i,2}\right) - \frac{1}{\gamma}\mathbb{E}_I(\mu\text{MPS}_{i,1}c_{i,1}) \right] \frac{dR}{R} - \text{Cov}_I\left(\mu\text{MPC}_{i,1}, \frac{b_{i,1}}{\pi^A}\right) \frac{dP^A}{P^A}$$

$$+ \underbrace{\sum_s \frac{P_t^s}{P_t^A} \left(\mathbb{E}_I(\text{MPC}_{i,1}) + \text{Cov}_I(\mu\text{MPC}_{i,1}, \gamma_i^s) \right) dY_1^s}_{\text{Heterogeneous earnings effect}}$$

$$+ \sum_t \frac{1}{R^{t-1}} \underbrace{p\left(\mathbb{E}_I(\text{MPC}_{i,1}) + \text{Cov}_I(\mu\text{MPC}_{i,1}, \gamma_i^B) \right) Y_t^B \frac{dp}{p}}_{\text{Relative price effect on earnings}}$$

$$- \sum_t \frac{1}{R^{t-1}} \underbrace{\mathbb{E}_I\left(\mu\text{MPC}_{i,1}\alpha^i p^{\alpha^i} c_{i,t} \right) \frac{dp}{p}}_{\text{Relative price effect on expenditures}}.$$

Outline

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3. Quantitative analysis

Data

- Build 3 linked datasets with price rigidities (consumer and producer prices), expenditures and payrolls
  - Covers full U.S. economy (except shelter in most cases)
- CPI-ACS sample:
  - merge price rigidity data from Nakamura and Steinsson (2008) (at the ELI level) to earnings data from the ACS (at the industry level)
- PPI-ACS sample:
  - match price rigidity data from Pasten et al. (2016) (at the 6-digit NAICS level) to ACS industries
- CPI-CEX sample:
  - merge price rigidity data from Nakamura and Steinsson (2008) (at the ELI level) to spending data from the CEX (at the UCC level).

New facts

Two empirical findings:

1. Prices more rigid in product categories selling to more educated/richer households (consistent with Cravino-Lan-Levchenko, 2019)

   Examples:

   - Services (frequency: 6.39%, share of sales to College: 37.9%)
   - Taxi fares (frequency: 4.41%, share of sales to College: 62.3%)
   - Fast food lunch (frequency: 7%, share of sales to College: 34.4%)

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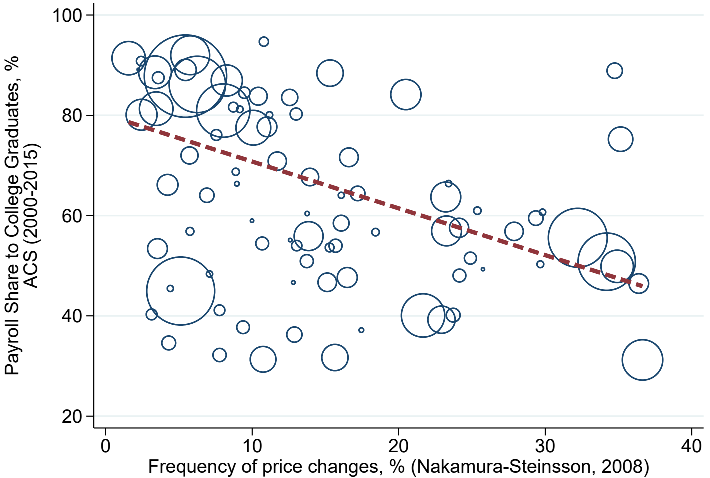
2. Prices more rigid in product categories employing more educated/richer households

   Examples:
   - Computer electronics (frequency: 28.95%, payroll share to College: 72.15%)
   - Poultry processing (frequency: 35.1%, payroll share to College: 14.43%)

