Bond Market Views of the Fed

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Motivation

- Large increase in **inflation** after the pandemic. Possibly due to several "inflationary" shocks experienced (supply chain disruptions, expansionary fiscal policies, ...)

- But many observers also emphasized the changes in the Fed monetary policy framework
  - Statement on long run growth and monetary policy strategy (August 2020)
  - *"Inflation has risen, largely reflecting transitory factors"* (April-November 2021)

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- Two questions:
  1. **Did the private sector change its view on the Fed's stance on inflation?**
  2. **To what extent this shift contributed to inflation dynamics**?

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- Two questions:
  1. **Did the private sector change its view on the Fed's stance on inflation?**
  2. **To what extent this shift contributed to inflation dynamics**?
- This paper: answers these questions in two steps
  1. **Use high frequency financial market data to detect shifts in the Fed's policy**
  2. **Combine these estimates with a NK model to measure role of monetary policy**

This idea in a nutshell

Suppose the private sector thinks the monetary authority follows a Taylor rule

$$i_t = i^\star + \psi_\pi \left(\pi_t - \bar{\pi}\right) + \varepsilon_t$$

This idea in a nutshell

Taking expectations in year $k > t$, and using $\mathbb{E}_t[\varepsilon_k] = 0$, we have

$$\mathbb{E}_t[i_k] = c + \psi_\pi \mathbb{E}_t[\pi_k]$$

This idea in a nutshell

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- From bond market prices we obtain daily data on $\mathbb{E}_t[i_k]$ and $\mathbb{E}_t[\pi_k]$
- With expectations data vs. actual realizations
  - Have information even at ZLB
  - Time variation of $\{\psi_{\pi,k}\}_{k \geq t}$
- **Do we see a reduction in ψ_π after 2020?**
- **Findings**: significant and **sizable reduction in ψ_π** post 2020

Counterfactual analysis

- Estimate benchmark NK model with
  - Supply, demand and monetary policy shocks
  - Markov-Switching regimes about monetary policy rule ("Hawk" vs. "Dove")
  - **Parameters of the Dovish regime chosen to replicate high-frequency evidence**
- Model accounts for the rise in inflation through the interactions of
  - **Large supply shocks**
  - **Less responsive monetary authority**
- Counterfactual: what if there was no shift in the monetary policy rule?
  - **Inflation would have have peaked at 5% (instead of 9%)**

Literature

- Estimation of monetary policy rules: Clarida, Gali and Gertler (2000), De Bortoli, Gali and Gambetti (2020), Hamilton, Pruitt and Borger (2011), Bauer, Pflueger and Sunderam (2022), King and Lu (2022)
  - We exploit high-frequency identification to test for a shift in the monetary policy rule
- High-frequency identification of monetary shocks: Kuttner (2001), Piazzesi and Swanson (2008), Gertler and Karadi (2015), Nakamura and Steinsson (2018), Bauer and Swansson (2023)
  - We use monetary events to identify shifts in the policy rule (rather than effects of shocks)
- Drivers of recent spikes in inflation: Gagliardoni and Gertler (2023), Comin, Johnson and Jones (2023), Ferrante, Graves and Iacoviello (2023), Doh and Yang (2023), Bianchi, Faccini, and Melosi (2023).
  - We detect shift in policy rule and assess the impact on recent inflation dynamics
- Macro effects of regime shifts in monetary policy: Bianchi (2013), Bianchi and Ilut (2017), Bianchi, Lettau and Ludvigson (2022), Bianchi, Ludvigson and Ma (2023)

Outline

The data

- Daily data on nominal and real (TIPS) yields on zero-coupon bonds (ZCBs) from Gurkaynak, Sack and Wright (2007, 2008). Main sample: 2000-2022

- Yields on ZCBs maturing in year $t+k$ are linked to the expected average short term rate between now and year $t+k$ (risk-neutral measure)

$$i_t^{(k)} = \mathbb{E}_t^{\mathcal{Q}}\left[\frac{1}{k}\sum_{i=0}^{k-1} i_{t+i}^{(1)}\right] = \mathbb{E}_t\left[\bar{i}_k\right] + \text{term premium}_t^{(k)}$$

