Heterogeneous Price Rigidities and Monetary Policy

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\(^2\)LSE

June 27, 2019
Introduction

- What are the implications of heterogeneity for monetary policy (MP)?
  - MP has distributional effects
  - Accounting for heterogeneity also important to understand MP transmission
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- Previous work:
  - Savers and debtors
  - Incidence of unemployment
  - Income composition
  - Cash holdings heterogeneity

Does heterogeneity in price rigidities across sectors matter?
- Price stickiness is known to be heterogeneous across sectors
- How are households exposed to this dimension of heterogeneity?
- What are the implications for effects of MP?
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This paper

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

2. Heterogeneous Agent New Keynesian model with many sectors and household types
   - College-educated households considerably more sensitive to MP (via earnings and expenditure channels)
   - Between-type debtor-saver channel pushes in opposite direction
   - Aggregate effects of MP on inflation and real GDP dampened
   - Structural change from goods to services implies flattening of PC (weaker MP)
Literature


**Literature**


**Our contribution:** We document and study a set of novel *earnings* and *expenditure* channels of monetary policy transmission


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*Our contribution*: Two novel stylized facts about the cross-sectional exposure of households to price rigidity (and thus monetary policy)


*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:**

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

subject to

\[
\begin{align*}
\frac{c_{i,1}^{A}}{R} + \frac{c_{i,2}^{A}}{R} + p_1 c_{i,1}^{B} + p_2 \frac{c_{i,2}^{B}}{R} &= \frac{b_{i,1}}{\pi_1^A} + \gamma^i (Y_1^A) + \frac{\gamma^i (Y_2^A)}{R} + p_1 \gamma^i (Y_1^B) + p_2 \frac{\gamma^i (Y_2^B)}{R}
\end{align*}
\]

where \( p_t = \frac{P_t^B}{P_t^A} \) is relative price, \( \alpha^i \) expenditure exposure and \( \gamma^i \) earnings exposure.
Consider the general perturbation \( \{dR, dY_A, dY_B, dp, d\pi_A\} \)

- Proposition: Household \( i \)'s behavioral consumption response can be decomposed into:
  - Substitution effect
  - Interest rate exposure
  - Bond revaluation
  - Heterogeneous earnings channel
  - Relative price effect on real earnings
  - Relative price effect on real expenditures
Simple perturbation: partial equilibrium

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

Define:

\[
MPC_{i,1} \equiv \frac{\partial}{\partial y_i} p_{\alpha_i} c_{i,1}.
\]
Consider the general perturbation \( \{dR, dY_1^A, dY_1^B, dp, d\pi^A\} \)

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\[
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\]

**Proposition**: Household \( i \)'s behavioral consumption response can be decomposed into

\[
dc_{i,1} = -\frac{1}{\gamma} MPS_{i,1} c_{i,1} \frac{dR}{R} + MPC_{i,1} \left\{ b_{i,2} \frac{dR}{R} - \frac{b_{i,1}}{\pi^A} \frac{dP^A}{P^A} \right\} + \gamma_i^A dY_1^A + p\gamma_i^B dY_1^B + \gamma_i^B p \left( Y_1^B + \frac{1}{R} Y_2^B \right) \frac{dp}{p} - \alpha_i p^{\alpha_i} \left( c_{i,1} + \frac{1}{R} c_{i,2} \right) \frac{dp}{p}.
\]

- Substitution effect
- Interest rate exposure
- Bond revaluation
- Heterogeneous earnings channel
- Relative price effect on real earnings
- Relative price effect on real expenditures
Simple perturbation: general equilibrium

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

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

\[
+ \sum_s \frac{P_t^s}{P_t^A} \left( \mathbb{E}_I (\text{MPC}_{i,1}) + \text{Cov}_I (\mu \text{MPC}_{i,1}, \gamma_i^s) \right) dY_1^s
\]

**Heterogeneous earnings effect**

\[
+ \sum_t \frac{1}{R^{t-1}} \left( \mathbb{E}_I (\text{MPC}_{i,1}) + \text{Cov}_I (\mu \text{MPC}_{i,1}, \gamma_i^B) \right) Y_t^B \frac{dp}{p}
\]

