Monetary Policy, Markup Dispersion, and Aggregate TFP

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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?

Bils/Klenow (04), Nakamura/Steinsson (08), Gorodnichenko/Weber (16), Carvalho (06), Pasten/Schoenle/Weber (18), Clayton/Jaravel/Schaab (18), ...

A novel mechanism

Initial condition

$\hookrightarrow$ firms with more rigid prices optimally set higher markups

MP shock lowers marginal cost

$\hookrightarrow$ increases markup dispersion

$\hookrightarrow$ losses in allocative efficiency

$\hookrightarrow$ lower aggregate TFP & GDP

Empirical and quantitative findings

Empirical evidence

- Sectors 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

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), Baqaee/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 efficicency

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

Environment

Price-setting problem

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

$\rightarrow$ profits fall more rapidly for low markups than for high markups: precautionary motive: set higher markups when adjustment costly

Environment

Price-setting problem

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

$\rightarrow$ profits fall more rapidly for low markups than for high markups: precautionary motive: set higher markups when adjustment costly

Firms take aggregate prices and demand as given

$$\log \begin{pmatrix} P_{t+j}/\bar{P} \\ W_{t+j}/\bar{W} \\ Y_{t+j}/\bar{Y} \end{pmatrix} \sim \mathcal{N}\left(\begin{bmatrix} -\frac{\sigma_p^2}{2} \\ -\frac{\sigma_w^2}{2} \\ -\frac{\sigma_y^2}{2} \end{bmatrix}, \begin{bmatrix} \sigma_p^2 & & \\ \sigma_{pw} & \sigma_w^2 & \\ \sigma_{py} & \sigma_{wy} & \sigma_y^2 \end{bmatrix} \right)$$

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 θ_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)

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

$$\frac{\partial \mathbb{V}_t[\log \mu_{it}]}{\partial \log W_t} < 0.$$

Markup dispersion and aggregate TFP

Compute final aggregate output (Y_t) as CES aggregate of variety goods

Compute aggregate TFP as Solow residual (e.g., $\mathrm{TFP}_t = \log Y_t - \log L_t$)

2nd-order approximation around $\mu_{it} = \eta/(\eta - 1)$ yields

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

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

$\rightarrow$ Higher markup dispersion lowers aggregate TFP

$\rightarrow$ Intuition: high-μ firms produce too little, low-μ firms too much

Testable implications

1. Industries with more rigid prices have higher markups
2. Markup dispersion increases after MP shocks
3. Markups increase by more for firms with high pre-shock markups
4. Aggregate TFP falls after MP shocks

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

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

- Industry-level (s) NBER-CES manufacturing database

$$\text{output elasticity}_{st} = \frac{\text{Payroll}_{st}}{R_{st}\text{Capital stock}_{st} + \text{Payroll}_{st} + \text{Materical costs}_{st}}$$

$$\text{revenue share}_{st} = \frac{\text{Payroll}_{st}}{\text{Revenues}_{st}}$$

Measuring markups and price rigidity

Markups can be estimated as

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

- Industry-level (s) NBER-CES manufacturing database
- Quarterly firm-level (i) Compustat balance sheet data

$$\text{output elasticity}_{it} = \text{output elasticity}_{st}$$

$$\text{revenue share}_{it} = \frac{\text{Costs of goods sold}_{it}}{\text{Revenues}_{it}}$$

Measuring markups and price rigidity

Markups can be estimated as

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

- Industry-level (s) NBER-CES manufacturing database
- Quarterly firm-level (i) Compustat balance sheet data

Price rigidity: price adjustment frequency in PPI micro data

from Pasten/Weber/Schoenle (18)

① Industries with more rigid prices have higher markups

Regress average industry-level markup on average price stickiness

	Markup	
	All employees	Production workers
Price adjustment frequency	-0.1363	-0.2791
	(0.0558)	(0.0571)

Regressions of markups (in logs, averaged over 2005-2011) on price adjustment frequency, at the four-digit manufacturing level. $N = 177$. 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), ... ▸ Series

$$\varepsilon_\tau^{\text{MP}} = \text{f}_{\tau+20\text{ min.}} - \text{f}_{\tau-10\text{ min.}}$$

