Monetary Policy, Markup Dispersion, and Aggregate TFP

Matthias Meier and Timo Reinelt

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Motivation

What is the transmission mechanism of monetary policy?

Rigid prices are central in the workhorse New Keynesian model

Monetary transmission under heterogeneity in price rigidity?

Empirical evidence: Bils/Klenow (04), Nakamura/Steinsson (08), Gorodnichenko/Weber (16), ...
Model dynamics: Carvalho (06), Nakamura/Steinsson (10), Pasten/Schoenle/Weber (19), ...
Optimal monetary policy: Aoki (01), Eusepi/Hobijn/Tambalotti (11), ...
A novel mechanism

Initial condition

\[ \rightarrow \text{firms with more rigid prices set higher markups} \]

\[ (\text{this can be optimal in the NK model}) \]

Contractionary monetary policy shock

\[ \rightarrow \text{lowers marginal cost} \]

\[ \rightarrow \text{increases markup dispersion} \]

\[ \rightarrow \text{lower aggregate TFP} \]
Empirical and quantitative findings

Empirical evidence

- Firms with more rigid prices have higher markups
- MP shocks raise markup dispersion across firms
- Aggregate TFP falls by 0.5% two years after 1sd MP shock
  Response of markup dispersion can account for TFP response

New Keynesian model with heterogeneous price rigidity

- Explains half of peak response in markup dispersion
Related literature

Monetary policy and heterogeneous price rigidity
Carvalho (06), Gorodnichenko/Weber (16), Pasten/Schoenle/Weber (18), Clayton/Jaravel/Schaab (18), Baqae/Farhi (17), ...

- This paper: precautionary price setting

Aggregate productivity response to MP shocks
Evans/Santos (02), Christiano/Eichenbaum/Evans (05), Moran/Queralto (18), Garga/Singh (19), Jorda/Singh/Taylor (19), ...

- This paper: allocative efficiency

Allocative efficiency over the business cycle
Eisfeldt/Rampini (06), Bloom (09), Khan/Thomas (13), Ascari/Sbordone (14), Meier (18), ...

- This paper: evidence on response to business cycle shock
Introduction

Mechanism

Empirical evidence

New Keynesian model

Conclusion
Price-setting problem (under CES preferences and CRS technology)

\[
\max_{\{P_{it+j}\}_{j=0}^T} \mathbb{E}_t \sum_{j=0}^T \beta^t \left[ \left( \frac{P_{it+j}}{P_{t+j}} - W_{t+j} \right) \left( \frac{P_{it+j}}{P_{t+j}} \right)^{-\eta} Y_{t+j} \right] - \text{adjustment cost}_{it+j}
\]

→ profits fall more rapidly for low prices than for high prices:
precautionary motive to set higher markups
Environment

Price-setting problem (under CES preferences and CRS technology)

\[
\max_{\{P_{it+j}\}_{j=0}^T} \mathbb{E}_t \sum_{j=0}^T \beta^t \left[ \left( \frac{P_{it+j}}{P_{t+j}} - W_{t+j} \right) \left( \frac{P_{it+j}}{P_{t+j}} \right)^{-\eta} - y_{t+j} - \text{adjustment cost}_{it+j} \right]
\]

→ profits fall more rapidly for low prices than for high prices: 
precautionary motive to set higher markups

Aggregate prices and demand \((P_t, W_t, Y_t)\) follow a joint log-normal process that is iid in levels or growth rates
Summary of main theoretical results

Suppose firms face different Calvo or Rotemberg frictions

- Under weak conditions, firms set markups $\mu_{it}^* > \eta/(\eta - 1)$, and markups $\mu_{it}^*$ decrease in price adjustment frequency.

- Similar for Rotemberg friction.
Summary of main theoretical results

Suppose firms face different Calvo or Rotemberg frictions

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- Similar for Rotemberg friction

Markup dispersion increases in marginal costs if firms with higher markups have lower pass-through from marginal costs to price.
Summary of main theoretical results

Suppose firms face different Calvo or Rotemberg frictions

- Under weak conditions, firms set markups $\mu^*_{it} > \eta/(\eta - 1)$, and markups $\mu^*_{it}$ decrease in price adjustment frequency.
- Similar for Rotemberg friction.

Markup dispersion increases in marginal costs if firms with higher markups have lower pass-through from marginal costs to price.

Aggregate TFP decreases in markup dispersion (see Hsieh/Klenow 09, Baqae/Farhi 19).