Earnings channel: CPI-ACS

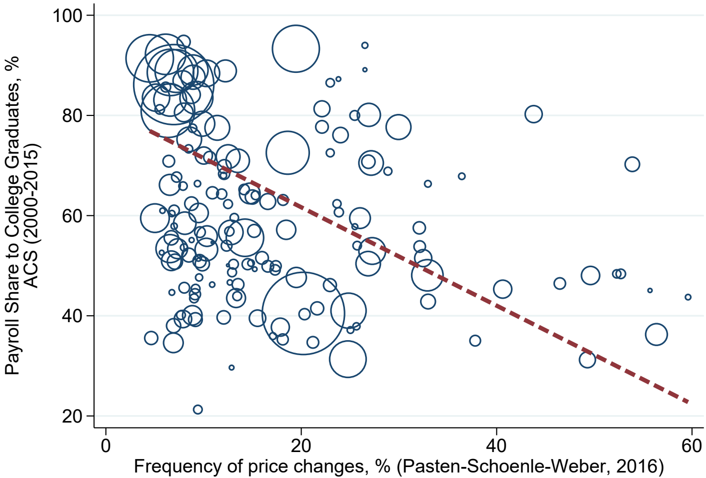


Notes: Includes All Prices Changes

Earnings channel: CPI-ACS

	Share of Payroll to College Graduates (%)		
	(1)	(2)	(3)
Frequency of Price Changes (%)	-0.9330***	-0.463**	-0.5505**
	(0.2649)	(0.2119)	(0.2396)
Excluding industries with price change frequency $>$ p95	Yes	Yes	No
2-digit Naics Code F.E.	No	Yes	No
Sample Size	86	86	94

Earnings channel: PPI-ACS

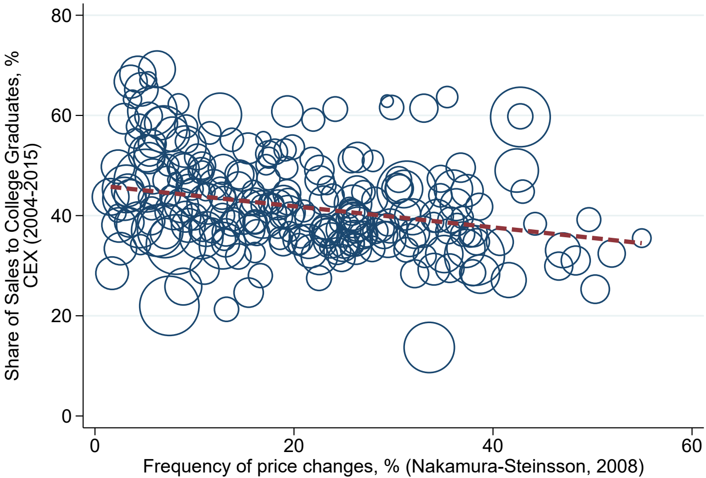


Notes: Includes All Prices Changes

Earnings channel: PPI-ACS

	Share of Payroll to College Graduates (%)		
	(1)	(2)	(3)
Frequency of Price Changes (%)	-0.9823***	-0.2027	-0.3771*
	(0.2149)	(0.1306)	(0.1978)
Excluding industries with price change frequency > p95	Yes	Yes	No
2-digit Naics Code F.E.	No	Yes	No
Sample Size	163	163	169