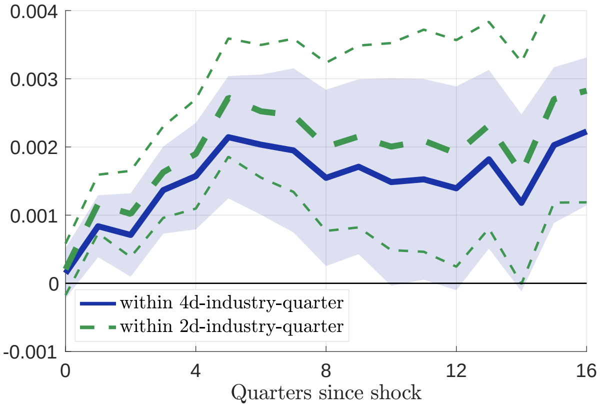
Time series of shocks: 1995Q1–2018Q3

Estimate local projections

$$y_{t+h} - y_{t-1} = \alpha^h + \beta^h \varepsilon_t^{\text{MP}} + \gamma_0^h \varepsilon_{t-1}^{\text{MP}} + \gamma_1^h (y_{t-1} - y_{t-2}) + u_t^h$$

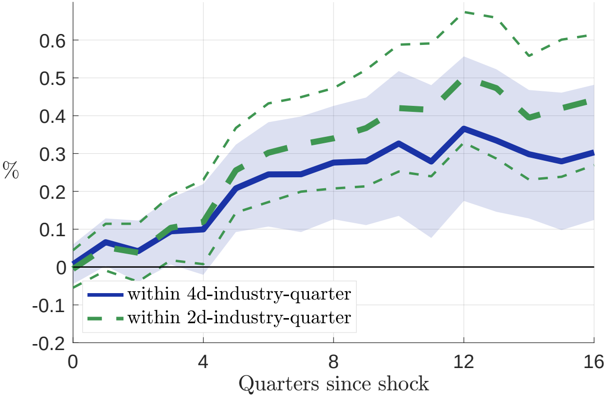
where β^h are the impulse responses at horizon $h = 0, \ldots, 16$

② MP shock raises within-industry 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. ▸ Mean

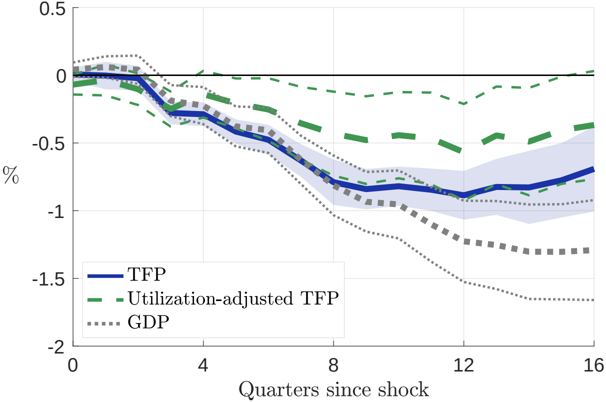
③ Markups of high-markup firms increase by more



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.

$$y_{it+h} - y_{it-1} = \alpha_t^h + B^h Z_{it-1} \varepsilon_t^{MP} + \Gamma^h Z_{it-1} + u_{it}^h,$$

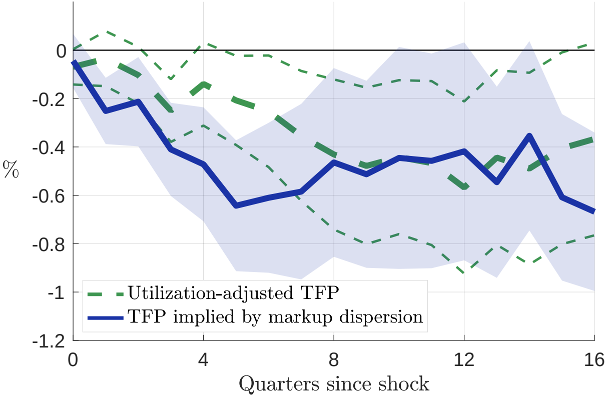
④ Aggregate TFP falls and GDP falls



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. ▸ Details ▸ More

Imputed aggregate TFP response

Using $\Delta \text{TFP}_t = -\frac{\eta}{2}\Delta \mathbb{V}_t(\log \mu_{it})$ and $\eta = 6$, we can account for most of the TFP response by the increase in markup dispersion



Robustness

Monetary policy shocks

- Alternative future prices ▷
- News component of monetary policy ▷
- Unconventional MP ▷