**Relative price effect on earnings**

\[
- \sum_t \frac{1}{R^{t-1}} \mathbb{E}_I \left( \mu \text{MPC}_{i,1} \alpha_i p^{\alpha_i} c_{i,t} \right) \frac{dp}{p}.
\]

**Relative price effect on expenditures**
Outline

1. Conceptual framework

2. Data and stylized facts

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

<table>
<thead>
<tr>
<th>Frequency of Price Changes (%)</th>
<th>Share of Payroll to College Graduates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>-0.9330***</td>
</tr>
<tr>
<td></td>
<td>(0.2649)</td>
</tr>
</tbody>
</table>

- 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

Payroll Share to College Graduates, %
ACS (2000-2015)

Frequency of price changes, % (Pasten-Schoenle-Weber, 2016)

Notes: Includes All Prices Changes
<table>
<thead>
<tr>
<th>Frequency of Price Changes (%)</th>
<th>Share of Payroll to College Graduates (%)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<tbody>
<tr>
<td>-0.9823***</td>
<td>-0.2027</td>
<td></td>
<td></td>
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<tr>
<td>(0.2149)</td>
<td>(0.1306)</td>
<td></td>
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<td>Excluding industries with price change frequency &gt; p95</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>2-digit Naics Code F.E.</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sample Size</td>
<td>163</td>
<td>163</td>
<td>169</td>
<td></td>
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</tbody>
</table>
Expenditure channel: CPI-CEX

Notes: Includes All Prices Changes
## Expenditure channel: CPI-CEX

<table>
<thead>
<tr>
<th></th>
<th>Share of Sales to College Graduates (%)</th>
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<td>(1)</td>
</tr>
<tr>
<td><strong>Frequency of Price Changes (%)</strong></td>
<td>-0.2108**</td>
</tr>
<tr>
<td></td>
<td>(0.0824)</td>
</tr>
<tr>
<td>Excluding industries with price change frequency &gt; p95</td>
<td>Yes</td>
</tr>
<tr>
<td>Expenditure Category F.E.</td>
<td>No</td>
</tr>
<tr>
<td>Sample Size</td>
<td>242</td>
</tr>
</tbody>
</table>
Interaction between Earnings / Expenditure channels

Payroll Share of College Graduates, %
ACS (2000-2015)

Share of Sales to College Graduates, %

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

- Robustness
  - Excluding sales
  - Different measures of income and education
  - Broad sector fixed effects (e.g. within goods)

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 (relative price, labor demand)
- Monetary policy has relatively larger effect on richer, low-MPC households → dampened aggregate effect
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- Start from one-asset heterogeneous-agent New Keynesian model
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  - Different price rigidity: $\delta^s$
  - Sectors employ two types of workers: $N^s_{C,t}$ and $N^s_{NC,t}$
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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)

\[ \dot{a}_{i,t} = (\dot{i}_{t} - \pi_{t}^{N})a_{i,t} + z_{i,t}n_{i,t}w_{i,t}p_{i,t} + \tau_{i,t}p_{i,t} - c_{i,t}p_{i,t}, \quad a_{i,t} \geq a_{i} \]

- Interest income
- Labor income
- Transfer income
- Consumption

- Intermediate goods producer production function

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

- Two Phillips Curves (under Rotemberg pricing)

\[ \dot{\pi}_{t}^{s} = \pi_{t}^{s} \left( \dot{i}_{t} - \pi_{t}^{s} - \frac{\dot{Y}_{t}^{s}}{Y_{t}^{s}} \right) - \frac{\epsilon - 1}{\delta^{s}} \left( \frac{\epsilon}{\epsilon - 1} MC_{t}^{s} - 1 \right) \]

- HJB
- Taylor rule
- Kolmogorov forward equation
- Channel decomposition
Calibration and estimation strategy

- Heterogeneous expenditure shares: $\alpha^s_i$ $\rightarrow$ CPI-CEX data
- Heterogeneous sectoral skill intensities: $Z^s_e$ $\rightarrow$ CPI-ACS data
- Heterogeneous sectoral price stickiness: $\delta^s$ $\rightarrow$ CPI data
- Heterogeneous discount rate: $\rho_i$ $\rightarrow$ Household MPC
- Heterogeneous borrowing constraint: $a_i$ $\rightarrow$ Isolate debtor-saver channel
Our novel earnings + expenditure channels

- How can we cleanly isolate the effects of our channels?
Our novel earnings + expenditure channels

- How can we cleanly isolate the effects of our channels?