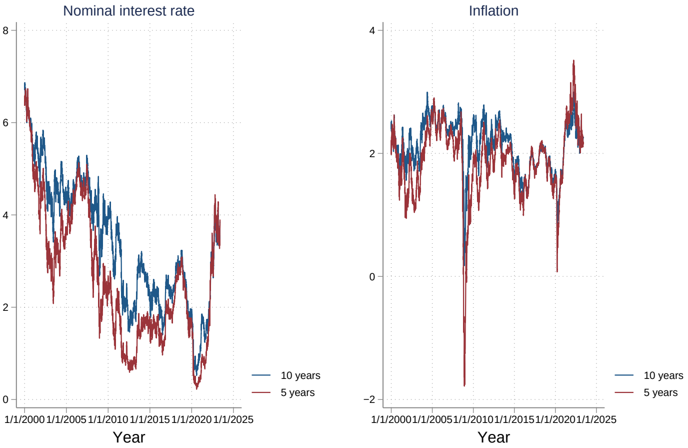
- Using the inflation compensation (difference in yields between a nominal bond and a corresponding TIPS), we can obtain expected average inflation

$$IC_t^{(k)} = i_t^{(k)} - r_t^{(k)} = \mathbb{E}_t^{\mathcal{Q}}\left[\frac{1}{k}\sum_{i=1}^{k} \pi_{t+i}\right] = \mathbb{E}_t\left[\bar{\pi}_k\right] + \text{inflation risk premium}_t^{(k)}$$

- Use different maturities to obtain forward rates. E.g. expected inflation in year k is

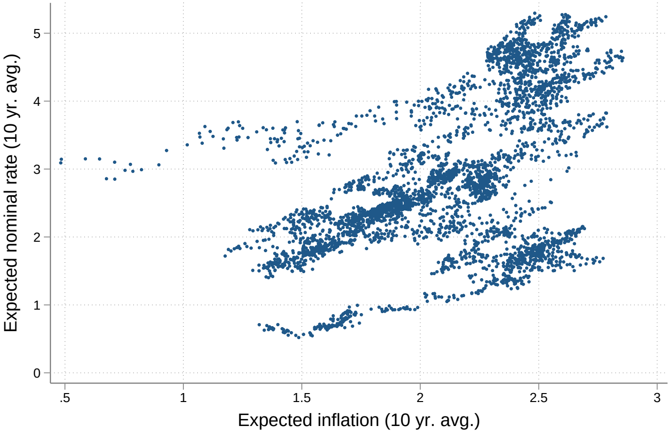
$$\mathbb{E}_t^{Q}\left[\pi_k\right] = (k-t) \times \mathbb{E}_t^{Q}\left[\bar{\pi}_k\right] - (k-1-t) \times \mathbb{E}_t^{Q}\left[\bar{\pi}_{k-1}\right]$$

The time path of risk-neutral expectations



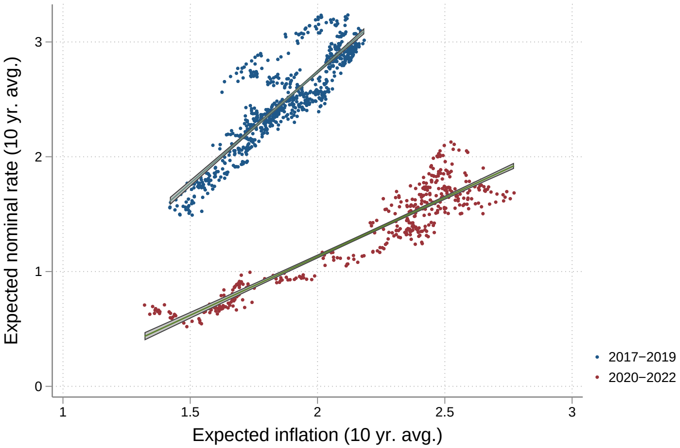
- Liquidity premium during financial crises (TIPS not as liquid as treasuries). We exclude 2008 and 2020:M1-2020:M6 from the sample

Correlation patterns



- Positive but weak ($R^2 = 0.13$) relation between expected $\mathbb{E}_t^Q\left[\,\bar{i}_k\,\right]$ and $\mathbb{E}_t^Q\left[\,\bar{\pi}_k\,\right]$

Correlation patterns



- Much **stronger relation** ($R^2 \approx 0.9$) if we condition on sub-samples
- Important to control for time-variation in the **intercept** and **slope**

Outline

1 The data

2 Conceptual framework and empirical analysis

3 Conterfactual analysis

Conceptual framework

Suppose conduct of monetary policy described by a Taylor rule. In year k we have

$$i_k = \rho_i i_{k-1} + (1 - \rho_i)\left\{i_k^\star + \psi_\pi\left(\pi_k - \bar{\pi}\right)\right\} + \varepsilon_{m,k}$$

