Bond Market Views of the Fed

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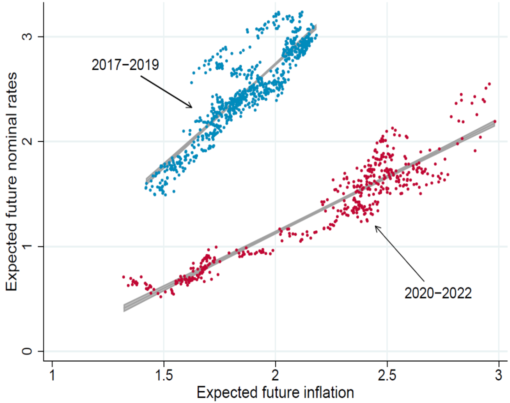
- This paper: answers these questions in two steps
  1. Use **bond market data** to detect shifts in the Fed's policy
  2. Combine these estimates with a NK model to **measure role of monetary policy**

Two main results



- Detect a decline in the sensitivity of nominal rates to inflation at [0-5] yrs horizon

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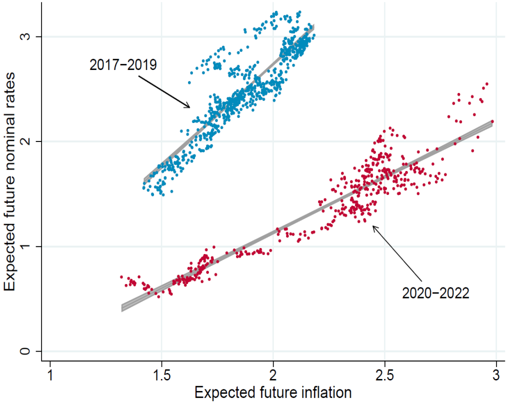

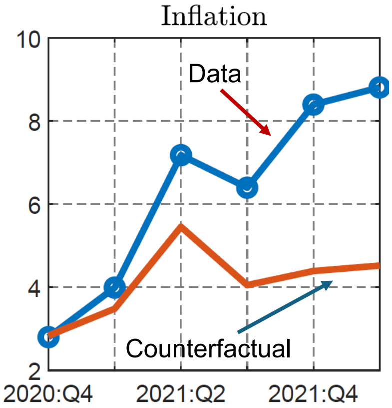

- Detect a decline in the sensitivity of nominal rates to inflation at [0-5] yrs horizon
- Through the lens of a benchmark NK model, a policy shift of this magnitude has large effects on inflation

Outline

▸ Literature

This idea in a nutshell

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

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) \{i^\star + \psi_\pi (\pi_t - \bar{\pi})\} + \varepsilon_t$$

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- **Want**: **test for changes in ψ_π** and measure expected **duration** of new "regime"
- **Issues**:
  - Only few years of realized data, all at the ZLB
  - Hard (impossible?) to estimate persistence with only one spell
  - Standard endogeneity issues

This idea in a nutshell

Taking expectations in year k, we have

$$\mathbb{E}_t\left[i_k - \rho_i i_{k-1}\right] = c + (1-\rho_i)\psi_\pi \mathbb{E}_t[\pi_k] + \mathbb{E}_t[\varepsilon_k]$$

- From bond prices we obtain high frequency information on $\mathbb{E}_t[i_k]$ and $\mathbb{E}_t[\pi_k]$
- Expectations data vs. actual realizations
  - We have information even if economy is currently at the ZLB
  - We can exploit the **term structure** (vary k) to measure persistence of changes in ψ_π
  - We can address endogeneity, thanks to high-frequency nature of the data

Empirical specification

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

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

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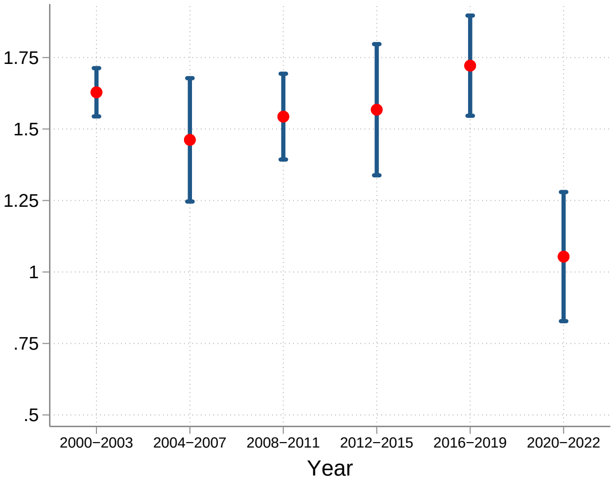
- Fixing $\rho_i = 0.8$, we **test for the stability of** ψ_π by estimating

$$\Delta\mathbb{E}_t\left[\bar{i}_{t,k} - \left(\frac{k-1}{k}\right)\rho_i \bar{i}_{t,k-1}\right] = c + \sum_{s=1}^{6} \psi_{\pi,s}\left(D_{t,s} \times \Delta\mathbb{E}_t\left[(1-\rho_i)\overline{\pi}_{t,k}\right]\right) + e_t,$$