- Recall GE Proposition: It’s all about the covariance terms

\[
\text{Cov}_I(MPC_i, \alpha_i^s) \quad \text{Cov}_I(MPC_i, Z_e^s)
\]
Our novel earnings + expenditure channels

- How can we cleanly isolate the effects of our channels?

- Recall GE Proposition: It’s all about the covariance terms

\[ \text{Cov}_I(MPC_i, \alpha^s_i) \quad \text{Cov}_I(MPC_i, Z^s_e) \]

- We compare two models:
  - Same steady state
  - Same marginal distributions for: \( \delta^s, \alpha^s_i \) and \( Z^s_e \) (also \( \rho_i \) and \( a_i \))
  - Only difference is joint distribution (covariance terms)

- We turn off between-type debtor-saver for now (turn back on later)
Our novel earnings + expenditure channels

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Consumption decomposition

![Graph showing consumption decomposition for College and Non-College segments. The graph plots deviation from steady state in levels against college and non-college categories. The graph includes lines for consumption, savings, earnings, dividends, and rebates. The y-axis represents deviation in a range of -4 to 3 x 10^-3, and the x-axis ranges from 0 to 10 for both College and Non-College segments.](image)
Between-type debtor-saver channel
Structural change: from goods to services

- Secular increase of spending share on services over time

- Share of spending on goods: 60% in 1946 to 32% in 2009 (Boppart 2014)

- Effective degree of rigidity in economy increases: this leads to flattening of Phillips curve
Structural change: from goods to services

\( Y_t \) (% from SS)

\( \pi_t \) (%)
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 channels
  - Real effects of MP dampened
  - College-educated (richer) households significantly more sensitive to MP
Table 1: Parameters for Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$</td>
<td>Curvature of (relative) labor supply curve</td>
<td>1.5</td>
<td>Smets and Wouters (2007)</td>
</tr>
<tr>
<td>$\theta_C$</td>
<td>P(Non-College</td>
<td>College)</td>
<td>0.45/35</td>
</tr>
<tr>
<td>$\theta_{NC}$</td>
<td>P(College</td>
<td>Non-College)</td>
<td>0.22/35</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>Elasticity of substitution between intermediates</td>
<td>11</td>
<td>Basu and Fernald (1997)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>CRRA for upper-level utility function</td>
<td>1.5</td>
<td>N/A</td>
</tr>
<tr>
<td>$1 - \alpha^{NC}$</td>
<td>Non-college spending in A</td>
<td>41.5%</td>
<td>CEX</td>
</tr>
<tr>
<td>$1 - \alpha^C$</td>
<td>College spending in A</td>
<td>58.5%</td>
<td></td>
</tr>
<tr>
<td>$Z^{NC}_A$</td>
<td>Non-college prod in A</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>$Z^{C}_A$</td>
<td>College prod in A, normalized</td>
<td>1.14</td>
<td>QCEW</td>
</tr>
<tr>
<td>$Z^{NC}_B$</td>
<td>Non-college prod in B</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>$Z^{C}_B$</td>
<td>College prod in B</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>$\delta^A$</td>
<td>Price adj. cost in A</td>
<td>190</td>
<td>Nakamura and Steinsson (2008)</td>
</tr>
<tr>
<td>$\delta^B$</td>
<td>Price adj. cost in B</td>
<td>10</td>
<td></td>
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</tbody>
</table>
Baseline with 1 household type, 1 sector

- Household Consumption (% ss)
- Labor Supply Sector A (% ss)
- Labor Supply Sector B (% ss)
- Sectoral PPI Inflation (1)
- Sectoral Production (% ss)
- Sectoral Wages (College) (% ss)
- Relative Price (% ss)
- Nominal Interest Rate (% l)
- Real Interest Rate (% l)