Conceptual framework

Taking expectations at date t, this becomes

$$\mathbb{E}_t[i_k - \rho_i i_{k-1}] = (1 - \rho_i)\left\{\mathbb{E}_t[i_k^\star] + \psi_\pi \mathbb{E}_t[\pi_k - \bar{\pi}]\right\} + \mathbb{E}_t[\varepsilon_{m,k}]$$

Conceptual framework

Taking first differences wrt t (E.g., $\Delta\mathbb{E}_t[x_k] = \mathbb{E}_t[x_k] - \mathbb{E}_{t-1}[x_k]$), we obtain

$$\Delta\mathbb{E}_t[i_k - \rho_i i_{k-1}] = (1-\rho_i)\Delta\mathbb{E}_t[i_k^\star] + (1-\rho_i)\psi_\pi\Delta\mathbb{E}_t[\pi_k] + \Delta\mathbb{E}_t[\varepsilon_{m,k}]$$

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Assume

- Daily innovations about the "neutral rate" $i_k^\star$ are negligible, $\Delta\mathbb{E}_t[i_k^\star] \approx 0$
- Forecast revisions of future monetary policy shocks are small, $\Delta\mathbb{E}_t[\varepsilon_{m,k}] \approx 0$

Empirical specification

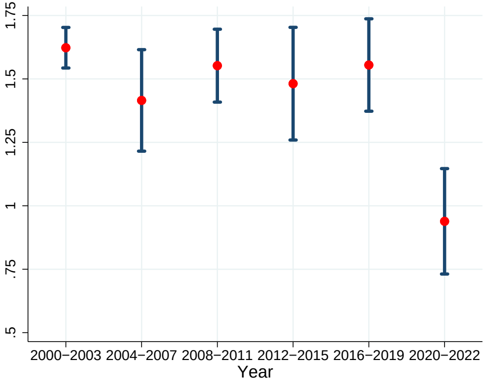
Up to ρ_i, we can estimate the following relation with OLS

$$\Delta\mathbb{E}_t[\,\bar{i}_k - \rho_i \bar{i}_{k-1}\,] = \psi_\pi \Delta\mathbb{E}_t[(1-\rho_i)\bar{\pi}_k] + \eta_t$$

- Fix $\rho_i = 0.8$ (annual), consistent with structural estimates of Taylor rule
- Assume $\Delta\mathbb{E}_t^Q\left[\bar{i}_k\right] \approx \Delta\mathbb{E}_t\left[\bar{i}_k\right]$ and $\Delta\mathbb{E}_t^Q\left[\bar{\pi}_k\right] \approx \Delta\mathbb{E}_t\left[\bar{\pi}_k\right]$ and use daily changes
- Test for a structural break by estimating ψ_π across subsamples
- Baseline: expected average inflation and nominal rate over the next 10 years
- Split average over the next 10 years into two
  - Expectation over the next 5 years
  - Expectation between 6 and 10 years from now

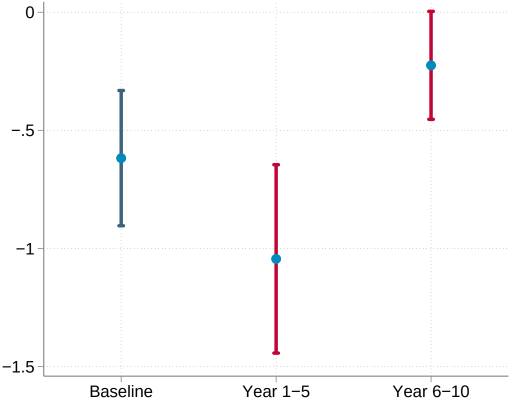
Estimating ψ_π across sub-samples

$$\Delta\mathbb{E}_t[\,\bar{i}_k - \rho_i \bar{i}_{k-1}\,] = \psi_\pi \Delta\mathbb{E}_t[(1-\rho_i)\bar{\pi}_k] + \eta_t$$



$\hat{\psi}_\pi^{\text{OLS}}$ remarkably **stable between 2000-2019**, **drops significantly in 2020-2022**

Short vs long-run expectations



- Evidence stronger for shorter maturities
- Consistent with the policy shift being perceived as transitory

Results consistent with FRB communications/actions

- Strategy Review (August 2020) and adoption of Flexible Average Inflation Targeting

  "[...] the Committee seeks to achieve inflation that averages 2 percent over time, and therefore judges that, following periods when inflation has been running persistently be- low 2 percent, appropriate monetary policy will likely aim to achieve inflation moderately above 2 percent for some time."

