A New Keynesian Model for Financial Markets

Thomas M. Mertens[1], Tony Zhang[2,a]

NBER Summer Institute

[1]Federal Reserve Bank of San Francisco, [2]Federal Reserve Board

[a]The views expressed here are solely those of the authors and do not necessarily represent those of the Board of Governors of the Federal Reserve, the Federal Reserve Bank of San Francisco, or the Federal Reserve System.

Motivation

- How restrictive are short-term and long-term interest rates right now?
- Long literature on the "natural rate of interest." (e.g., Wicksell (1898), Keynes (1930), Friedman (1968)).
- The "natural" rate keeps the level of economic activity constant
- Modern literature (and policymaking) estimates long-run neutral real rates, r^*. (e.g., Laubach and Williams (2003))

This paper

- Return to the original idea of estimating a nominal natural interest rate.
- We obtain estimates at different horizons
- We use expectations from financial market data
- We build on textbook NK model and solve under risk-neutral expectations

$\Rightarrow$ Derive nominal natural interest rates and real-time stance of policy

Model overview

- Textbook New Keynesian model
- Quadratic adjustment cost for changing prices (Rotemberg pricing)
- Central bank follows a Taylor rule

$\Rightarrow$ Rewrite in terms of risk-neutral expectations

$\Rightarrow$ Provide novel log-linearization of NK Model

Re-write model in terms of risk-neutral expectations

- Price nominal asset return $\widetilde{R}_{t+1}$ with $M_{t+1} = \beta \frac{u'(C_{t+1})}{u'(C_t)} \frac{P_t}{P_{t+1}}$

$$\mathbb{E}_t \left[M_{t+1} \widetilde{R}_{t+1} \right] = 1$$

- Obtain risk-neutral pricing via

$$\widehat{\mathbb{E}}_t[\widetilde{R}_{t+1}] = \int \widetilde{R}_{t+1}(s) \frac{M_{t+1}(s) g_t(s)}{\int M_{t+1}(s) g_t(s) ds} ds = \frac{1}{\mathbb{E}_t[M_{t+1}]}$$

- Apply to inflation swaps

$$S_t \mathbb{E}_t \left[M_{t+1} \right] = \mathbb{E}_t \left[M_{t+1} \Pi_{t+1} \right]$$

- Inflation swap prices are determined by risk-neutral expectations of inflation

$$S_t = \widehat{\mathbb{E}}_t \left[\Pi_{t+1} \right]$$

FinNK: Risk premiums affect first-order dynamics

- Log-linearize textbook New Keynesian with risk-neutral expectations

$$x_t = -\frac{1}{\gamma}(i_t - \widehat{\mathbb{E}}_t[\pi_{t+1}] - r^*) + \mathbb{E}_t[x_{t+1}] + g_t \qquad \text{(IS curve)}$$

$$\pi_t = \lambda x_t + \beta \widehat{\mathbb{E}}_t[\pi_{t+1}] + u_t \qquad \text{(Phillips curve)}$$

$$i_t = \theta_0 + \theta_\pi \pi_t + \theta_x x_t \qquad \text{(Taylor rule)}$$

$\Rightarrow$ Risk-neutral expectations have direct counterparts in financial data.

- Standard New Keynesian model known for lack of internal propagation.

- Assume $g_t = g_t^\ell + g_t^s$ and $u_t = u_t^\ell + u_t^s$, each shock is AR(1).

Risk premiums affect shape of inflation swap curves and yield curves

- Shocks generate risk premiums:$\widehat{\mathbb{E}}_t[u^\ell_{t+1}] = \mu^\ell_t + \mathbb{E}_t[u^\ell_{t+1}] = \mu^\ell_t + \rho^\ell u^\ell_t$

- Forward inflation swap rates (interest rates) inherit AR structure of underlying shocks:

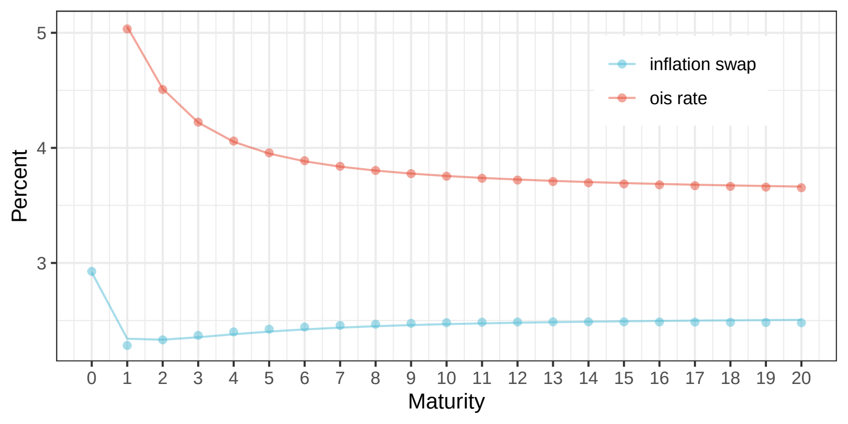
$$\widehat{\mathbb{E}}_t[\pi_{t+n}] = \kappa_0 + \sum_{i\in\{s,\ell\}} \left(\sum_{m=0}^{n-1} \left(\rho^i_u\right)^m \kappa_{i,u}\mu^i_u + \sum_{m=0}^{n-1} \left(\rho^i_g\right)^m \kappa_{i,g}\mu^i_g \right) + \sum_{i\in\{s,\ell\}} \left(\kappa_{i,u} \left(\rho^i_u\right)^n u^i_t + \kappa_{i,g} \left(\rho^i_g\right)^n g^i_t \right),$$

- Calibrate deep parameters: $\beta, \lambda, \gamma, r^*$ and Taylor rule coefficients

- Estimate shocks, shock persistence, and risk premiums using daily OIS and swap rates

Estimates give us market perceptions of shocks and economic output

Figure 1: Model Fit: June 18, 2024



- Fit is good: median fitting error on any day and maturity is 3 bps.

What is the “natural” policy rate that maintains level of economic activity?

- Use IS curve to solve for $\tilde{i}_t$ that keeps expected output gap constant:

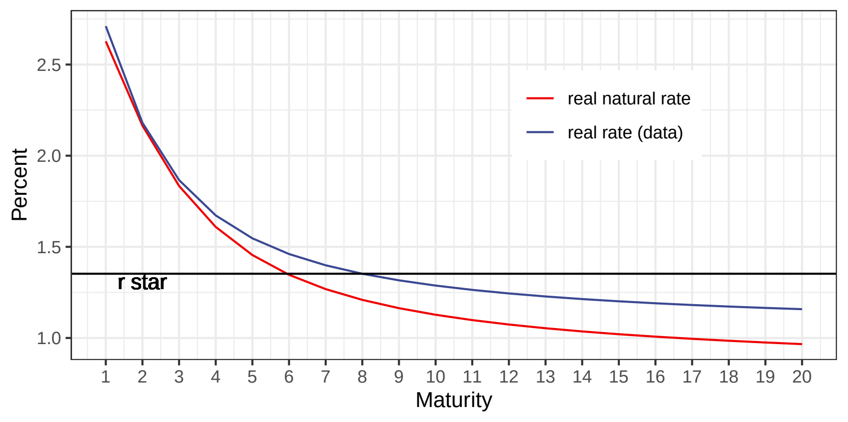
$$\tilde{i}_t = r_t^* + \widehat{\mathbb{E}}_t[\pi_{t+1}] + \gamma g_t$$

- Iterate forward to derive forward nominal natural rates:

$$\widehat{\mathbb{E}}_t\left[\tilde{i}_{t+\tau}\right] = r^* + \widehat{\mathbb{E}}_t[\pi_{t+\tau+1}] + \gamma \sum_{i=0}^{\tau-1} \left(\rho_g^s\right)^i \mu_{g,t}^s + \gamma \sum_{i=0}^{\tau-1} \left(\rho_g^\ell\right)^i \mu_{g,t}^\ell + \gamma \left(\rho_g^s\right)^\tau g_t^s + \gamma \left(\rho_g^\ell\right)^\tau g_t^\ell$$