Expenditure channel: CPI-CEX

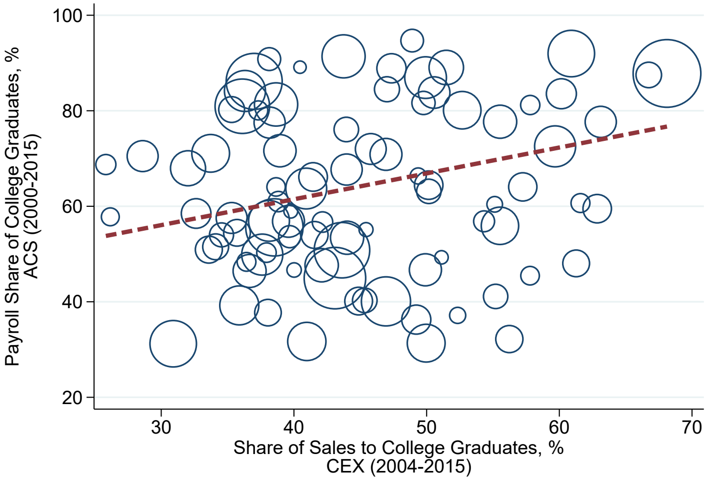


Notes: Includes All Prices Changes

Expenditure channel: CPI-CEX

	Share of Sales to College Graduates (%)		
	(1)	(2)	(3)
Frequency of Price Changes (%)	-0.2108**	-0.1904*	-0.1256**
	(0.0824)	(0.0977)	(0.0376)
Excluding industries with price change frequency > p95	Yes	Yes	No
Expenditure Category F.E.	No	Yes	No
Sample Size	242	242	254

Interaction between Earnings / Expenditure channels



Notes: OLS Coeff. 0.5416*** (s.e. 0.2264), N=88

New facts

- Implications for monetary policy tightening:
  - NK model prediction for sector with more rigid prices:
    less deflation, but bigger output gap
  - More educated households suffer more: preferred goods relatively more expensive, stronger labor demand contraction
  - Feedback loop on consumption of more educated households: demand for goods in more rigid sector falls even more ($\rightarrow$ relative price, labor demand)
  - Monetary policy has relatively larger effect on richer, low-MPC households $\rightarrow$ dampened aggregate effect

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  - Monetary policy has relatively larger effect on richer, low-MPC households $\rightarrow$ dampened aggregate effect
- Robustness
  - Excluding sales
  - Different measures of income and education
  - Broad sector fixed effects (e.g. within goods)

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  - Different price rigidity: δ^s
  - Sectors employ two types of workers: $N^s_{C,t}$ and $N^s_{NC,t}$
  - Each sector has its own, fully segmented labor market (business cycle frequency)

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- Two household types $i \in \{C, NC\}$: college and non-college
  - Within type heterogeneity: uninsurable earnings risk (standard incomplete markets model)
  - Different sector-specific productivities: Z^s_e (equivalent to γ_i in simple model)
  - Different tastes: α^s_C and α^s_{NC}

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- Policy experiment: contractionary 100bps monetary policy shock

Model details

- CES consumption baskets

$$c_{i,t} = \left[\sum_s^N (\alpha_i^s)^{\frac{1}{\eta}} (c_{i,t}^s)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

- Household budget constraint (assumptions on profit rebate important)

$$\dot{a}_{i,t} = \underbrace{(i_t - \pi_t^N) a_{i,t}}_{\text{Interest income}} + \underbrace{z_{i,t} n_{i,t} w_{i,t} p_{i,t}}_{\text{Labor income}} + \underbrace{\tau_{i,t} p_{i,t}}_{\text{Transfer income}} - \underbrace{c_{i,t} p_{i,t}}_{\text{Consumption}}, \quad a_{i,t} \geq \underline{a}$$

- Intermediate goods producer production function

$$Y_t^s(j) = \left[\sum_{e \in C, NC} (Z_e^s)^{\frac{1}{\kappa}} N_{e,t}^s(j)^{\frac{\kappa-1}{\kappa}} \right]^{\frac{\kappa}{\kappa-1}}$$

- Two Phillips Curves (under Rotemberg pricing)

$$\dot{\pi}_t^s = \pi_t^s \left(i_t - \pi_t^s - \frac{\dot{Y}_t^s}{Y_t^s} \right) - \frac{\epsilon - 1}{\delta^s} \left(\frac{\epsilon}{\epsilon - 1} MC_t^s - 1 \right)$$