Computstat data (treatment, delisting) ▷

Alternative explanations for the TFP decline ▸ R&D ▸ Firm-level TFP

New Keynesian model with heterogeneous price rigidity

Model setup

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

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

- 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

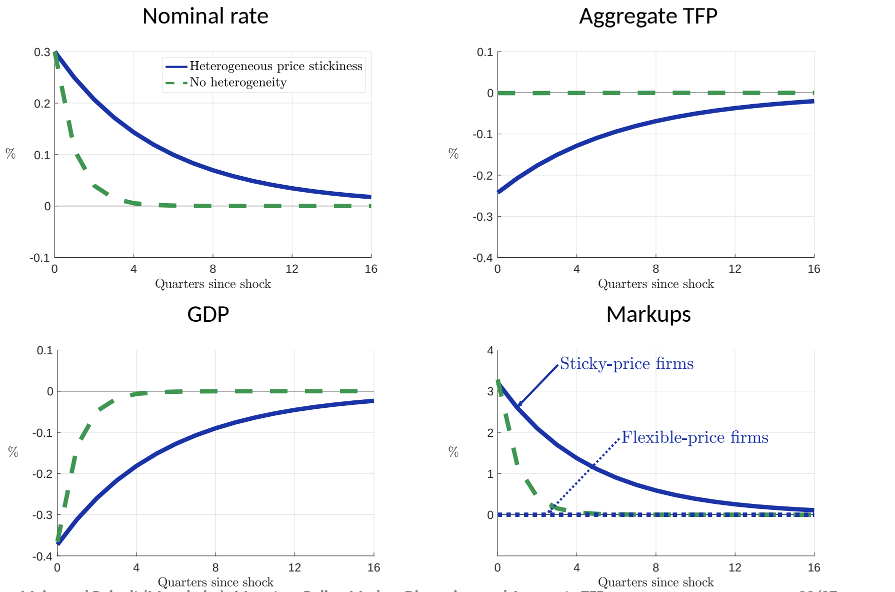
- Target *relative* labor response to MP shock
- Target federal funds rate response to MP shock
- More details Table

Model solution

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

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

MP shock lowers TFP in the model

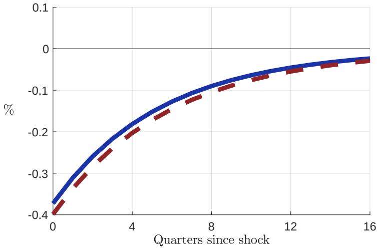


What is natural output?

Suppose the monetary authority (mis)perceives aggregate TFP responses to MP shocks for aggregate productivity shocks

The standard deviation of GDP will increase by 10%

GDP response



solid line: baseline natural output; dashed line: misperceived natural output

tfp shock

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

Conclusion

Heterogeneity in firm-level price-setting frictions important for the monetary transmission mechanism

- On average, firms with more rigid prices set higher markups
- Monetary policy shocks then increase the relative markup of firms with more rigid prices
- Higher markup dispersion, and adverse aggregate TFP response

Our contributions: provide new empirical evidence, characterize novel mechanism, study quantitative relevance in New Keynesian model

Thank you!

Markup dispersion and aggregate TFP

A simple model (Hsieh/Klenow 09, Baqaee/Farhi 19)

- CES aggregation of differentiated goods Y_i into aggregate output Y
- Y_i produced with CRS technology, marginal costs MC
- Firms monopolistically competitive and maximize profits

$$(\tau_i P_i - MC)\, Y_i \quad \text{s.t.} \quad Y_i = (P_i/P)^{-\eta} Y$$

- Markup $\mu_i = \tau_i^{-1} \frac{\eta}{\eta - 1}$, where τ_i is a markup wedge
- Aggregate TFP

$$\text{TFP} \approx -\frac{\eta}{2}\mathbb{V}[\log \mu_i] \; + \; [\text{aggregate exogenous productivity}]$$

Back

Aggregate productivity

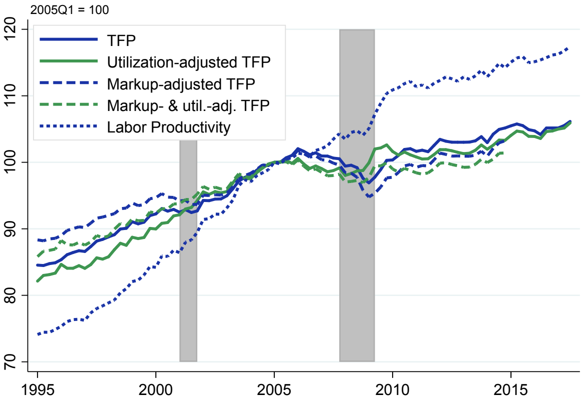
Solow's (57) residual

$$\mathrm{TFP}_t = \log Y_t - w_t \log K_t - (1 - w_t) \log L_t, \quad w_t = \frac{R_t K_t}{P_t Y_t}$$