All details are provided in the paper: see Propositions 1-3.
Testable implications

1. Firms that adjust prices less frequently have higher markups
2. Markup dispersion increases after MP shocks
3. Markups respond more for firms that adjust prices less frequently
4. Aggregate TFP falls after MP shocks
Introduction

Mechanism

**Empirical evidence**

New Keynesian model

Conclusion
Measuring markups and price rigidity

Markups can be estimated as

\[ \mu = \frac{\text{output elasticity of } X}{\text{revenue share of } X} \]

assuming cost minimization with flexible factor \( X \)  (De Loecker/Warzynski 12)
Measuring markups and price rigidity

Markups can be estimated as

\[ \mu = \frac{\text{output elasticity of } X}{\text{revenue share of } X} \]

- Quarterly firm-level Compustat balance sheet data

output elasticity_{it} = \begin{cases} 
\text{Cost share}_{st} \\
\text{Translog elasticity}_{it} \\
\text{Cobb Douglas elasticity}_{st} 
\end{cases}

revenue share_{it} = \frac{\text{Costs of goods sold}_{it}}{\text{Sales}_{it}}

De Loecker/Eeckhout/Unger (19)
Measuring markups and price rigidity

Markups can be estimated as

\[ \mu = \frac{\text{output elasticity of } X}{\text{revenue share of } X} \]

- Quarterly firm-level Compustat balance sheet data

Price adjustment frequency constructed from

- Five-digit sector-level averages from PPI micro data
  Pasten/Weber/Schoenle (19)
- Firm-level sales composition across sectors using Compustat segment files
Firms with more rigid prices have higher markups

<table>
<thead>
<tr>
<th></th>
<th>log(Markup)</th>
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<tbody>
<tr>
<td>Price adjustment frequency</td>
<td>-0.499 (0.003)</td>
</tr>
<tr>
<td></td>
<td>-0.347 (0.004)</td>
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<tr>
<td></td>
<td>-0.069 (0.008)</td>
</tr>
<tr>
<td>Implied price duration</td>
<td>0.080 (0.001)</td>
</tr>
<tr>
<td></td>
<td>0.054 (0.001)</td>
</tr>
<tr>
<td></td>
<td>0.015 (0.001)</td>
</tr>
<tr>
<td>Two-digit industry FE</td>
<td>N</td>
</tr>
<tr>
<td>Four-digit industry FE</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

Separate regressions of log markups on price adjustment frequency and implied price duration from 2005 until 2011. Robust standard errors in parentheses.
Identification of dynamic effects

**MP shocks** constructed as high-frequency changes in the 3-months ahead federal funds future price around FOMC announcements

Kuttner (01), Gertler/Karadi (15), Gorodnichenko/Weber (16), ...

\[ \varepsilon_{MP}^{T} = f_{T+20 \text{ min.}} - f_{T-10 \text{ min.}} \]

Time series of shocks: 1995Q1–2018Q3

Estimate local projections

\[ y_{t+h} - y_{t-1} = \alpha^h + \beta^h \varepsilon_{t}^{MP} + \gamma^h Z_{t-1} + u_t^h \]

where \( \beta^h \) are the impulse responses at horizon \( h = 0, \ldots, 16 \)
2. MP shock raises **markup dispersion**

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Markups of rigid-price firms increase by more

\[ y_{it+h} - y_{it-1} = \alpha_t^h + B^h Z_{it-1} \epsilon_{t, MP} + \Gamma^h Z_{it-1} + u_{it}^h, \]

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Aggregate TFP falls and GDP falls

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Imputed aggregate TFP response

Using $\Delta TFP_t = -\frac{\eta}{2} \Delta V_t (\log \mu_{it})$ with $\eta = 6$ closely matches the (utilization-adjusted) TFP response:
Robustness

Monetary policy shocks

- Alternative future prices
- News/information component
- Unconventional MP

Compustat: data treatment, delisting

Alternative explanations for the TFP decline
Introduction

Mechanism

Empirical evidence

New Keynesian model

Conclusion
New Keynesian model with heterogeneous price rigidity

Model setup

- 1 sector, rep. household, CES preferences, CRS technology
- Taylor rule

\[ R_t = R_{t-1}^{\rho_r} \left[ \frac{1}{\beta} \left( \frac{P_t}{P_{t-1}} \right)^{\phi_{\pi}} \left( \frac{Y_t}{\tilde{Y}_t} \right)^{\phi_y} \right]^{1-\rho_r} \exp\{\nu_t\}, \quad \nu_t \sim \mathcal{N}(0, \sigma^2_{\nu}) \]

- **Heterogeneous Calvo friction**: half of firms adjust always, half of firms adjust with 1/8 quarterly reset probability
New Keynesian model with heterogeneous price rigidity

Model calibration

- Target *relative* labor response to MP shock
- Target federal funds rate response to MP shock
- More details

Model solution

- To capture precautionary price-setting motive, requires (at least) third-order approximation
- Use Meyer-Gohde (15) algorithm

Stochastic steady state: sticky-price firms set 5% higher markup
Nominal rate

Aggregate TFP

GDP

Average markups
What is natural output?