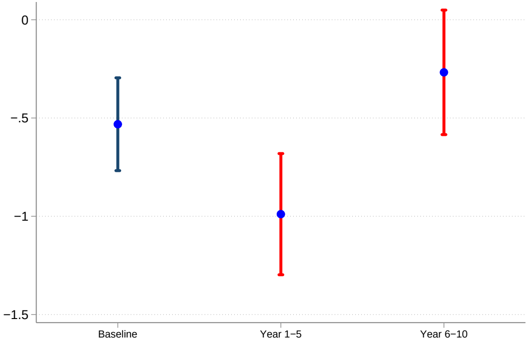
Estimating ψ_π across sub-samples



- **ψ_π remarkably stable pre 2020**, **drops significantly after 2020**

Exploiting the term structure

$$\Delta \mathbb{E}_t \left[\bar{i}_{t,k} - \rho_i \frac{k-1}{k} \bar{i}_{t,k-1} \right] = c + \psi_\pi \Delta \mathbb{E}_t \left[(1-\rho_i) \overline{\pi}_{t,k} \right] + d \left(D_t \times \Delta \mathbb{E}_t \left[(1-\rho_i) \overline{\pi}_{t,k} \right] \right) + e_t,$$



- Significant reduction in interest rate sensitivity in the 2020-2022 period
- Lower sensitivity expected in the **medium-term** ([1-5] yr horizon), not in the long-run

Sensitivity analysis

1 Misspecification of the reaction function can lead to biased estimates of ψ_π

- We are not controlling for the output gap. Bias may dampen sensitivity post 2020 due to larger prevalence of supply shocks in this period ▸ Details
  - Repeat the analysis conditioning **on the same type of shock** pre/post 2020
- We are not allowing for time-variation in $i^\star$ and $\pi^\star$
  - Allow for time-variation using long-horizon forward

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

- We control explicitly for the ZLB constraint and find comparable results

3 Risk premia and liquidity premia/convenience yields ▸ Details

- Take out risk premium on treasuries and TIPS
- Risk-neutral expectations recovered from Swaps

▸ Results

Outline

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, $\frac{\phi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} \frac{1}{1+\bar{\pi}} - 1 \right)^2$
- 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 $\bar{\pi}_t = \frac{1}{N} \sum_{j=0}^{N} \pi_{t-j}$

Parameters

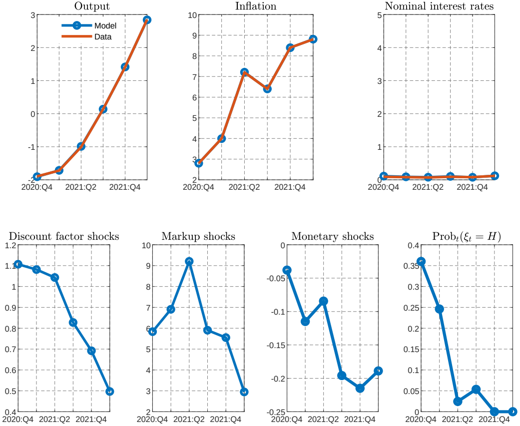
Panel A: **Fixed parameters**		
	Value	Notes
σ	1.000	Intertemporal elasticity of substitution of 1
ν	1.000	Frish elasticity of 1
χ	0.833	Normalize output to 1 in steady state
$\overline{\mu}$	1.200	20% markup in steady state
$\pi^\star$	0.005	Inflation target of 2%
β	0.995	Annualized real interest rate 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	0.90	[0.87,0.92]	Beta	0.50	0.29
ρ_μ	0.83	[0.73,0.93]	Beta	0.50	0.29
ρ_θ	0.94	[0.92,0.97]	Beta	0.50	0.29
$\sigma_\mu \times 100$	2.67	[1.85,3.48]	InvGamma	1.00	Inf
$\sigma_\theta \times 100$	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
$\psi_\pi(D)$	0.66	Point estimates of d, 1-5 yrs. **Data: -1.00, Model: -1.00**
P_{DD}	0.83	Point estimates of d, 6-10 yrs. **Data: 0.00, Model: -0.03**