- We use Fernald's (14) aggregate TFP
- and utilization-adjusted aggregate TFP: $\mathrm{TFP}_t^{\text{util}} = \mathrm{TFP}_t - u_t$
- and aggregate labor productivity

Back

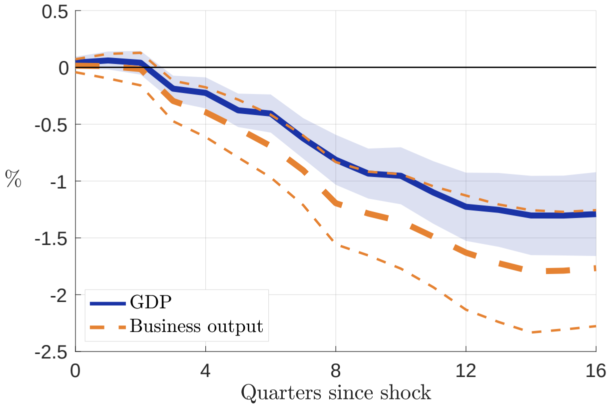
Measured aggregate productivity



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.

Back

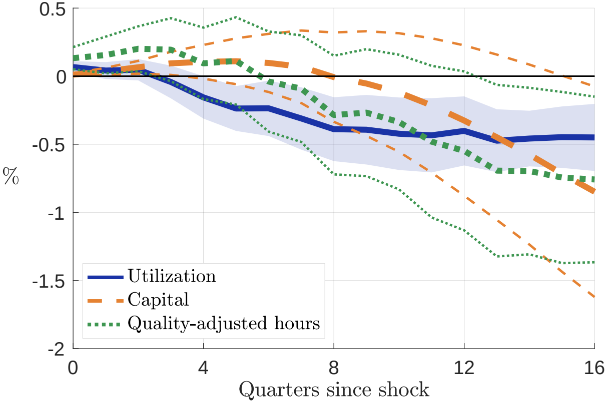
Response of aggregate output



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.

Back

Response of aggregate inputs



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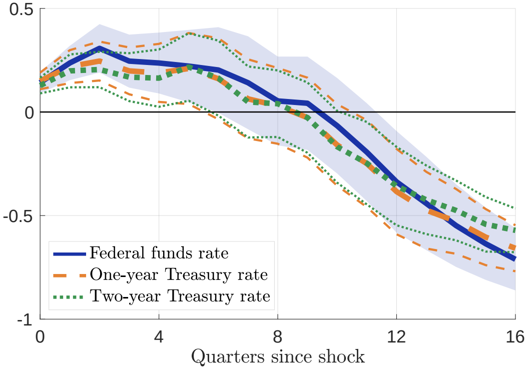
Back

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.

Back

Markups

Solow residual mis-measured if there is market power

Consider a price markup over marginal costs $\mu = \frac{P}{X}$

The labor share is then $w_\ell = \frac{WL}{PY} = \frac{1}{\mu}\frac{WL}{XY} = \frac{1}{\mu}\frac{\partial y}{\partial \ell}$

A contractionary MP shock ($\Delta a = 0$) can affect measured TFP

$$\Delta \mathrm{TFP} = \frac{\mu - 1}{\mu}(\Delta y - \Delta k)$$

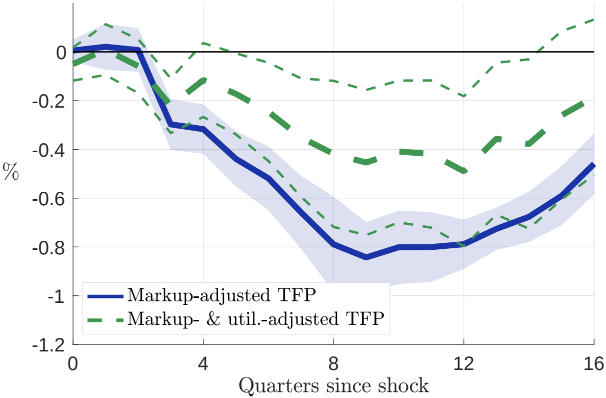
$\rightarrow$ given any markup $\mu > 1$