If monetary authority (mis)perceives endogeneous TFP responses as exogeneous productivity shocks, the std. of GDP is 10% higher

*solid line: baseline natural output; dashed line: misperceived natural output*
Why not a standard New Keynesian model?

Standard NK models with homogeneous price rigidity

- Markup dispersion is zero at the steady state
- First-order approximation: unchanged markup dispersion
- Second-order approximation: increased markup dispersion after positive and negative shocks

NK model with trend inflation and homogeneous price rigidity

- Markup dispersion *decreases* after contractionary MP shock

Ascari/Sbordone (14)
Introduction

Mechanism

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Conclusion

Heterogeneity in price rigidity matters for monetary transmission

→ quantitatively relevant misallocation channel of monetary policy

Our contributions

- characterize novel mechanism
- provide novel empirical evidence in its support
- study quantitative relevance in New Keynesian model
Thank you!
Aggregate productivity

Solow’s (57) residual

\[ TFP_t = \log Y_t - w_t \log K_t - (1 - w_t) \log L_t, \quad w_t = \frac{R_t K_t}{P_t Y_t} \]

- We use Fernald’s (14) aggregate TFP
- and utilization-adjusted aggregate TFP: \( TFP_{t}^{\text{util}} = TFP_t - u_t \)
- and aggregate labor productivity
Measured aggregate productivity

Aggregate productivity at quarterly frequency. TFP and utilization-adjusted TFP are from Fernald (2014), labor productivity is real output per hour in the nonfarm business sector. Markup adjustment is based on Hall (1986) using markup estimates from De Loecker et al. (2018). Shaded gray areas indicate NBER recession dates.
Response of aggregate output

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Response of aggregate inputs

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Interest rate response

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Firms with more rigid prices have higher markups (translog)

<table>
<thead>
<tr>
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<th>log(Markup)</th>
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<tbody>
<tr>
<td>Price adjustment frequency</td>
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Separate regressions of log markups on price adjustment frequency and implied price duration from 2005 until 2011. Robust standard errors in parentheses.
MP shock raises markup dispersion (translog)

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Cross-sectional variance of log markup in Compustat data at quarterly frequency. Four- and two-digit industry-quarter fixed effects are removed, respectively. Shaded gray areas indicate NBER recession dates.
Cross-sectional variance of log markup in Compustat data at quarterly frequency. Four- and two-digit industry-quarter fixed effects are removed, respectively. Shaded gray areas indicate NBER recession dates.
Markups of rigid-price firms increase by more (translog)

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.

Interaction with price adjustment frequency
Interaction with implied price duration (inverted)

Meier and Reinelt (Mannheim): Monetary Policy, Markup Dispersion, and Aggregate TFP 10/34
Monetary policy shocks at quarterly frequency. Shaded gray areas indicate NBER recession dates.
Monetary policy shocks II

Monetary policy shocks at quarterly frequency. Shaded gray areas indicate NBER recession dates.
TFP response for alternative monetary policy shocks

Robustness
Utilization-adjusted TFP response for alternative monetary policy shocks I

- Three-month Fed funds future surprises
- Current-month Fed funds future surprises
- ’Policy indicator’ of 0m/3m/2q/3q/4q-future surprises
TFP response for alternative monetary policy shocks II

Robustness

Meier and Reinelt (Mannheim): Monetary Policy, Markup Dispersion, and Aggregate TFP
Utilization-adjusted TFP response for alternative monetary policy shocks II

Three-month Fed funds future surprises
Purged of Greenbook forecasts
Sign-restricted stock market comovement
Unscheduled meetings and conference calls included
QE announcements excluded
Markup dispersion (2d) response for alternative monetary policy shocks I

Three-month Fed funds future surprises
'Policy indicator' of 0m/3m/2q/3q/4q-future surprises
Markup dispersion (4d) response for alternative monetary policy shocks I

-0.001
0
0.001
0.002
0.003

0 4 8 12 16

Quarters since shock

Three-month Fed funds future surprises
'Policy indicator' of 0m/3m/2q/3q/4q-future surprises
Markup dispersion (2d) response for alternative monetary policy shocks II