HJB | Taylor rule | Kolmogorov forward equation | Channel decomposition

Calibration strategy

- Heterogeneous expenditure shares: α_i^s
- Heterogeneous sectoral skill intensities: Z_e^s
- Heterogeneous sectoral price stickiness: δ^s

Summary of quantitative exercise

- Consider two cases: baseline (homogeneous price rigidities) and full model

- Cross-sectional effect: Compute distributional effects between C and NC as

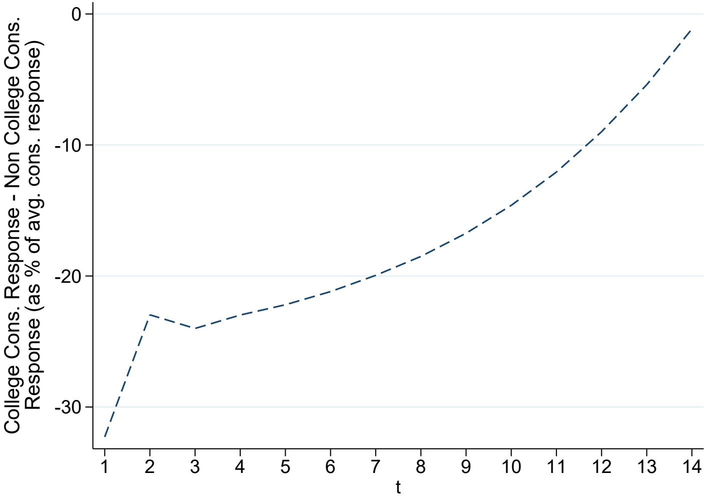
$$\Delta = \frac{\Delta C^C}{C_{SS}^C} - \frac{\Delta C^{NC}}{C_{SS}^{NC}},$$

  then difference full model from baseline, $\Delta - \Delta^{baseline}$ and normalize by aggregate consumption response

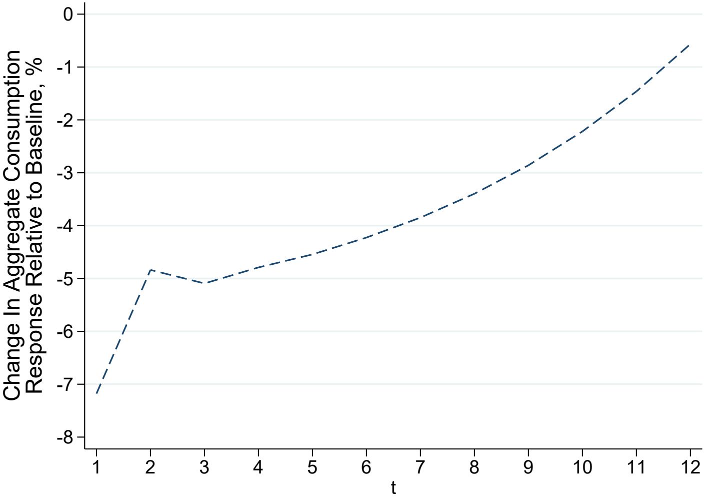
- Aggregate effect: change in aggregate consumption response in full model relative to baseline

$$\frac{\Delta C}{\Delta C^{baseline}}$$

Summary of quantitative exercise: cross-sectional



Summary of quantitative exercise: aggregate



Conclusion

- This paper re-evaluates the implications of heterogeneous price stickiness for the transmission and the distributional effects of monetary policy

- Establish new facts using micro data:
    1. Richer/more educated households purchase in more rigid sectors
    2. Richer/more educated households work in more rigid sectors