$\rightarrow$ amplified if markup grows

Hall (1986): $\Delta \mathrm{TFP}_{\text{markup}} = \Delta y - (1 - \mu w_\ell)\Delta k - \mu w_\ell \Delta \ell$

Back to Robustness

MP shocks lower markup-adjusted TFP



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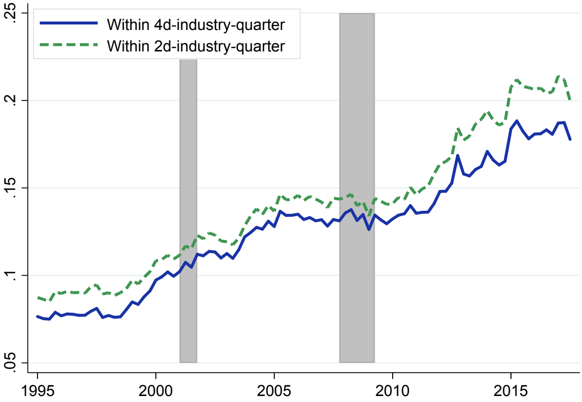
Back to Robustness

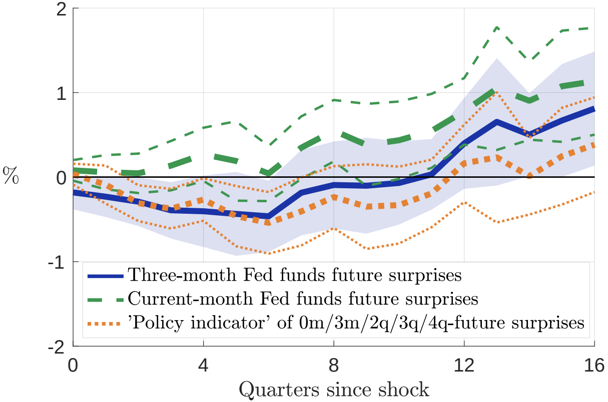
Markup dispersion



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.

Back to Measurement

Response of the mean markup



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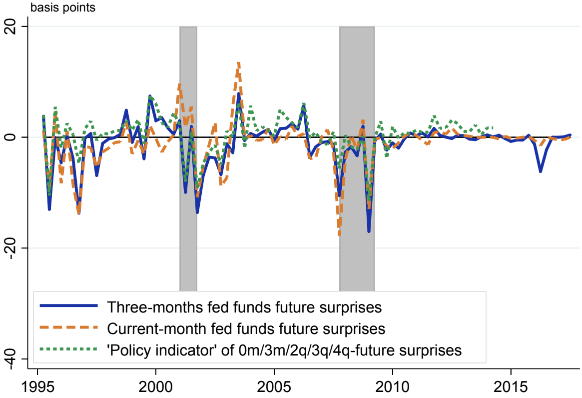
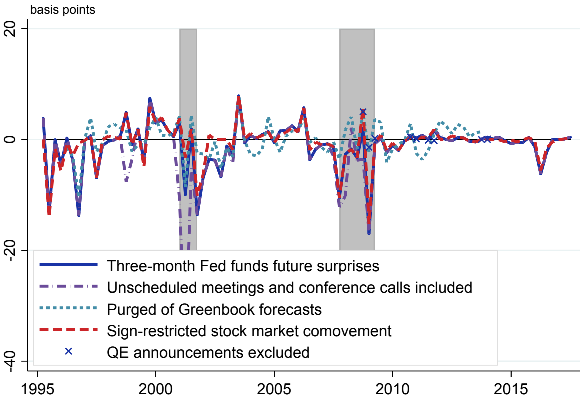
Monetary policy shocks I



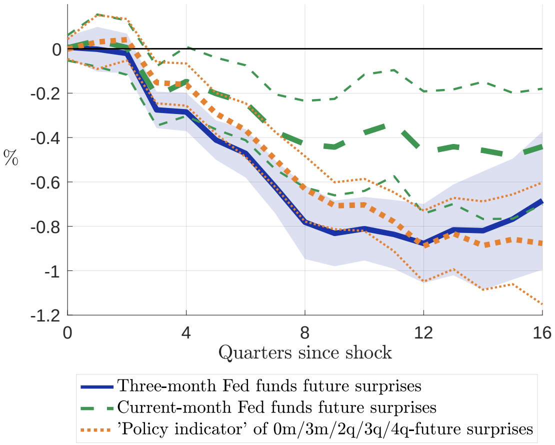
Monetary policy shocks at quarterly frequency. Shaded gray areas indicate NBER recession dates. Back to Identification