  FOMC press releases between **September 2020** and **December 2021**

  "[...] the Committee will aim to achieve inflation moderately above 2 percent for some time so that inflation averages 2 percent over time and longer-term inflation expectations remain well anchored at 2 percent."

Results consistent with FRB communications/actions

- Strategy Review (August 2020) and adoption of Flexible Average Inflation Targeting

- As inflation starts to rise, the Fed makes it explicit that it sees these increases as **temporary** and hence in line with its objective. Between **April 2020** to **November 2021** FOMC press releases state

  "Inflation has risen, largely reflecting transitory factors."

- Davig and Foerster (2022) show that communicating a delay of the return to the target is equivalent to a decrease in ψ_π in the canonical Taylor rule

Sensitivity analysis

1 Misspecification bias: Output gap

2 At the zero lower bound, interest rates less responsive to inflation

- Controlling explicitly for the zero lower bound constraint ▸ Details

3 Liquidity premia/convenience yields and risk premia

- Risk-neutral expectations recovered from swaps ▸ Details
- Take out risk premium on treasuries and TIPS ▸ Details

4 Steepening of Phillips curve post Covid (Benigno and Eggertsson, 2022)

- Need the slope of the Phillips curve to increase by a factor of 10 to replicate the empirical results. Historically, the slope is much more stable (Hazell et al., 2022)

Misspecification bias: Output gap

- Suppose conduct of monetary policy is described by

$$i_k = \rho_i i_{k-1} + (1 - \rho_i) \left\{ i_k^\star + \psi_\pi (\pi_k - \bar{\pi}) + \psi_y \tilde{y}_k \right\} + \varepsilon_k$$

- Taking expectations and first differences as before we obtain

$$\Delta \mathbb{E}_t [i_k - \rho_i i_{k-1}] = (1 - \rho_i) \psi_\pi \Delta \mathbb{E}_t [\pi_k] + (1 - \rho_i) \psi_y \Delta \mathbb{E}_t [\tilde{y}_k] + \Delta \mathbb{E}_t [\varepsilon_{m,k}]$$

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- OLS does not identify ψ_π but

$$\hat{\psi}_\pi^{\text{OLS}} \to \psi_\pi + \frac{\text{Cov}\left(\Delta\mathbb{E}_t[\,\bar{\pi}_k\,], \psi_y \Delta\mathbb{E}_t[\bar{\tilde{y}}_k]\right)}{\text{Var}\left(\Delta\mathbb{E}_t[\,\bar{\pi}_k]\right)}$$

Detecting a structural break in ψ_π

$$\hat{\psi}_\pi^{\text{OLS}} \to \psi_\pi + \frac{\text{Cov}\left(\Delta \mathbb{E}_t[\,\bar{\pi}_k\,], \psi_y \Delta \mathbb{E}_t[\bar{\tilde{y}}_k]\right)}{\text{Var}\left(\Delta \mathbb{E}_t[\,\bar{\pi}_k]\right)}$$

- A reduction in $\hat{\psi}_\psi^{\text{OLS}}$ between two sub-samples could signal two things
  - A shift in the policy rule
  - A reduction in the correlation between inflation and the output gap (E.g. **supply shocks becoming more important**)
- **Our approach**: test for a break in ψ_π by **conditioning on a monetary shock**
  - Window around monetary events (E.g. FOMC meetings). Regress $\Delta \mathbb{E}_t^Q[\,\bar{i}_k - \rho \bar{i}_{k-1}]$ on $\Delta \mathbb{E}_t^Q[(1-\rho_i)\bar{\pi}_k]$ and test for a structural break in ψ_π in 2020
  - Assumption: **conditional** correlation between inflation and the output gap constant across sub-samples **under the null hypothesis of no shift in policy**

The logic of the test in the 3-equations NK model

The bias in the 3-equations NK model

Consider the log-linearized 3-equations NK model. Then

$$\hat{\psi}_{\pi}^{\text{OLS,m}} \rightarrow \psi_{\pi} + \psi_{y} \frac{1-\beta\rho_{y}}{\kappa},$$

where κ is the slope of the Phillips curve, β is the rate of time preference and ρ_y solves

$$\rho_y = \left[\rho_i + \frac{\sigma\rho_y}{\rho_y - \left[1-\sigma\kappa\left(\frac{\rho_y}{1-\beta\rho_y}\right)\right]}(1-\rho_i)\left(\psi_y + \psi_\pi \frac{\kappa}{1-\beta\rho_y}\right)\right]$$