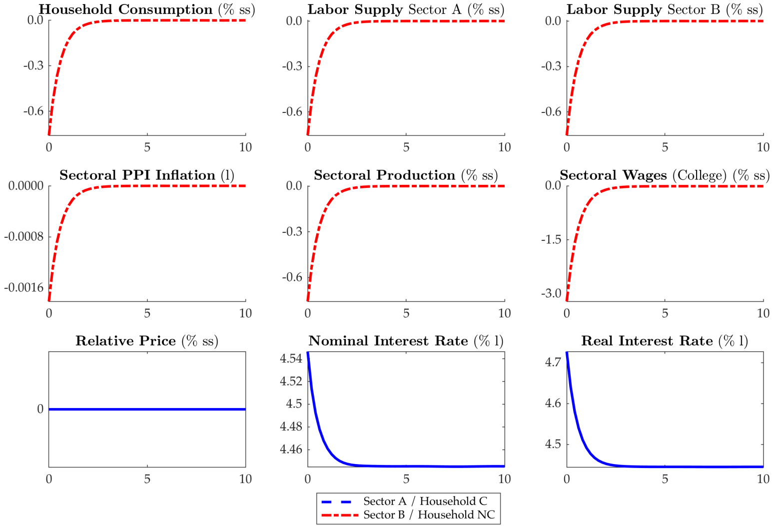
- Quantitative model to assess implications of these new facts
    - Real effects of MP dampened in the presence of heterogeneous price stickiness
    - Consumption of college households 30% more sensitive to MP shocks
    - Aggregate effects of monetary policy muted by 5 - 10% due to novel earnings and expenditure channels

Calibration

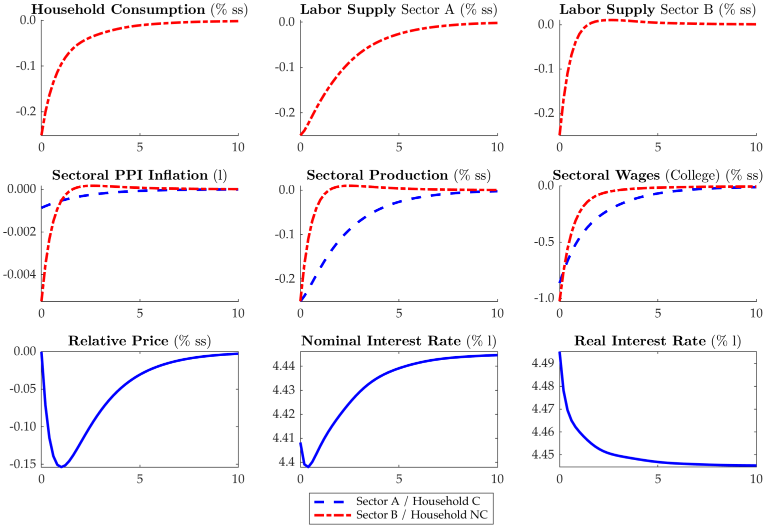
Table 1: Parameters for Calibration

		Value	Source
ϕ	Curvature of (relative) labor supply curve	1.5	Smets and Wouters (2007)
θ_C	P(Non-College|College)	0.45/35	Ferrare (2016)
θ_{NC}	P(College|Non-College)	0.22/35	
ϵ	Elasticity of substitution between intermediates	11	Basu and Fernald (1997)
γ	CRRA for upper-level utility function	1.5	N/A
$1-\alpha^{NC}$	Non-college spending in A	41.5%	CEX
$1-\alpha^{C}$	College spending in A	58.5%	
Z_A^{NC}	Non-college prod in A	0.33	QCEW
Z_A^{C}	College prod in A, normalized	1.14	
Z_B^{NC}	Non-college prod in B	0.47	
Z_B^{C}	College prod in B	0.66	
δ^A	Price adj. cost in A	190	Nakamura and Steinsson (2008)
δ^B	Price adj. cost in B	10	