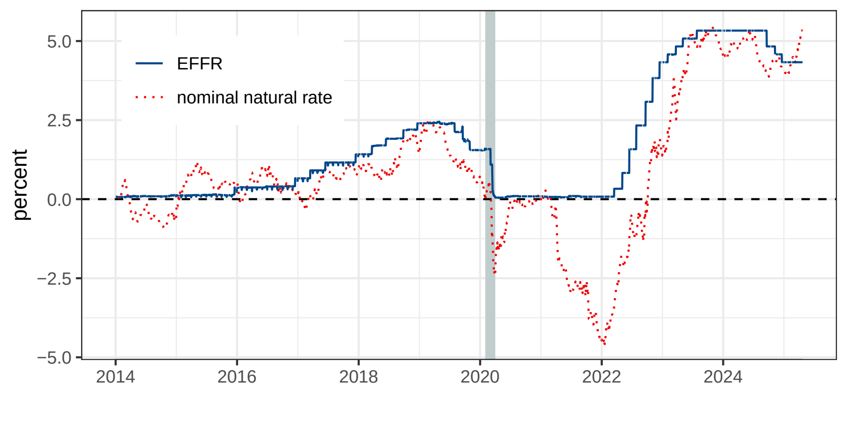
- Subtracting off $\widehat{\mathbb{E}}_t[\pi_{t+\tau+1}]$ derives real natural rates.

Real natural rates differs from r^*, particularly in the short-run (June 18, 2024)



- Average natural real rate approaches r^* in the long run plus adjustment for risk premiums.

What is the 1-year nominal natural rate over time?



- Natural rate is negative during ZLB period post-pandemic.

What would optimal policy dictate?

- Suppose the central bank set policy optimally under discretion

$$\min_{i_t} \sum_{s=t}^{\infty} \beta^{s-t} \left(\pi_s^2 + \alpha x_s^2\right)$$

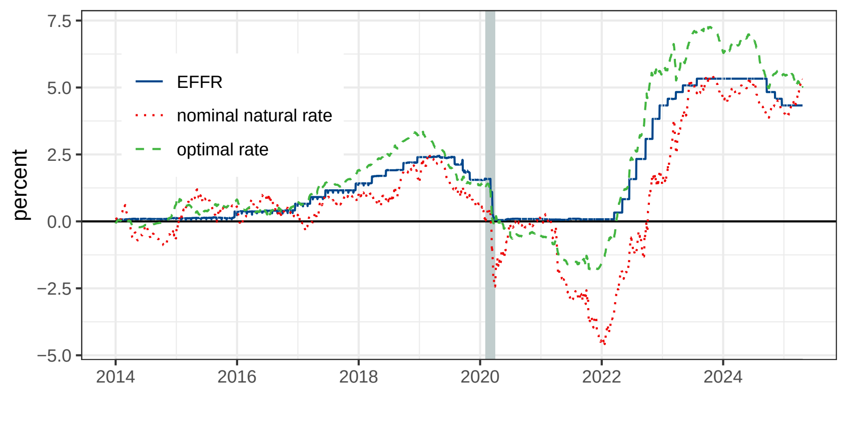
where α is the weight on the output gap.

- The rule that implements this policy is

$$i_t^{opt} = r_t^* + \left(1 + \frac{\beta\lambda\gamma}{\alpha + \lambda^2}\right)\widehat{\mathbb{E}}_t[\pi_{t+1}] + \gamma\mathbb{E}_t[x_{t+1}] + \frac{\lambda\gamma}{\alpha + \lambda^2}u_t + \gamma g_t. \tag{1}$$

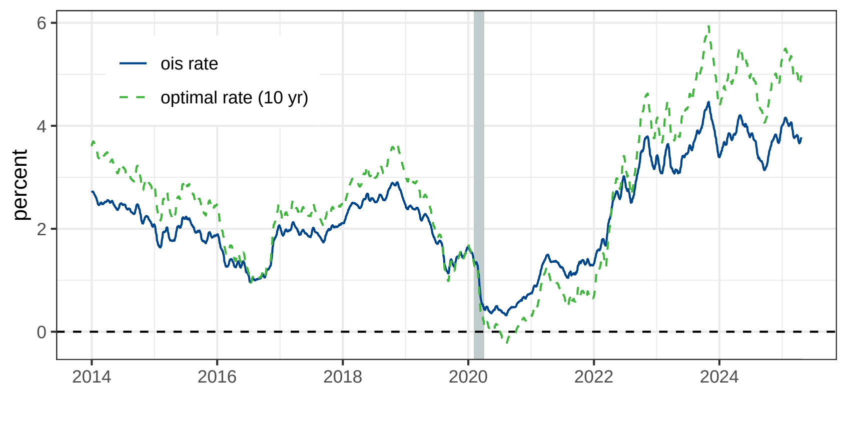
- Compute i_t^{opt} using estimates of $\mathbb{E}_t[x_{t+1}]$, u_t, g_t and data for $\widehat{\mathbb{E}}_t[\pi_{t+1}]$. Calibrate α.