- Under the null hypothesis of no change in the policy rule, the asymptotic bias of $\hat{\psi}_{\pi}^{\text{OLS,m}}$ is constant across sub-samples as long as (κ, σ, β) are constant
- A reduction in $\hat{\psi}_{\pi}^{\text{OLS,m}}$ across the two sub-samples indicates a reduction in ψ_π (ρ_y not sensitive to ψ_π in standard calibrations)

Empirical specification

$$\Delta \mathbb{E}_t[\,\bar{i}_k - \rho_i \bar{i}_{k-1}\,] = a + \psi_\pi \,\Delta \mathbb{E}_t[(1-\rho_i)\bar{\pi}_k] + d\;(\Delta \mathbb{E}_t[(1-\rho_i)\bar{\pi}_k] \times D_{2020:M8}) + \eta_t$$

- Fix $\rho_i = 0.90^4$, consistent with structural estimates of Taylor rule
- Test for a structural break ($d \neq 0$) by focusing on monetary events
  - FOMC meetings, minutes releases and governor speeches $\approx$ 450 observations
- Baseline: expected average inflation and nominal rate over the next 10 years
- Split average over the next 10 years into two
  - Expectation over the next 5 years
  - Expectation between 6 and 10 years from now

Baseline results

	Full sample	Monetary events
ψ_π	$1.55^{\star\star\star}$	$1.11^{\star\star\star}$
	(0.03)	(0.089)
d	$-0.61^{\star\star\star}$	$-0.79^{\star\star}$
	(0.11)	(0.35)
R^2	0.41	0.28
N. obs.	4038	455

- Reject the null hypothesis that coefficients are the same across sub-samples
- Consistent with a more Dovish monetary policy

Outline

Taking stock

- Document sizable and robust reduction in interest rate sensitivity to inflation
- To what extent did this policy shift contribute to the rise in US inflation after 2020?
- We answer this question within a standard 3-equations NK economy with Markov switching regimes in the monetary policy rule (Hawk vs. Dove)
  - Estimate most of the parameters in a pre-sample using Bayesian methods
  - **Estimate parameters of Dovish regime to fit high-frequency evidence**
- Belief counterfactual (Bianchi, 2013)
  - Filter sequence of shocks that rationalizes data on nominal rates, inflation and output
  - Given filtered shocks, ask how the economy would have behaved under Hawkish regime

The economy in one slide

- Households have preferences

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \tilde{\theta}_t \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{l_t^{1+\nu}}{1+\nu} \right) \right]$$

- Competitive final good firms use intermediates to produce final good

$$y_t = \left(\int_0^1 y_{i,t}^{\frac{1}{\mu_t}} \, di \right)^{\mu_t}$$

- Monopolistic competitive firms use labor to produce intermediate goods, $y_{i,t} = n_{i,t}$. They face quadratic adjustment costs when setting prices, $\frac{\phi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} \frac{1}{1+\bar{\pi}} - 1 \right)^2$

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- Monetary authority follows Taylor rule with Markov switching regimes

$$1+i_t=(1+i_{t-1})^{\rho_i}\left\{\bar{i}\left[\frac{1+d(\xi_t)\pi_t+[1-d(\xi_t)]\bar{\pi}_t}{1+\pi^\star}\right]^{\psi_\pi(\xi_t)}\left(\frac{y_t}{\bar{y}_t}\right)^{\psi_y}\right\}^{1-\rho_i}\exp\{\sigma_m\varepsilon_{m,t}\}$$

where $\xi_t\in\{H(awk),D(ove)\}$ is a two-state Markov chain with transition matrix $\mathbf{P}$ and $\bar{\pi}_t=\frac{1}{N}\sum_{j=0}^{N}\pi_{t-j}$

Equilibrium conditions and model parameters

- Shocks: μ_t, θ_t, $\varepsilon_{m,t}$ and ξ_t; Endogenous variables: c_t, y_t, π_t, i_t