![Graph showing markup dispersion response to alternative monetary policy shocks. The graph includes lines for three-month Fed funds future surprises, purged of Greenbook forecasts, sign-restricted stock market comovement, unscheduled meetings and conference calls included, and QE announcements excluded. The x-axis represents quarters since shock, and the y-axis displays the dispersion response.](image-url)
Markup dispersion (4d) response for alternative monetary policy shocks II

- Three-month Fed funds future surprises
- Purged of Greenbook forecasts
- Sign-restricted stock market comovement
- Unscheduled meetings and conference calls included
- QE announcements excluded
Data treatments: keep firms with sales below 1 mln.

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.

Robustness
Data treatments: keep firms sales growth below -67% or above 100%

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.

Robustness
Data treatments: keep top/bottom 5% of markup observations

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Data treatments: keep Great Recession periods

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Data treatments: 16 consecutive quarters

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Number of firms over time

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.

Robustness
Response of number of firms to shock

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
R&D response

Solid/dashed line: response to a one standard deviation MP shock (increases FFR by up to 30 bp). Shaded area/dotted line: Newey-West one-standard error bands.
Parametrization

Utility function: \( \log(C_t) - N_t^{1+\varphi} / (1 + \varphi) \)

<table>
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<th>Parameter</th>
<th>Value</th>
<th>Target/Source</th>
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<td>Discount factor</td>
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<tr>
<td>Substitution elasticity</td>
<td>( \eta )</td>
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</tr>
<tr>
<td>Calvo Parameter 1</td>
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<tr>
<td>Calvo Parameter 2</td>
<td>( \theta_2 )</td>
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</tr>
<tr>
<td>Taylor rule output coefficient</td>
<td>( \phi_y )</td>
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</tr>
<tr>
<td>Taylor rule inflation coefficient</td>
<td>( \phi_\pi )</td>
<td>0.05</td>
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<tr>
<td>Inverse Frisch elasticity</td>
<td>( \varphi )</td>
<td>1/0.125</td>
</tr>
<tr>
<td>MP shock variance</td>
<td>( \sigma_\nu )</td>
<td>0.58%</td>
</tr>
</tbody>
</table>
Aggregate productivity shock

(a) Nominal rate

(b) Aggregate TFP

(c) GDP

(d) Markups
Precautionary price setting with Calvo

Heterogeneous Calvo (83) price adjustment probability $1 - \theta_i \in (0, 1)$

**Proposition 1 (precautionary price setting)**

If $P_t = \bar{P}$, $W_t = \bar{W}$, and

$$(\eta - 1)\sigma_p^2 + \sigma_{py} + \eta \sigma_{pw} + \sigma_{wy} > 0,$$

then the firm **optimally sets a higher markup** ($\mu_{it} \equiv P_{it}/W_{it}$) than statically optimal, and the markup further increases in $\theta_i$,

$$\mu_{it}^* > \frac{\eta}{\eta - 1}, \quad \text{and} \quad \frac{\partial \mu_{it}^*}{\partial \theta_i} > 0.$$
Response of markup dispersion

Pass-through from real marginal costs to price: $\varepsilon_{it} \equiv \frac{d \log P_{it}}{d \log W_t}$

Proposition 2 (markup dispersion)

Suppose $\text{corr}(\log \mu_{it}, \varepsilon_{it}) < 0$ [satisfied under Proposition 1]. Then markup dispersion decreases in real marginal costs

$$\frac{\partial \nabla_t [\log \mu_{it}]}{\partial \log W_t} < 0.$$
Consider quadratic Rotemberg (1982) price adjustment costs, parametrized by a \textit{firm-specific} cost shifter $\phi_i \geq 0$

Similar to Calvo, we provide (weak) conditions under which firm-level heterogeneity in $\phi_i$ generates a negative correlation between markups and pass-through corr($\log \mu_{it}, \varepsilon_{it}$) < 0
Markup dispersion and aggregate TFP

Aggregate output = CES aggregator

Aggregate TFP = Solow residual

2nd-order approx. of aggr. TFP around \( \log \mu_{it} = \log \frac{\eta}{\eta-1} \):

\[
\text{TFP}_t \approx -\frac{\eta}{2} \nabla_t [\log \mu_{it}] + \text{aggregate exogenous productivity}
\]

(see Hsieh/Klenow 09, Baqae/Farhi 19)

→ higher markup dispersion lowers aggregate TFP