Monetary policy shocks II



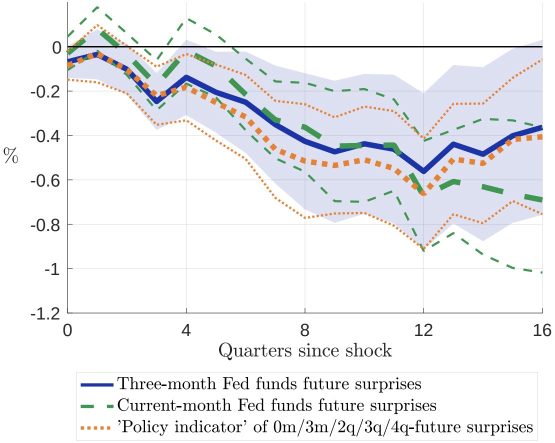
Monetary policy shocks at quarterly frequency. Shaded gray areas indicate NBER recession dates. Back to Identification

TFP response for alternative monetary policy shocks I



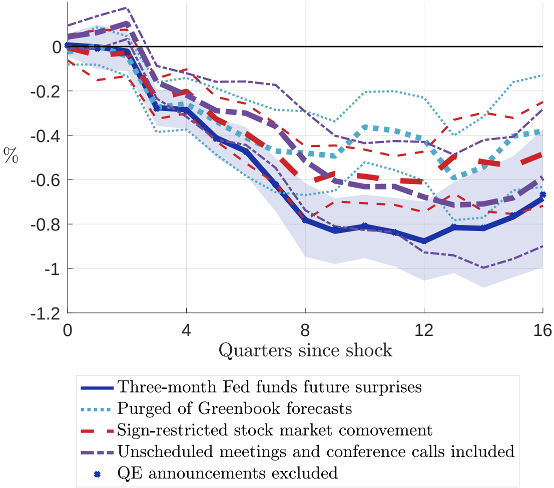
◂ Robustness

Utilization-adjusted TFP response for alternative monetary policy shocks I

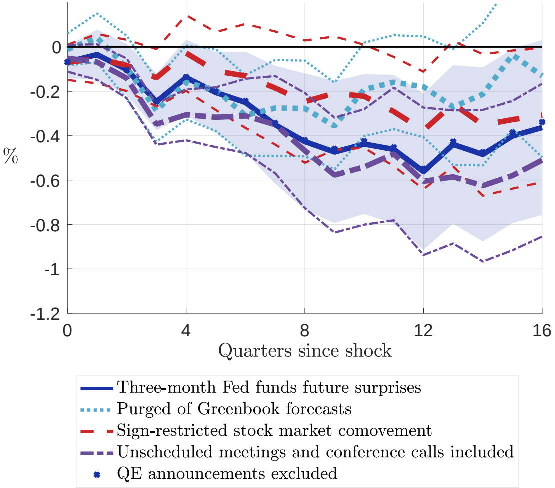


Robustness

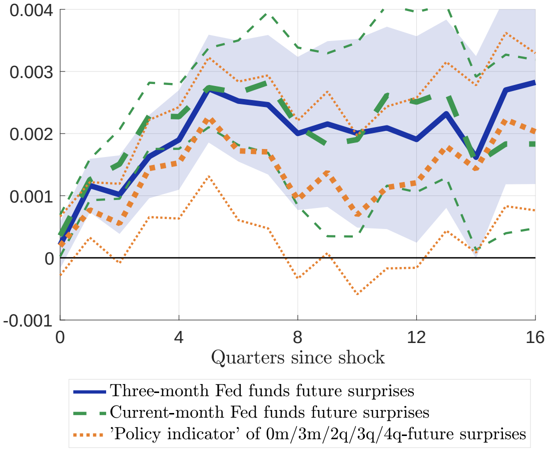
TFP response for alternative monetary policy shocks II