$$
\begin{aligned}
1 &= (1+i_t)\beta\mathbb{E}_t\left[\exp\{\hat{\theta}_{t+1}\}\left(\frac{c_t}{c_{t+1}}\right)^{\sigma}\frac{1}{1+\pi_{t+1}}\right] \\
\tilde{\pi}_t &= \frac{1}{\phi(\exp\{\hat{\mu}_t\}-1)}y_t\left[\exp\{\hat{\mu}_t\}\chi c_t^{\sigma}y_t^{\nu}-1\right]+\beta\mathbb{E}_t[\exp\{\hat{\theta}_{t+1}\}\tilde{\pi}_{t+1}] \\
1+i_t &= (1+i_{t-1})^{\rho_i}\left\{\bar{i}\left[\frac{1+d(\xi_t)\pi_t+[1-d(\xi_t)]\bar{\pi}_t}{1+\pi^{\star}}\right]^{\psi_\pi(\xi_t)}\left(\frac{y_t}{\bar{y}_t}\right)^{\psi_y}\right\}^{1-\rho_i}\exp\{\sigma_m\varepsilon_{m,t}\} \\
y_t &= c_t+\frac{\phi}{2}\left(\frac{\pi_t-\bar{\pi}}{1+\bar{\pi}}\right)^2 \\
\hat{\theta}_t &= \rho_\theta\hat{\theta}_{t-1}+\sigma_\theta\varepsilon_{\theta,t} \\
\hat{\mu}_t &= (1-\rho_\mu)\bar{\mu}+\rho_\mu\hat{\mu}_{t-1}+\sigma_\mu\varepsilon_{\mu,t}
\end{aligned}
$$

- Parameters: preferences, $[\sigma,\nu,\chi,\beta]$; policy, $[\pi^{\star},\rho_i,N,\psi_\pi(H),\psi_\pi(D),\psi_y,P_{HH},P_{DD}]$; shocks, $[\bar{\mu},\rho_\mu,\sigma_\mu,\rho_\theta,\sigma_\theta,\sigma_m]$

Estimation

We fix $\{\sigma, \nu, \chi, \bar{\mu}, \pi^\star, \beta\}$ at conventional values and proceed in two steps

1. Fit the single regime model on 1984:Q1-2019:Q4 sample to estimate structural shocks' process and $\{\phi, \rho_i, \psi_\pi(H), \psi_y\}$
   - Data: (de-trended) Employment, CPI inflation and Federal funds rate
   - Model fit the data reasonably well
   - Parameter estimates consistent with previous studies
2. Fix $P_{HH} = 0.994$ and $N = 12$. Choose $\{\psi_\pi(D), P_{DD}\}$ to fit the high frequency evidence
   - Simulate a monetary shock and compute $\mathbb{E}_t[\,\bar{i}_k - \rho_i \bar{i}_{k-1}]$ and $\mathbb{E}_t[\,(1-\rho_i)\bar{\pi}_k]$ 1-5 years ahead and $6-10$ years ahead
   - Perform an OLS regression as in the data and match point estimates for d

Parameters

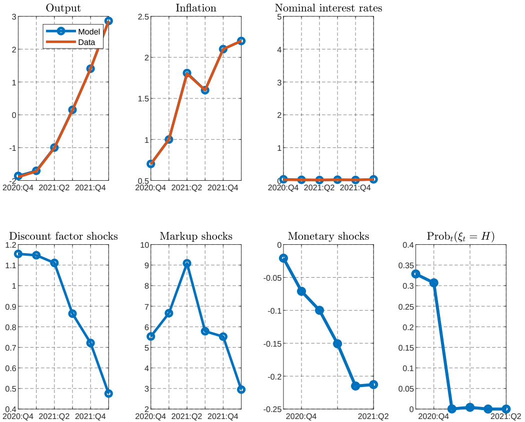
Panel A: **Fixed parameters**		
	Value	Notes
σ	1.000	Intertemporal elasticity of substitution of 1
ν	1.000	Frish elasticity of 1
χ	0.833	Normalize output to 1 in steady state
$\bar{\mu}$	1.200	20% markup in steady state
$\pi^\star$	0.005	Inflation target of 2%
β	0.995	Annualized real interest rate of 2% in steady state
N	12.000	3 year horizon when averaging inflation in the D regime
P_{HH}	0.994	40 years expected duration of H regime

Panel B: **Estimation of single regime model**					
Parameter	Posterior mean	90% interval	Prior distribution	Prior mean	Prior st. dev.
ϕ	58.35	[39.94,75.97]	Gamma	80.00	10.00
$\psi_\pi(H)$	2.52	[2.09,2.95]	Normal	1.50	0.50
ψ_y	0.29	[0.18,0.39]	Normal	1.50	0.50
ρ_i	0.89	[0.86,0.92]	Beta	0.50	0.29
ρ_μ	0.83	[0.73,0.93]	Beta	0.50	0.29
ρ_β	0.94	[0.92,0.96]	Beta	0.50	0.29
$\sigma_\mu \times 100$	2.67	[1.85,3.48]	InvGamma	1.00	Inf
$\sigma_\beta \times 100$	0.17	[0.14,0.20]	InvGamma	1.00	Inf
$\sigma_m \times 100$	0.18	[0.15,0.20]	InvGamma	1.00	Inf