Legend:
- Sector A / Household C
- Sector B / Household NC
Introducing sectoral price rigidity heterogeneity

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Heterogeneous Price Rigidities and Monetary Policy

Sector A / Household C
Sector B / Household NC
Comparison calibration: *add symmetric productivity differences*
Full calibration: asymmetric productivity differences and tastes
Differenced IRFs (Full – Comparison)
Marginal propensities to consume (MPC)
Asset holdings and borrowing constraints

Fraction of Constrained Households (% l)

Asset Holdings (l)

- Plot showing the fraction of constrained households and asset holdings over time.

Legend:
- Blue line: Sector A / Household C
- Red line: Sector B / Household NC
Disposable income and its decomposition

Disposable income (College) (% ss)

Disposable income (Non-College) (% ss)

Decomposition (College) (d ss)

Decomposition (Non-College) (d ss)

Back.
Households’ recursive optimization problem

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

$$
\begin{pmatrix}
\frac{d a_{i,t}}{dt} \\
\frac{d z_{i,t}}{dt}
\end{pmatrix} = \begin{pmatrix}
- r_t a_{i,t} + \alpha \sum_s z_{i,t}^s n_{i,t}^s w_{i,t}^s p_t^\alpha - p_t^\alpha c_{i,t} + \frac{T_{i,t}}{P_t^A}
\end{pmatrix} dt + \begin{pmatrix}
0 \\
\sigma(z_{i,t})
\end{pmatrix} dB_t.
$$

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

$$
\rho v_{i,t}(x_{i,t}) = \partial_t v_{i,t}(x_{i,t}) + \max_{c_{i,t},n_{i,t}} u(c_{i,t}, n_{i,t}) + \theta_i \left( v_{-i,t}(x_{-i,t}) - v_{i,t}(x_{i,t}) \right)
$$

$$
+ \partial_a v_{i,t}(x_{i,t}) \left( r_t a_{i,t} + \alpha \sum_s z_{i,t}^s n_{i,t}^s w_{i,t}^s p_t^\alpha - p_t^\alpha c_{i,t} + \frac{T_{i,t}}{P_t^A} \right)
$$

$$
+ \mu(z_{i,t}) \partial_z v_{i,t}(x_{i,t}) + \frac{1}{2} \sigma(z_{i,t})^2 \partial_{zz} v_{i,t}(x_{i,t})
$$

- FOCs:

$$
c_{i,t}^{-\gamma} = p_t^\alpha \partial_a v_{i,t}(x_{i,t})
$$

$$
c_{i,t}^\gamma (n_{i,t}^s)^\phi = z_{i,t}^s w_{i,t}^s.
$$
The Taylor rule

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

\[ i_t = i^*_t + \sum_s \left( \phi^s_{\pi} \pi_t^s + \phi^s_y (Y_t^s - Y) \right) + \xi_t, \]  

(1)
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

$$
\begin{align*}
\partial_t g_{i,t}(x_{i,t}) &= - \partial_a \left( [r_t a_{i,t} + \sum_s z_{s,i,t} n_{s,i,t} w_{s,i,t} p_t^\alpha - p_t^\alpha c_{i,t} + \frac{T_{i,t}}{P_t^A}] g_{i,t}(x_{i,t}) \right) \\
&\quad - \partial_z \left( \mu(z_{i,t}^s) g_{i,t}(x_{i,t}) \right) + \frac{1}{2} \partial_{zz} \left( \sigma(z_{i,t}^s)^2 g_{i,t}(x_{i,t}) \right) \\
&\quad - \theta_i g_{i,t}(x_{i,t}) + \theta_{-i} g_{-i,t}(x_{-i,t}).
\end{align*}
$$
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:

\[
C_{C,0} \left( \{ r_t, w_{C,t}, p_{C,t}, T_{C,t} \}_{t \in [0, \infty)}, g_0 \right) = \int_0^\infty \int_0^\infty c_C (a, z, \{ r_t, w_{C,t}, p_t, T_{C,t} \}_{t \in [0, \infty)}) \ g_0 \ d(z, a)
\]

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