Filtering

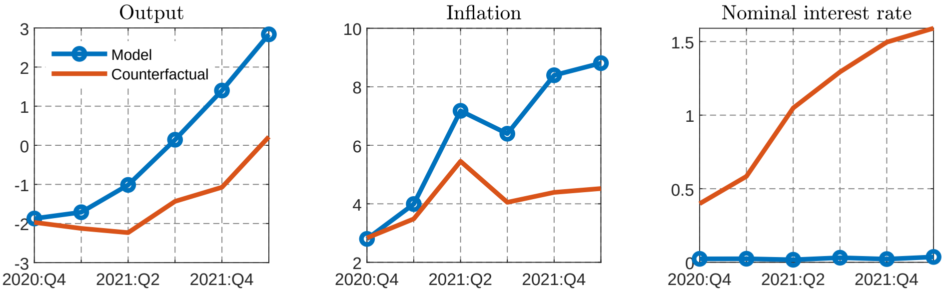
What realization of shocks do we need to fit the data post covid (2020:Q4-2022:Q1)?



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

Role of monetary policy during the pandemic

What if there was no shift in the policy regime post 2020?



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

Why is the change in the monetary rule so consequential?

Let's start from the log-linearized Phillips curve and Euler equation

$$\begin{aligned} \hat{\pi}_t &= \kappa \left(\hat{y}_t + \mu_t\right) + \beta \mathbb{E}_t[\hat{\pi}_{t+1}] \\ \hat{y}_t &= -\frac{1}{\sigma}\left(\hat{r}_t + \hat{\theta}_t\right) + \mathbb{E}_t[\hat{y}_{t+1}] \end{aligned}$$

Why is the change in the monetary rule so consequential?

Iterating forward these relationships we obtain

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

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

So, the difference between inflation across the two regimes is approximated by

$$\begin{aligned} \hat{\pi}_t^D - \hat{\pi}_t^{\mathrm{H}} &= -\frac{\kappa}{\sigma}\Big\{ \left(r_t^D - r_t^H\right) + (1+\beta)\left[\mathbb{E}_t(r_{t+1}|\xi_t = D) - \mathbb{E}_t(r_{t+1}|\xi_t = H)\right] \\ &+ (1+\beta+\beta^2)\left[\mathbb{E}_t(r_{t+2}|\xi_t = D) - \mathbb{E}_t(r_{t+2}|\xi_t = H)\right] + \ldots \Big\}, \end{aligned}$$

Sensitivity **increasing** in j. Due to "forward guidance puzzle" **and** forward-looking nature of inflation

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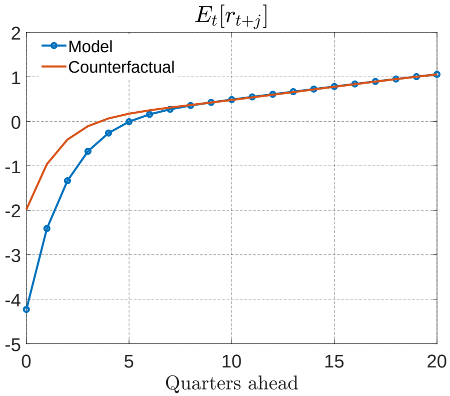


- Difference in real rates across two regimes empirically plausible
- Large effects on inflation due to "forward guidance puzzle" (squared)

Conclusion

- Test for perceived shifts in the monetary policy rule using bond market data

- Evidence of a reduction in the sensitivity of nominal interest rates to inflation during the pandemic. Can plausibly be interpreted as a shift in the policy rule

- When coupled with an off-the-shelf NK model, this change in the policy regime has quantitatively important implications for the dynamics of inflation over this episode

- Shift in medium-term expectations, but long-run sensitivity "anchored"
  - Different in emerging markets like Brazil and Turkey
  - "Monetary Policy without an Anchor": A theory to explain differences in the policy responses to the Covid shock and in the degree of "anchoring" of inflation expectations between emerging and advanced economies

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)
  - 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)

Return

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 k are linked to expectations of future short-term rate