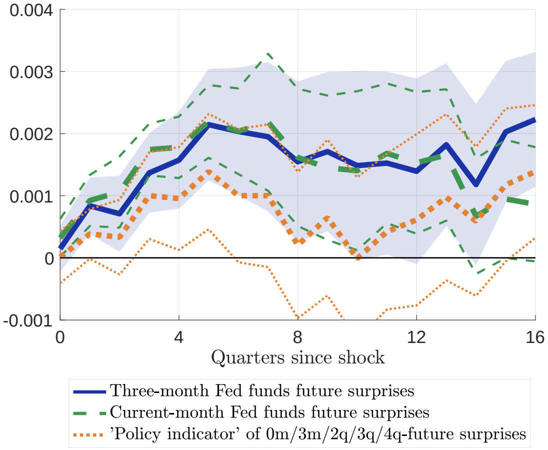
Utilization-adjusted TFP response for alternative monetary policy shocks II



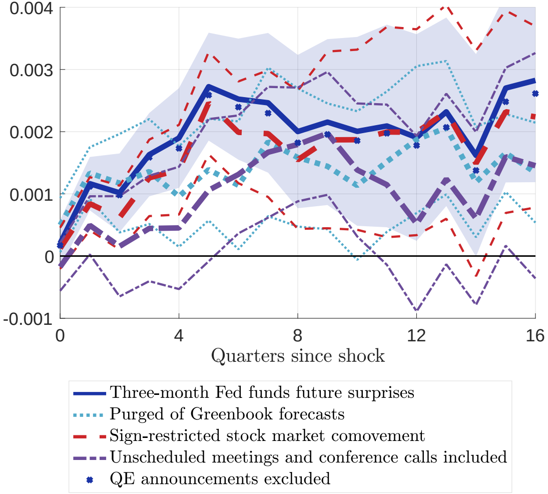
Markup dispersion (2d) response for alternative monetary policy shocks I



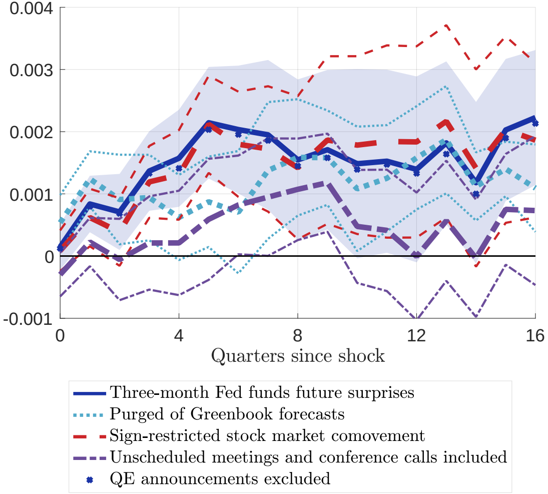
Markup dispersion (4d) response for alternative monetary policy shocks I



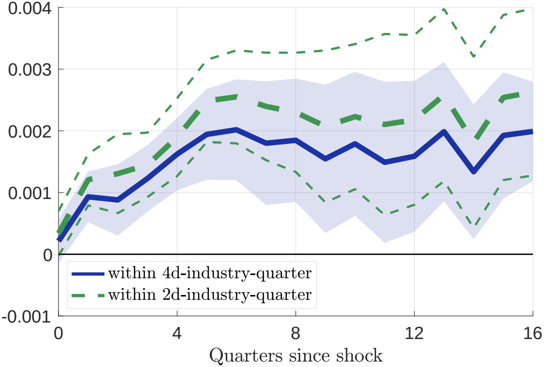
Markup dispersion (2d) response for alternative monetary policy shocks II



Markup dispersion (4d) response for alternative monetary policy shocks II



Data treatments: Drop excessive sales growth



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.

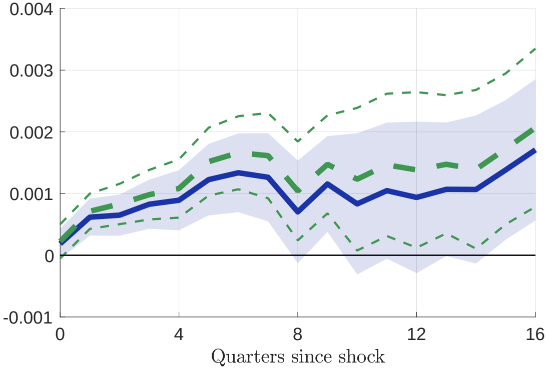
◂ Robustness

Data treatments: At least 16 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.