Optimal rate higher than natural rate to combat inflation



- Optimal rate peaks higher than observed rates and remains higher today.

Optimal 10-year rates behave similar to 1-year rates

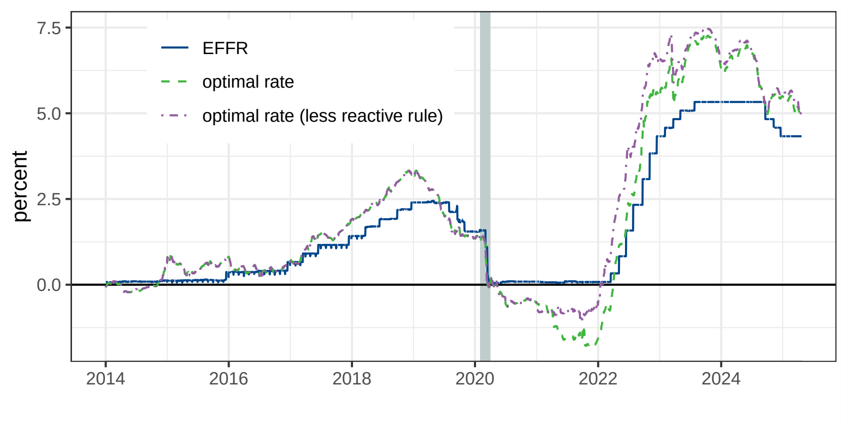


- Optimal 10-year rates less volatile than 1-year rates

What if market expectations of the Taylor rule change?

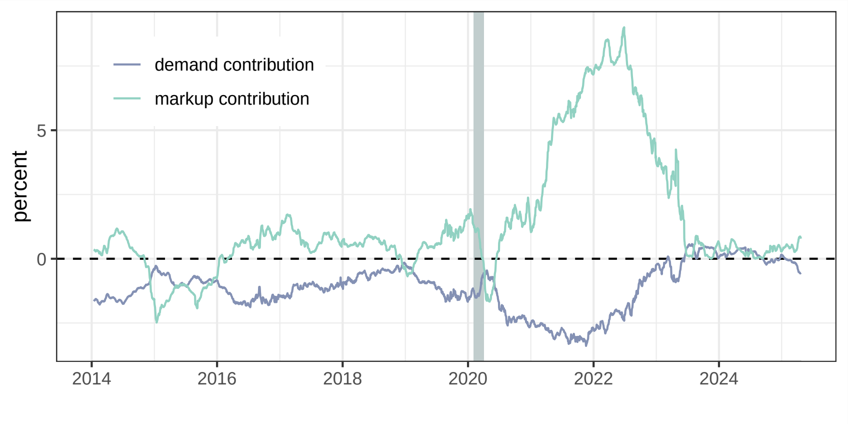
- Recent studies use asset prices to extract market perceptions of the Fed's policy rule (Bauer, Pflueger, and Sunderam 2024, Bocola et al. 2024)
- Bocola et al. (2024) find that post-pandemic Taylor rule coef. on π_t is closer to 1.
- Market observes Taylor rule, i_t, $\pi_t \Rightarrow$ Output gap x_t is a latent variable
- How would our estimated optimal policy change under this assumption?