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

- Inflation compensation are linked to expectations of future inflation

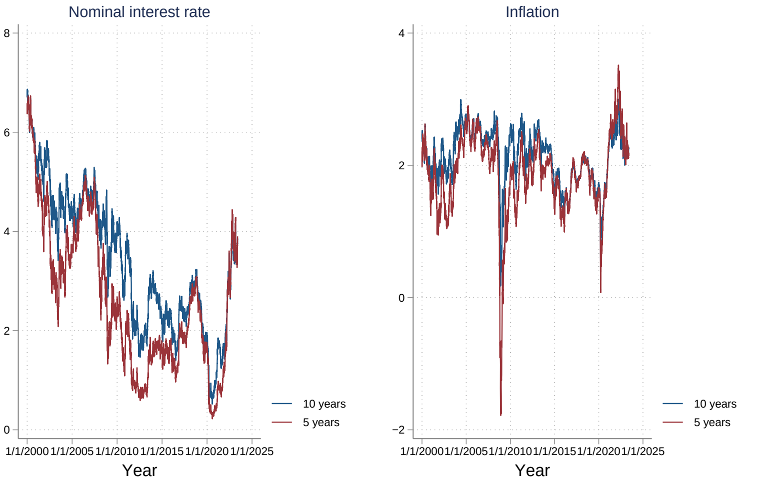
$$IC_t^{(k)} = i_t^{(k)} - r_t^{(k)} = \mathbb{E}_t^{\mathcal{Q}}\left[\frac{1}{k}\sum_{i=1}^{k} \pi_{t+i}\right] = \mathbb{E}_t\left[\bar{\pi}_k\right] + \text{inflation risk premium}_{k,t}$$

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

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

Return

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

Return

Misspecification bias: Output gap

- Suppose conduct of monetary policy is described by

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

- Taking expectations, first differencing and averaging across k as before

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

- OLS does not identify ψ_π but

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

Detecting a structural break in the policy rule

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

- A reduction in $\hat{\psi}_{\psi}^{\text{OLS}}$ between two sub-samples could signal two things
  - A shift in the policy rule
  - A change in the type of shocks the Fed is facing (E.g. larger **supply shocks** than before)

- **Our approach**: test for a break in ψ_{π} **conditioning on the same type of shock**
  - Forecasts updates around "monetary events" and oil shocks. Test for a 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

$$\hat{\psi}_\pi^{\text{OLS,m}} \to \psi_\pi + \psi_y \frac{1-\beta\rho_y}{\kappa},$$

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)

Results

Baseline specification:

$$\Delta \mathbb{E}_t \left[\bar{i}_{t,k} - \rho_i \frac{k-1}{k} \bar{i}_{t,k-1} \right] = c + \psi_\pi \Delta \mathbb{E}_t \left[(1-\rho_i) \overline{\pi}_{t,k} \right] + d \left(D_t \times \Delta \mathbb{E}_t \left[(1-\rho_i) \overline{\pi}_{t,k} \right] \right) + e_t,$$

	(1) Baseline	(2) Mon shocks	(3) Oil shocks	(4) $i^\star$ and $\pi^\star$	(5) Risk premia	(6) ZLB	(7) ZLB, options
$d_{[1-10]}$	$-0.53^{\star\star\star}$	$-0.87^{\star\star}$	-1.16	$-0.15^{\star\star\star}$	-0.19	-0.30	
	(0.12)	(0.43)	(1.18)	(0.06)	(0.20)	(0.21)	
$d_{[1-5]}$	$-0.99^{\star\star\star}$	$-1.94^{\star\star\star}$	$-1.99^{\star}$	$-0.29^{\star\star\star}$	$-1.02^{\star\star\star}$	$-1.09^{\star\star\star}$	
	(0.16)	(0.51)	(1.14)	(0.10)	(0.12)	(0.27)	
$d_{[6-10]}$	$-0.27^{\star}$	-0.69	-0.04	-0.22	$0.16^{\star\star\star}$	0.23	
	(0.16)	(0.41)	(1.25)	(0.16)	(0.05)	(0.15)	
N. obs.	3558	455	62	3558	3558	3558	

Return

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

- Most asset pricing models predict expected inflation, inflation compensation and nominal bond yields to functions of the same underlying factors X_t

- To approximate the relation between expected inflation and these factors, we estimate the following relation

$$SPF_t^{(n)} = \beta_{n,0} + \beta_{n,1} IC_t^{2y} + \beta_{n,2} IC_t^{5y} + \beta_{n,3} IC_t^{10y} + \beta_{n,4} i_t^{2y} + u_t^{(n)}$$

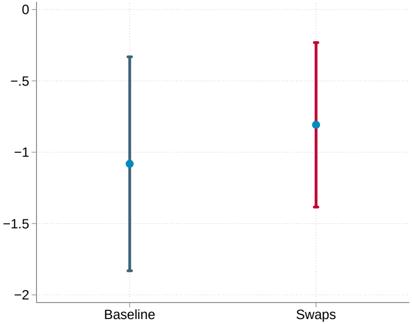
  over rolling sub-samples, where $SPF_t^{(n)}$ is the average inflation expectation at horizon n in the Survey of Professional Forecasters. We use the estimated β's to construct daily inflation expectations

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

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

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



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