Panel C: **Parameters of Dovish rule**		
	Value	Notes
$\psi_\pi(D)$	1.00	Point estimates of d, 1-5 yrs. **Data: -1.41, Model: -1.52**
P_{DD}	0.85	Point estimates of d, 6-10 yrs. **Data: -0.30, Model: -0.04**

Filtering

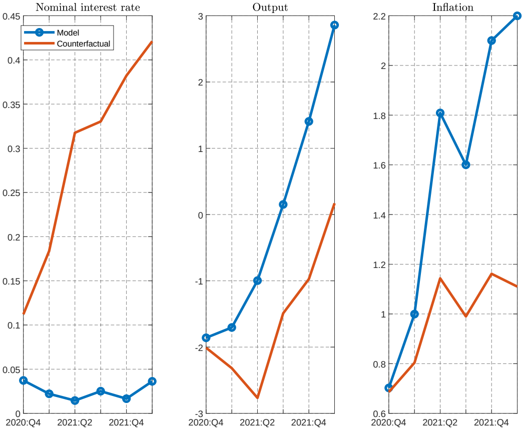
What realization of shocks do we need to fit the data post covid (2020:Q4-2022:Q1)?



- High markup shocks, increasing demand and a more Dovish monetary authority

Counterfactual

What was the role of monetary policy shift in propagating inflation?



- Without a shift in the policy regime, infltion would have peaked at 5%

Why is the change in the monetary rule so consequential?

We need negative supply shocks and positive demand shocks to fit the data

- Iterating forward the Phillips curve, we have

$$\hat{\pi}_t = \kappa \sum_{j=0}^{\infty} \beta^j \mathbb{E}_t[\hat{y}_{t+j}] + \kappa \sum_{j=0}^{\infty} \beta^j \mathbb{E}_t[\hat{\mu}_{t+j}]$$

  - A negative supply shock—as we estimate occurred in 2021—directly raises inflation
  - If the monetary authority is less responsive to changes in inflation, we get a smaller reduction in the output gap, hence a higher level of inflation

- Iterating forward the Euler equation, we have

$$\hat{y}_t = -\frac{1}{\sigma} \sum_{j=0}^{\infty} \mathbb{E}_t[\hat{i}_{t+j} - \hat{\pi}_{t+1+j}] - \frac{1}{\sigma} \sum_{j=0}^{\infty} \mathbb{E}_t[\hat{\theta}_{t+1+j}]$$

  - A positive demand shock raises inflation via the output gap
  - If the monetary authority is less responsive to changes in inflation, we get a smaller increase in real rate, and so a higher level of inflation

Conclusion

- Novel approach to test for perceived shifts in the monetary policy rule
- Robust evidence of a shift to a more Dovish regime shortly after the pandemic
- When coupled with a off-the-shelf New Keynesian model, this change in the policy regime explains the bulk of the observed increase in inflation

Controlling for a binding ZLB

Suppose interest rates follow the process

$$\begin{aligned} \hat{i}_k &= \rho_i i_{k-1} + (1-\rho_i)\left\{i_k^\star + \psi_\pi(\pi_k - \bar{\pi}) + \psi_y \tilde{y}_t\right\} + \varepsilon_k \\ i_k &= \max\left\{\hat{i}_k, 0\right\} \end{aligned}$$

If $\varepsilon_k | \mathcal{I}^t \sim \mathcal{N}(0, \sigma_\varepsilon)$, then we have

$$\mathbb{E}_t[\, i_k \,] = \rho_i \mathbb{E}_t[\, i_{k-1} \,] + (1-\rho_i)\left\{\mathbb{E}_t[i_k^\star] + \psi_\pi \mathbb{E}_t[\pi_k - \bar{\pi}] + \psi_y \mathbb{E}_t[\tilde{y}_t]\right\} + \underbrace{\frac{\varphi\left(\frac{\mathbb{E}_t[\hat{i}_k]}{\sigma}\right)}{1 - \Phi\left(\frac{\mathbb{E}_t[\hat{i}_k]}{\sigma}\right)}\sigma}_{f}$$