Robustness

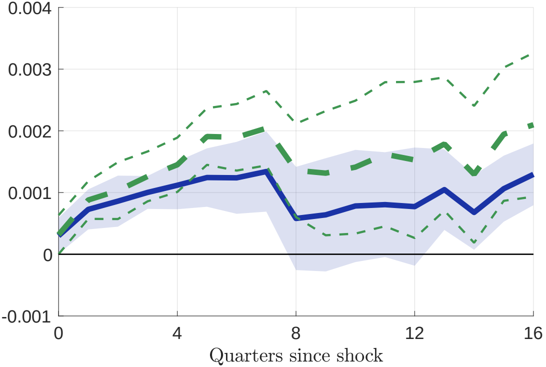
Data treatments: Drop top/bottom 5% markups



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: Drop small firms



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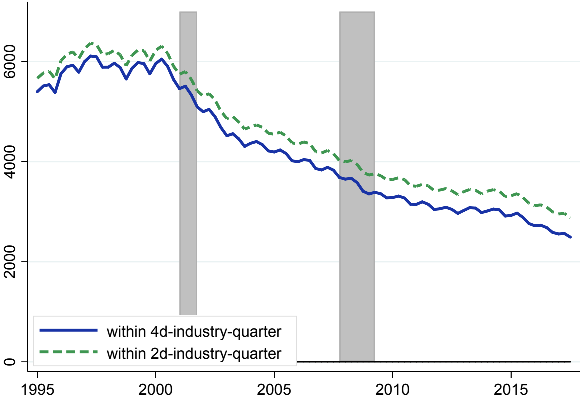
Robustness

Number of firms over time



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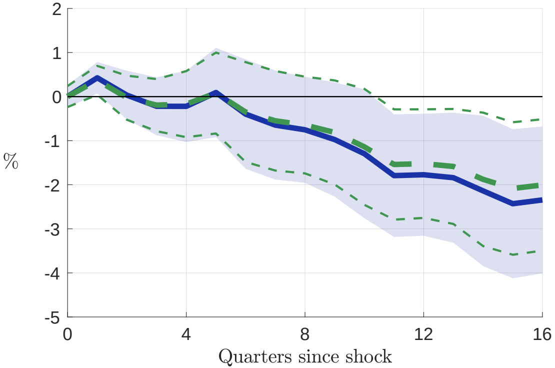
◂ Robustness

Response of number of firms to shock



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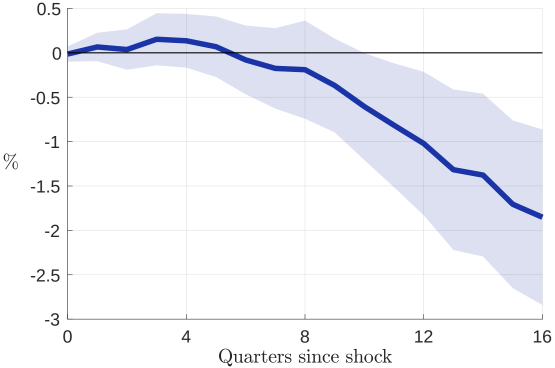
◂ Robustness

R&D response



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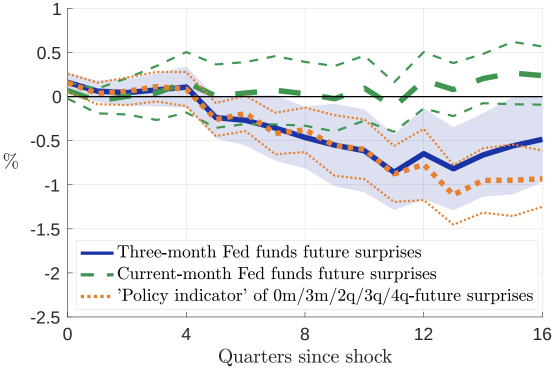
Robustness

Average firm-level TFP response



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◂ Robustness

Parametrization

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

Parameter		Value	Target/Source
Discount factor	β	0.99	Annual rate of 4%
Substitution elasticity	η	6	Christiano-Eichenbaum-Evans (05)
Calvo Parameter 1	θ_1	0	Average price adjustment
Calvo Parameter 2	θ_2	7/8	frequency of 1/4
Taylor rule output coefficient	ϕ_y	1.5	Christiano et al. (2016)
Taylor rule inflation coefficient	ϕ_π	0.05	
Inverse Frisch elasticity	φ	1/0.125	Labor response/output response
MP shock variance	σ_ν	0.58%	Interest rate response

Model

Aggregate productivity shock