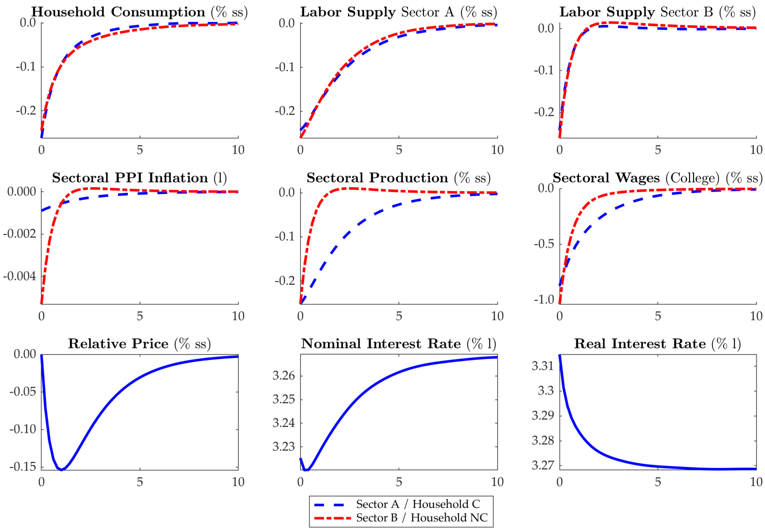
Baseline with 1 household type, 1 sector



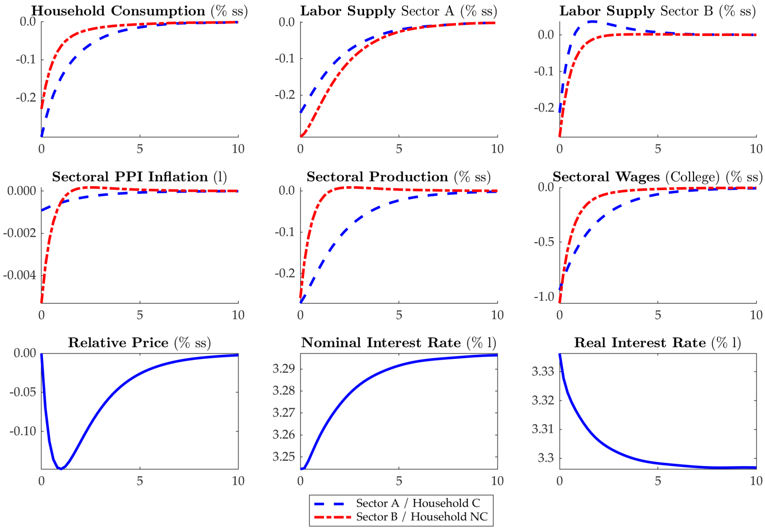
Introducing sectoral price rigidity heterogeneity



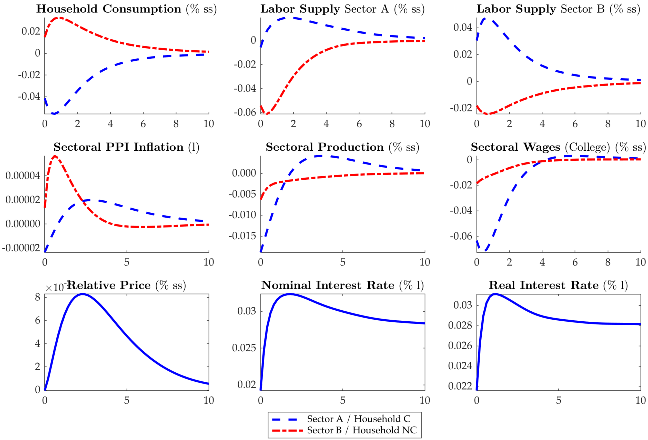
Comparison calibration: *add symmetric productivity differences*