Approximate the expression around $\mathbb{E}_t[i_{k-1}] = \bar{i}_{k-1}$, $\mathbb{E}_t[i_k^\star] = i^\star$, $\mathbb{E}_t[\pi_k] = \bar{\pi}$, $\mathbb{E}_t[\tilde{y}_k] = 0$

$$\mathbb{E}_t\left[i_k - \rho_i\left(1 + \frac{1}{\sigma} f_k'\right) i_{k-1}\right] = (1-\rho_i)\left(1 + \frac{1}{\sigma} f_k'\right)\left\{\mathbb{E}_t[i_k^\star] + \psi_\pi \mathbb{E}_t[\pi_k - \bar{\pi}] + \psi_y \mathbb{E}_t[\tilde{y}_t]\right\}$$

Controlling for a binding ZLB

For each k and sub-period s, we construct $\{f_k'\}$ by setting:

- $i^\star \Rightarrow$ sample average of the Laubach-Williams series in each sub-period s
- $\bar{i}_{k-1} \Rightarrow$ sample average of $\mathbb{E}_t^Q[i_{k-1}]$ in each sub-period s
- We set $\sigma = 0.03$, a fairly conservative value for this exercise

We then perform our analysis using the following equation

$$\Delta\mathbb{E}_t[\,\bar{i}_k\,] - \frac{1}{10}\sum_{k=1}^{10}\rho_i\left(1+\frac{1}{\sigma}f_k'\right)\Delta\mathbb{E}_t[\,i_{k-1}\,] = \psi_\pi\frac{1}{10}\sum_{k=2}^{10}\rho_i\left(1+\frac{1}{\sigma}f_k'\right)\Delta\mathbb{E}_t[\,(1-\rho_i)\pi_k\,] + \eta_t$$

Return

Controlling for risk premia

- For each k and t, there is an underlying non-linear relation between risk-neutral and physical expectations

$$\mathbb{E}_t^P[\bar{\pi}_k] = f_{k,t}\left(\mathbb{E}_t^Q[\bar{\pi}_k]\right)$$

- We obtain from the Survey of Professional forecasters (SPF) the average expected inflation rate. We then approximate $f_{k,t}$ using local linear regression

$$\mathbb{E}_t^P[\bar{\pi}_k] = a_t + b_{k,t}\mathbb{E}_t^Q[\bar{\pi}_k] + \varepsilon_t$$

  over rolling sub-samples. We use $\{a_t, b_{k,t}\}$ to construct daily inflation expectations

- We use the Fed board term structure model to infer $\mathbb{E}_t^P[\bar{i}_k]$

- We repeat our analysis with $\{\mathbb{E}_t^P[\bar{i}_k], \mathbb{E}_t^P[\bar{\pi}_k]\}$.

Return

Fed Information Effect

- Nakamura and Steinsson (2018) argue that information about state of the economy is revealed around FOMC meetings. This could invalidate our test
- We follow Jarocinski and Karadi (2020) and exclude from our analysis monetary events with positive comovement between interest rates revisions and stock returns
  - To rule out news about other demand shocks
- We also consider a specification where we exclude from the analysis monetary events with positive comovements between one-year ahead expected interest rates and inflation
  - To rule out news about supply shocks

Return

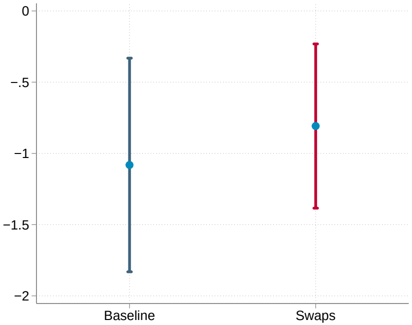
Sensitivity analysis, results

	(1) Baseline	(2) ZLB	(3) Fed inf. effect	(4) Risk premia
d (10 year avg)	$-0.79^{\star\star}$	$-0.87^{\star}$	$-1.12^{\star\star\star}$	$-0.28^{\star\star}$
	(0.36)	(0.54)	(0.38)	(0.12)
d (5 year avg, 1-5)	$-1.41^{\star\star\star}$	$-2.08^{\star\star\star}$	$-1.42^{\star\star\star}$	$-0.99^{\star\star\star}$
	(0.36)	(0.60)	(0.38)	(0.26)
d (5 year avg, 6-10)	-0.36	-0.33	$-0.52^{\star}$	$-0.07^{\star\star}$
	(0.23)	(0.29)	(0.26)	(0.03)
N. obs.	455	455	210	455

Return

Repeating the analysis using swaps

- Nominal and real treasuries may have different liquidity/convenience properties
- We repeat the analysis constructing expected inflation and nominal interest rates using
  - Overnight Index Swaps (OIS) tied to the federal funds rate
  - Inflation-Linked Swaps (ILS)
- Data limitations: need to start in 2005 and focus on the 5 years horizon



Return