Lower Taylor rule coefficient on π_t implies higher optimal policy rate



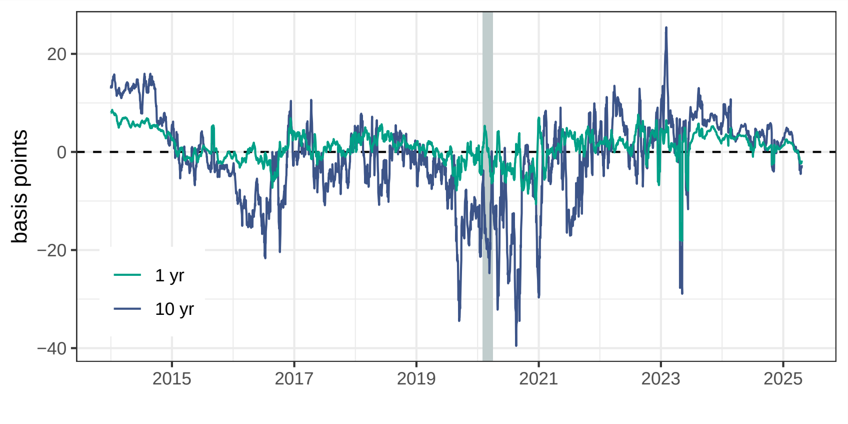
- When market expects FRB responds strongly to inflation, then low post-pandemic 1-year can only be justified with very negative output gap
- Weaker inflation response $\Rightarrow$ Less negative output gap $\Rightarrow$ Lift-off earlier

Contribution of shocks to current inflation



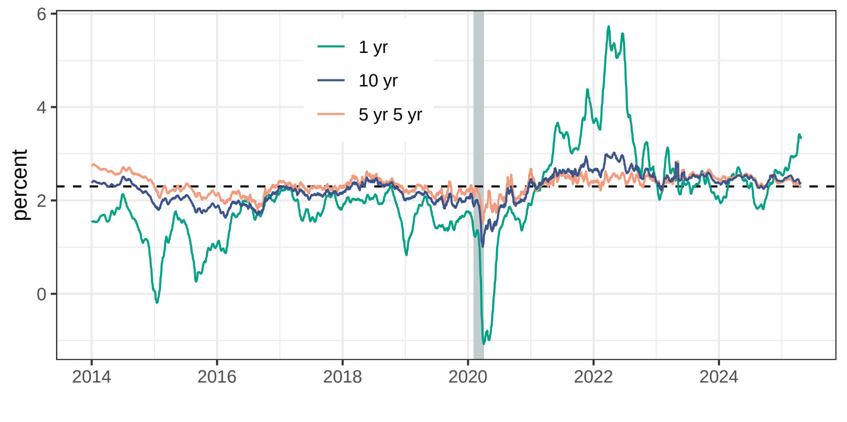
- Contribution of markup shocks spike post-pandemic
- Contribution of demand shocks mostly negative; Turned positive when yield curve inverted

Inflation risk premiums



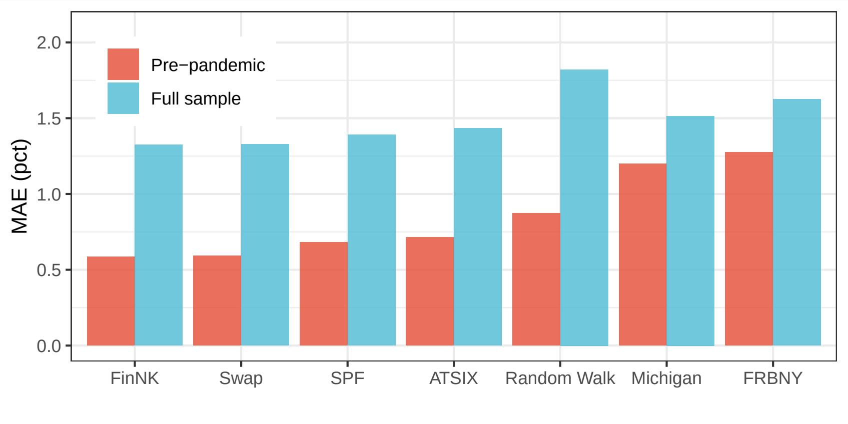
- Inflation risk premiums small at 1-year horizon; Larger at 10-year horizon
- Remark: Risk premiums not dependent on specification of SDF

1-year inflation forecast volatile, Long-term forecast is anchored



- Forecasts provided at daily frequency and are all "out-of-sample"

1-year forecast compares well against other forecasts



- These results extend those of Diercks et al. (2023) to more surveys

Review

- Estimated nominal natural rates and optimal policy rates using financial market prices.
- Provided a benchmark for the restrictiveness of financial conditions.
- Solved New Keynesian model with risk-neutral expectations.
- Derived inflation expectations that perform well relative to many alternatives.
- Currently only using financial data, but can combine with lower frequency macro data.