Full calibration: *asymmetric productivity differences and tastes*

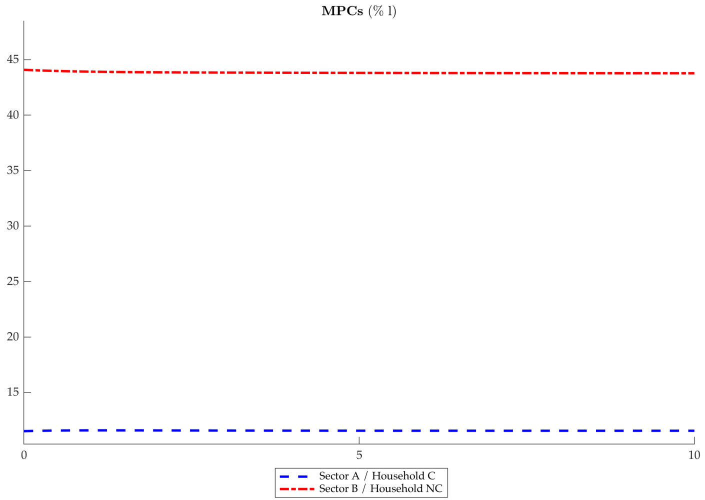


Differenced IRFs (Full – Comparison)



Back.

Marginal propensities to consume (MPC)



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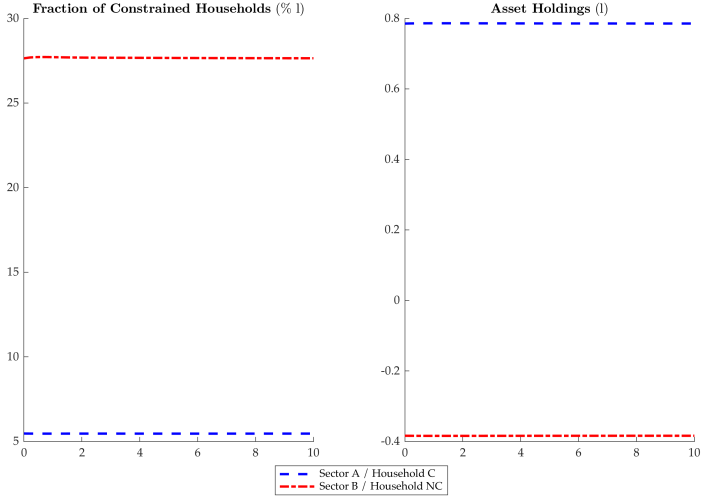
Asset holdings and borrowing constraints



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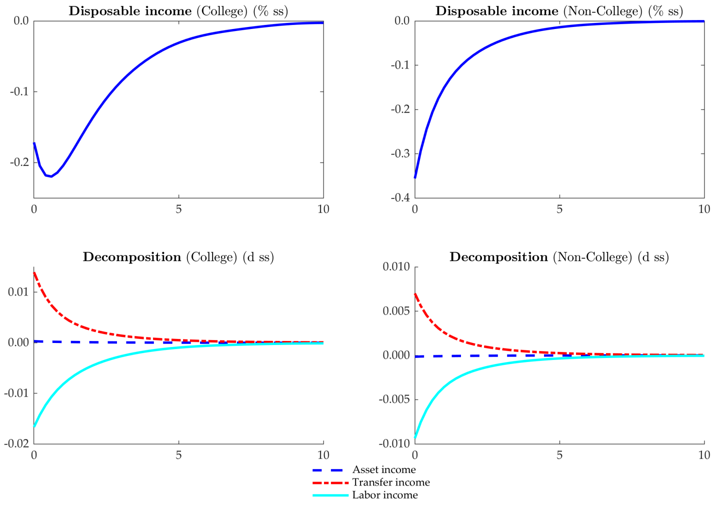
Disposable income and its decomposition



Back.

Households' recursive optimization problem

- We collect households' state variables in the vector $x_{i,t}$ with law of motion

$$\begin{pmatrix} da_{i,t} \\ dz_{i,t} \end{pmatrix} = \begin{pmatrix} r_t a_{i,t} + \sum_s z^s_{i,t} n^s_{i,t} w^s_{i,t} p_t^{\alpha^i} - p_t^{\alpha^i} c_{i,t} + \frac{T_{i,t}}{P_t^A} \\ \mu(z^s_{i,t}) \end{pmatrix} dt + \begin{pmatrix} 0 \\ \sigma(z^s_{i,t}) \end{pmatrix} dB_t.$$

- This gives us the recursive, continuous-time Bellman equation

$$\begin{aligned} \rho v_{i,t}(x_{i,t}) = & \partial_t v_{i,t}(x_{i,t}) + \max_{c_{i,t}, n_{i,t}} u(c_{i,t}, n_{i,t}) + \theta_i \Big(v_{-i,t}(x_{-i,t}) - v_{i,t}(x_{i,t}) \Big) \\ & + \partial_a v_{i,t}(x_{i,t}) \Big(r_t a_{i,t} + \sum_s z^s_{i,t} n^s_{i,t} w^s_{i,t} p_t^{\alpha^i} - p_t^{\alpha^i} c_{i,t} + \frac{T_{i,t}}{P_t^A} \Big) \\ & + \mu(z^s_{i,t}) \partial_z v_{i,t}(x_{i,t}) + \frac{1}{2} \sigma(z^s_{i,t})^2 \partial_{zz} v_{i,t}(x_{i,t}) \end{aligned}$$

- FOCs:

$$\begin{aligned} c_{i,t}^{-\gamma} &= p_t^{\alpha^i} \partial_a v_{i,t}(x_{i,t}) \\ c_{i,t}^{\gamma} (n^s_{i,t})^{\phi} &= z^s_{i,t} w^s_{i,t}. \end{aligned}$$

Back

The Taylor rule

- Assumptions on the Taylor rule are important
- For now, we assume equal weighting:

$$i_t = i_t^* + \sum_s \left(\phi_\pi^s \pi_t^s + \phi_y^s (Y_t^s - Y) \right) + \xi_t, \tag{1}$$

Back

Aggregation in our model

- We write Kolmogorov forward (KF) equations separately for each household type
- The KF equations characterizing the evolution of these density functions are given by

$$\partial_t g_{i,t}(x_{i,t}) = -\partial_a\Big(\big[r_t a_{i,t} + \sum_s z^s_{i,t} n^s_{i,t} w^s_{i,t} p_t^{\alpha^i} - p_t^{\alpha^i} c_{i,t} + \frac{T_{i,t}}{P_t^A}\big] g_{i,t}(x_{i,t})\Big)$$
$$- \partial_z\Big(\mu(z^s_{i,t}) g_{i,t}(x_{i,t})\Big) + \frac{1}{2}\partial_{zz}\Big(\sigma(z^s_{i,t})^2 g_{i,t}(x_{i,t})\Big)$$
$$- \theta_i g_{i,t}(x_{i,t}) + \theta_{-i} g_{-i,t}(x_{-i,t}).$$

Back

Channel decompositions

- Consider a perturbation $\{\xi_t\}$ that corresponds to a 100bps MP shock.
- We can decompose the effect on consumption as follows.

  For College:

$$C_{C,0}\left(\{r_t, w_{C,t}, p_{C,t}, T_{C,t}\}_{t\in[0,\infty)}, g_0\right)$$
$$= \int_{\underline{a}}^{\infty}\int_{\underline{z}}^{\overline{z}} c_C\left(a, z, \{r_t, w_{C,t}, p_t, T_{C,t}\}_{t\in[0,\infty)}\right) g_0 d(z,a)$$

$$dC_{C,0} = \int_0^{\infty} \frac{\partial C_{C,0}}{\partial r_t} dr_t + \frac{\partial C_{C,0}}{\partial w_{C,t}} dw_{C,t} + \frac{\partial C_{C,0}}{\partial p_t} dp_t + \frac{\partial C_{C,0}}{\partial T_{C,t}} dT_{C,t} dt$$

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